Exploring the Pernicious Effects of Redlining and Discriminatory Policies on an American City:

A Spatio-Temporal Case Study of New York City

by

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To Klausy and Kahlo, for being good cats, and brightening my world considerably at the height of the pandemic.

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Abbreviations

AIC	Akaike information criteria
BP	Breusch-Pagan
CBD	Central Business District
DCP	Department of City Planning
FHA	Federal Housing Administration
GWR	Geographically weighted regression
HOLC	Home Owners' Loan Corporation
HPD	Department of Housing Preservation and Development
HUD	Department of Housing and Urban Development
LM	Lagrange multiplier
MAUP	Modifiable areal unit problem
MTA	Metropolitan Transportation Authority
NTA	Neighborhood Tabulation Area
NYC	New York City
OLS	Ordinary least squares
SEM	Spatial error model
SLM	Spatial lag model
URA	Urban Renewal Area
VIF	Variance inflation factor

Abstract

In the summer of 2020, sustained violence against Black Americans by law enforcement erupted into nationwide protests following the callous murder of George Floyd. The cultural zeitgeist prompted a call to action, not only to rethink our policing, but also to examine larger systemic and institutionalized racism in our society. In urban planning circles, this discussion often begins with an examination of the role “redlining” maps created in the 1930s by the federal government, which controversially appraised lending risk with a racial lens, stigmatizing areas with Black residents, outlined in red, as risky for investment, and contributing to ensuing segregation.

Through examination of the nation’s largest metropolis, New York, this thesis evaluates whether redlining was only one factor of government policy – federal or municipal – entrenching segregation in the landscape. Global and local spatial clustering and segregation measures were conducted in 10-year intervals from 1910 to 2020 to evaluate underlying shifts in the spatial patterns of Black and White population segments over time. Linear regression, spatial error, and spatial lag models were then constructed to evaluate the degree to which redlining, urban renewal designations, public housing concentrations, zoning designations and historic districting contributed to the spatial segregation of Black and White populations in three distinct years: 1960, 1990 and 2020. The findings showed each era of new urban planning policy contributed to persisting segregation. The findings also showed that oftentimes a new generation of policy would spatially reference a prior era, to the benefit or detriment of a particular population: Urban renewal designations mimicked redlined areas and disproportionately concentrated public housing into increasingly Black enclaves, while exclusionary zoning tools like single-family zoning, often mimicked the safest investment designations in redlining maps, prolonging the privilege of predominantly White communities.

Chapter 1 Introduction

This introductory chapter begins with an overview of the project, then provides a description of the study area, New York City, and lastly, outlines the principal motivations for embarking on the themes of this thesis: persisting segregation in the urban environment and the role various government planning policies have played.

1.1. Overview

In the summer of 2020, while most of the nation was in lockdown from COVID-19, a teenage girl took a video on her cell phone of the murder of George Floyd, a Black man in Minneapolis, by a White officer, Derek Chauvin. The callous violence captured by her video sparked riots and protests throughout the nation and prompted calls for police reform and the examination of larger systemic and institutionalized racism in our society. This murder of a Black man by White police officers was not an isolated incident, and Minneapolis is not uniquely violent; from Eric Garner in Staten Island to Michael Brown in Ferguson to Breonna Taylor in Louisville, nationwide, Black Americans are killed by police officers at rates almost twice as high as that of White Americans (see Figure 1) (The Washington Post 2021).

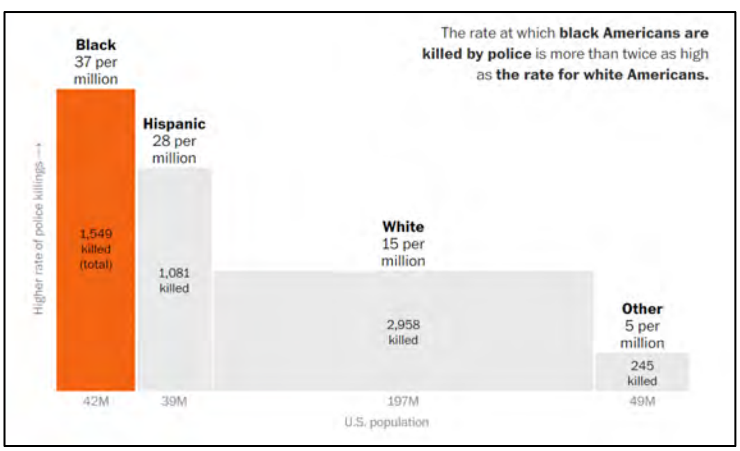

Figure 1. The disproportionate killing of Black and Hispanic Americans by police officers (The Washington Post 2021)

Government officials have long attributed these crimes to rogue police officers or the unique circumstances of particular communities[1], a misdirect that conveniently glosses over the fact that the neighborhoods where these crimes disproportionately occur have a shared legacy of being clustered within and segregated from the larger urban area, suffering from inferior amenities and public services (Rothstein 2014). Importantly, this segregation is not happenstance and did not emerge purely from the preferences or biases of people to live amongst those with similar skin color; rather, this spatial pattern was shaped by discriminatory government policies (Rothstein 2017). In the introspective moment following the death of George Floyd, city planning departments across the nation, including those representing its two largest cities, New York and Los Angeles, finally began to acknowledge the historical role they have played codifying segregation into the spatial pattern of American cities and their responsibility in devising policies that "played a large role in perpetuating racism and even violence against Black and Brown Americans" (NYC DCP 2020).

Central to many cities' discussions have been the historical "redlining" maps associated with the Home Owners' Loan Corporation (HOLC) and the Federal Housing Administration (FHA) that informed public and private housing lending practices in the first half of the 20th century. In these maps, the federal government demarcated the purported investment risk of different neighborhoods, directing how and where bank loans could be issued, and which mortgages the federal government would insure (Jackson 1987). The federal mapmakers deliberately singled out areas with high concentrations of racial minorities – chiefly Black

[1] The Justice Department, upon investigating Michael Brown's death in Ferguson, stated "The Department of Justice is investigating the death of Michael Brown and the racial practices of Ferguson's police department, but has not suggested recent events reflect anything broader than Ferguson's unique problems." (Rothstein 2014)

communities – as high risk, thereby limiting re-investment (Rothstein 2017). These racist practices caused massive repercussions to the urban fabric of most American cities. Because government officials favored the in vogue suburban home, and assigned the highest value to White enclaves, they helped usher in an era of suburbanization, further segregated cities and the surrounding regions, and left many older city centers (and the Black residents in them) without access to capital for acquiring homes, or reinvesting in their neighborhoods (Coates 2014).

Local land use policies like municipal zoning and urban renewal area designations layered onto this federal framework and often interlocked with its discriminatory nature, accelerating the disparity between White and minority neighborhoods (Rothstein 2017). Collectively, these policies not only helped engineer severe differences in socio-economic status and generational wealth (Rothstein 2017).

This thesis aims to study the spatial implications of redlining and subsequent federal, state and municipal policies and planning efforts, on Black communities through the lens of the nation's largest city, New York. The goal is to analyze how pervasive the legacy of HOLC mapping designations, along with other government planning efforts, have been by analyzing their influence in explaining Black and White spatial patterns over time.

To evaluate these hypotheses, several analyses are conducted. Spatial autocorrelation and segregation analyses are used to generate initial global measures of Black and White spatial patterns in the city. Linear regression analyses (ordinary least squares (OLS)) and spatial regression techniques (spatial lag models (SLM) and spatial error models (SEM)) are run to determine the correlation between various explanatory variables and demographic-oriented response variables. Geographically weighted regression (GWR) tools further probe at prominent, and statistically significant variables to explore their spatial heterogeneity.

The analysis places a particular emphasis on land use and other planning policies, including zoning, urban renewal designations, and redlining demarcations to determine whether they are significant in explaining persisting segregation, either directly or indirectly, or whether other factors, like conventional market forces, including subway access or distance to a Central Business District (CBD), might better explain the phenomenon. Running these same analyses at different decennial census intervals illuminates the degree to which the residue of institutional racism persists in the urban fabric.

1.2. Study Area

New York City (NYC) is a dynamic urban juggernaut; it is consistently reinventing itself, yet for generations has maintained its allure for the prospect of economic opportunity. The original settlement of the city by European colonists occurred on the island of Manhattan, at the southern tip. The colonial boundary – Wall Street – has evolved into the center of New York's colossal financial district, a staggering, but representative example of Manhattan's breakneck pace of development and redevelopment. The surrounding boroughs – the Bronx, Queens, Brooklyn, and Staten Island – developed after Manhattan, but are now large urban constellations in their own right. With a population of over 8.8 million people as of the 2020 census, New York is by far the largest city in the United States (NYC DCP n.d.; US Census Bureau n.d.). In fact, if divided, four of the five boroughs would be top 10 cities in the US in terms of population, led by Brooklyn, which would be the fourth largest city at over 2.7 million people (NYC DCP 2021).

The neighborhoods that accommodate these 8.8 million residents within the city limits vary widely – people live in dense residential towers, single-family detached homes, and numerous building types in between. The type of buildings associated with a particular neighborhood are a product of many factors, including the neighborhood's age and vintage of its regulatory framework, proximity to the Manhattan core and public transit, and localized market dynamics.

Each boroughs' population growth, and the neighborhoods therein, varied widely and was associated with national immigration policies, cultural trends, the development of the subway system, and later, federal housing policies.

The pre-19th-century city was concentrated in lower Manhattan and near the Brooklyn waterfront, as access to services, amenities, and employment, was largely determined by a walking radius. As Manhattan's population exploded after the 1850s with immigrants pouring in for economic opportunity and cultural freedoms, neighborhoods like the Lower East Side became some of the densest conglomerations of people on Earth. Reformers sought to protect the welfare of the most destitute and instituted regulations that mandated light and air into tenement buildings and incrementally mandated basic fire safety and quality of life measures (Plunz 2016). These measures also sought to de-densify immigrant enclaves, through provisions like height limits, for public health and safety purposes.

With the advent of urban omni-buses, elevated trains, and then the subway system, population dispersion could accelerate in earnest beginning in the early 20th century (Jackson 1987). When the subway system was expanded in many locations in the outer boroughs, there was farmland or small villages, such as in rural Queens (Figure 2). Within decades many subway-adjacent had been completely transformed, including the area around the same transit line in Queens (also in Figure 2).

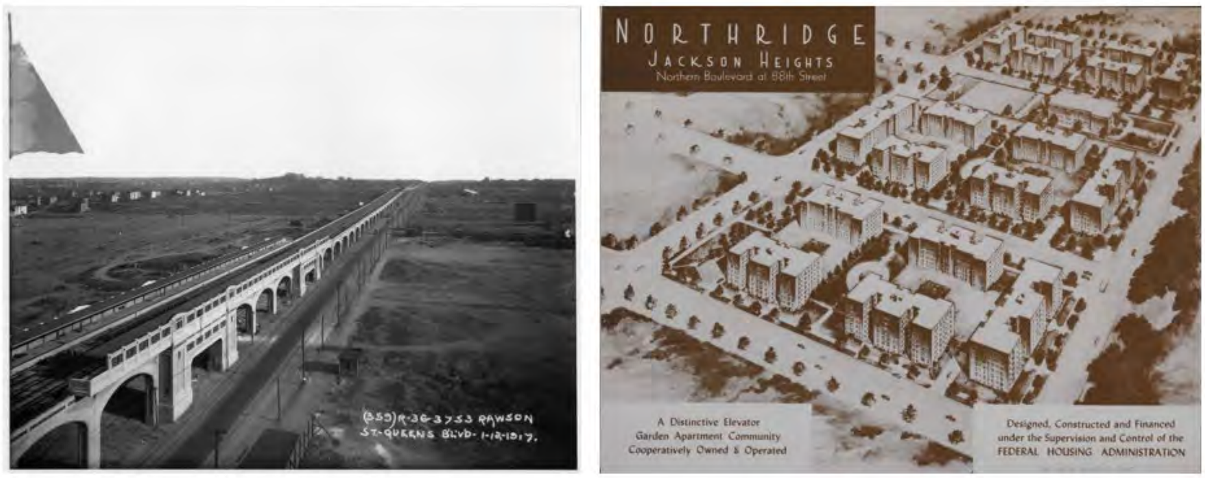

Figure 2. Images of the expanding subway system in NYC (Queens, 1917 and the 1950s) (Cohen 2017; Keller Williams Realty 2017)

The manner in which the 20th-century city formed and the racially segregated byproducts, is largely the subject of this thesis; while market forces certainly interplayed with the city's massive infrastructure investments, federal, state, and local policies steered investment and influenced the social and physical patterns that would come to characterize the urban landscape The sequence of images in Figure 3 visualize the physical differences in generational housing construction; from left, old law tenements in the Lower East Side rose in the 19th-century city, while new law tenements were erected in the Bronx after the subway was constructed, "tower-in-the-park" style urban renewal transformed Stuyvesant Town in the early post-war years, while suburban subdivisions emerged in Staten Island after the construction of the Cross-Staten Island Expressway. Each represents a microcosm that figures into the demographic and socio-economic pattern of the city.

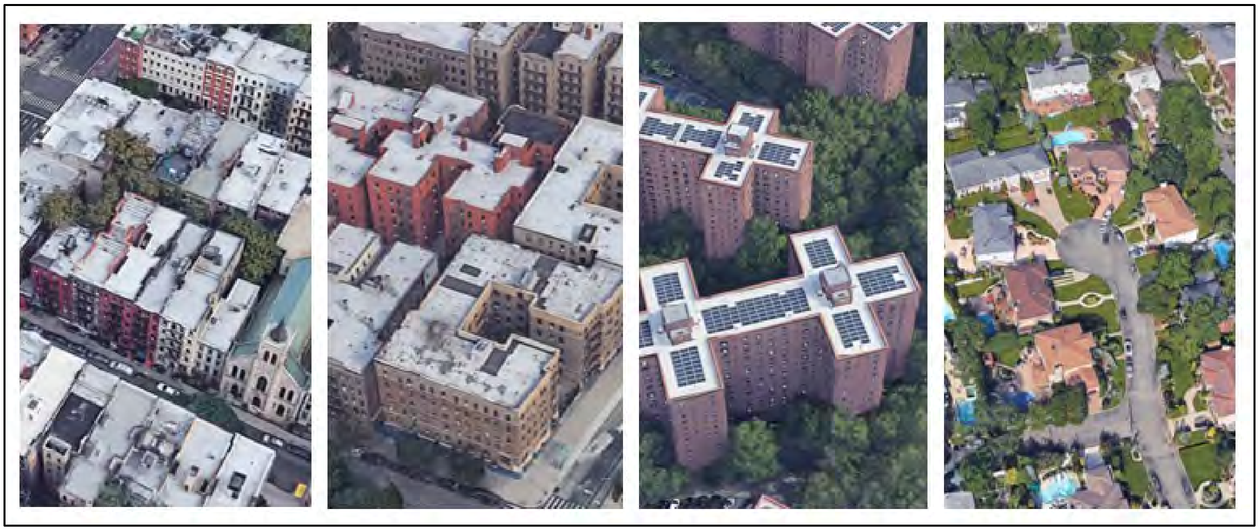

Figure 3. Generational shifts in housing patterns in NYC (Google 2022)

A graph showing the population growth of New York, by borough, is shown in Figure 4 (Gibson and Jung 2005). The initial dominance of Manhattan can be seen, as well as the eventual dispersion of population to Brooklyn, Queens, and the Bronx. Staten Island is not interconnected to the subway system, and thus remains mostly suburban. The graph also shows the precipitous drop in population in the post-war years, along with a renaissance where the initial 1950s population peak was overtaken in the 2000s.

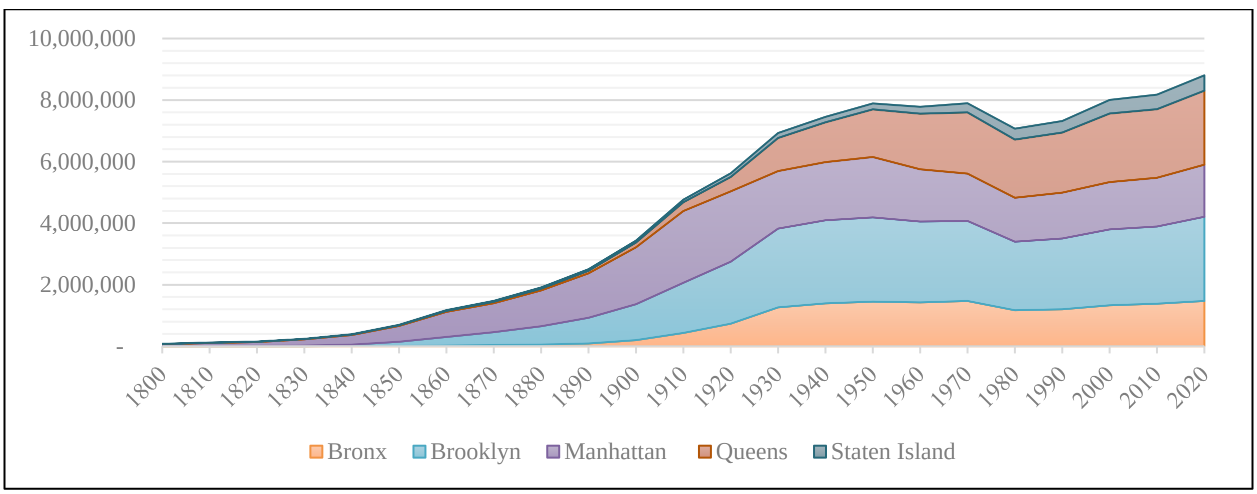

Figure 4. Population growth, by borough, of NYC

The map in Figure 5 shows the relative density and spatial pattern of its principal races and ethnicities. Manhattan south of 96th Street, western and southern Brooklyn, western Queens, and much of Staten Island is White, while Harlem, the South Bronx, northern Bronx, central Brooklyn, central and southeastern Queens, and northern Staten Island are segregated pockets of Black and Latino populations. Melting pot that it is, there are moments of relative mixing and integration, such as southern Brooklyn, northeastern Queens, and eastern Bronx, but by and large, New York is highly segmented along racial lines.

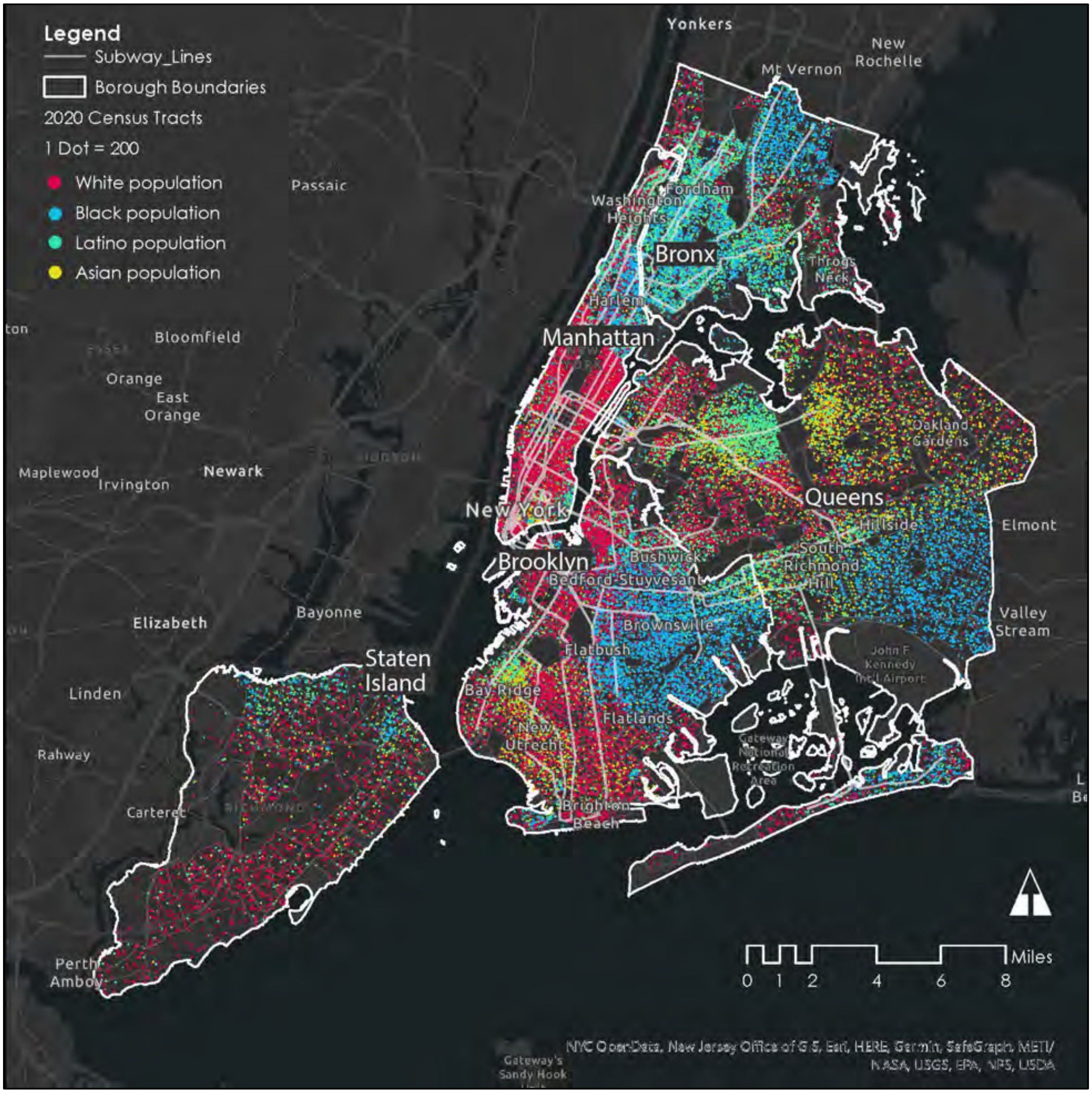

Figure 5. Distribution and density of population in NYC, by race, in 2020

1.3. Motivation

While this thesis is centered around New York City, the motivation for its subject matter was inspired by violence against the Black community in cities across America.

In May of 2022, a racially motivated mass killing targeting a Buffalo supermarket in a low-income, predominantly Black neighborhood drew national attention and an outpouring of grief for the victims. Many in the community itself were vocal about the hypocrisy of this ephemeral concern, as it followed generations of sustained apathy for their wellbeing – Few rallied to protect their neighborhood from being targeted for running a highway through it, stood up and questioned why their children were disproportionately under-represented from the nearby magnet school, or fought to bring a supermarket to the neighborhood when it lacked an affordable healthy food option. In the words of resident Marlene Brown: "We don't want to be protected after the fact. We want to be protected and treated like we matter, without it taking a White supremacist shooting up our community. Time and time again they've shown nobody cares about us here. It's a pattern" (Closson 2022).

Ms. Brown's quote is apt; the long arc of institutional racism is often glossed over, along with its role in generating the long-standing disparity between communities. The shooting in a Tops supermarket (the location of which is denoted by a star in Figure 6) occurred just a few blocks from one of the only areas north of the downtown area that housed a Black population in the 1930s and was redlined for their "infiltration". Today, the diagonal arterial of Main Street remains a dividing line in the city, with the east side being a low-income Black community. The racism that stigmatized their community nearly one hundred years ago, seems to have ossified the urban fabric in time; encapsulating (and potentially even intensifying) its segregation.

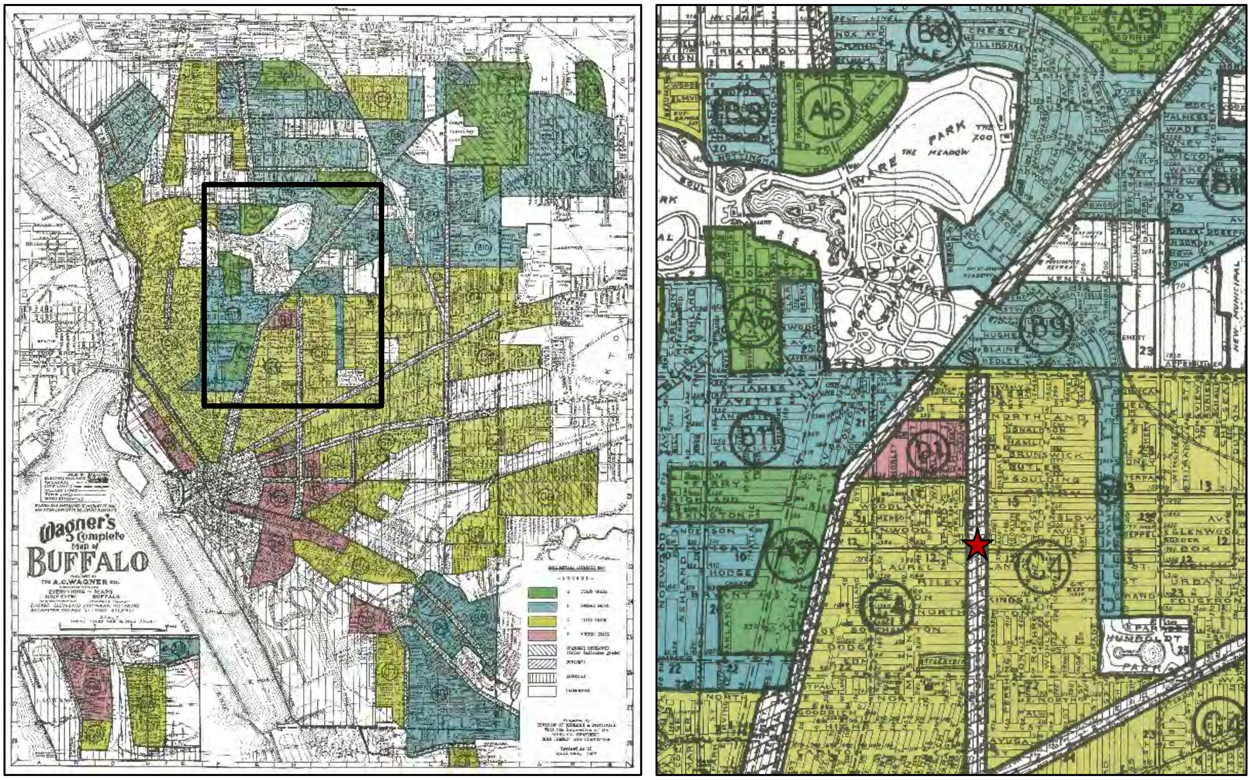

Figure 6. HOLC map for Buffalo, NY, with inset denoting the supermarket (Nelson, et al. n.d.)

Since much of this violence occurs in urban America, and many Black communities are hyper-segregated, it seems opportune to explore the role of governmental policies that might have informed the current division, this “pattern” in Ms. Brown’s words, and trace its effects – from redlining to exclusionary zoning, to urban renewal plans. Bringing light to these practices and examining the degree to which their perniciousness has persisted, is timely and important.

The eminent researcher on government-brokered segregation in cities, Richard Rothstein, used St. Louis to provide a clear example that illustrate how these racist policies link up with present-day violence against Black Americans. In the 1930s, areas near the historic downtown were redlined by the HOLC because they housed Black residents (Nelson, et al. n.d.). In the 1950s, these areas became targeted for urban renewal projects, and neighborhoods were razed to construct the Gateway Arch, a museum, a stadium, interstate highways, and middle-class housing (Figure 7). Roughly 78% of all families displaced by urban renewal in St. Louis were

Black families (ed. Nelson and Ayers n.d.). Meanwhile, public housing projects like the Pruitt-Igoe houses, were constructed in more isolated areas, with less access to jobs and opportunity, and housed large numbers of displaced Black residents in segregated enclaves because the private housing market would often not lend or rent to them. By the 1970s, Pruitt-Igoe had become a symbol of the dysfunction of public housing, and disinvestment was so bad that the federal government dynamited the complex and relocated the residents (also in Figure 7). Residents were given vouchers by the St. Louis Housing Authority and were predominantly assisted in moving to inner-ring suburbs whose zoning permitted multi-family housing in the form of apartments – communities like Ferguson. Outer ring suburbs, whose White residents were more affluent, incorporated themselves and used exclusionary zoning tactics like single-family zoning districts to effectively block Black residents through socio-economic barriers to entry. In 1970, less than 1% of Ferguson was comprised of Black residents; by 1980, it was around 14%; by 1990, 25%; by 2000, 52%; and by 2010, 67% (Rothstein 2014).

Figure 7. Images showing the impact of urban renewal (1950s) and housing policies in St. Louis (1972) (Rothstein 2014)

In providing this history of St. Louis that ties the historical planning practices of redlining, urban renewal, public housing failures, and zoning, with the emergence of Ferguson as an enclave of low-income Black Americans – the type of place that leaves young Black men like Michael Brown vulnerable to discrimination and police brutality – Richard Rothstein underscored: “Every policy and practice segregating St. Louis over the last century was duplicated in almost every metropolis nationwide” (Rothstein 2015, 169). It is difficult if not impossible to redress issues like police brutality when the underlying institutional racism that has segregated cities for over a century, and its role in fostering a vast divide in political power, societal privilege, public safety, and economic opportunity, remains veiled (Rothstein 2017). Identifying the persistence of this division is important to advance the discussion of equity in communities across the nation.

Fixing the problems of historic racist policies will require interventions to dismantle the spatial barriers that still exist in our cities’ built environments and will necessitate course corrections in their land-use frameworks. Identifying explanatory variables for the segregated patterns of today is important, even if the degree of influence of such variables differ from city to city (Logan and Stults 2021). In the short term, isolating these variables can inform policymakers where to target their efforts to improve integration and access. The racism embedded in the American city will take the collective work of many planners, and policymakers, in conjunction with other civic actors, to dismantle completely. This project humbly aims to advance that goal towards advocating greater urban integration and equitable access to opportunities, amenities, resources, and protections amongst the various populations that characterize American cities.

Chapter 2 Background and Related Work

This section is divided into two core components. First, a core historical backdrop pertaining to the role governmental policies in the role of accelerating housing segregation in US cities is surveyed to convey the salient policy issues, but also illuminate the relevancy of specific variables in the regression analyses. This first section also includes a NYC backdrop where race and its intersectionality with planning and land use planning is discussed, along with the local figures that played an outsized role in its manifestation. Second, after this backdrop, a literature review details the pre-eminent research informing the backdrop, and details other studies that informed the research methods. In each of these sections, the limitations associated with the existing research are briefly outlined.

2.1. Historical Backdrop to Institutional Racism in Planning Issues

In 1619, Africans were sold as slaves to European colonists in modern-day America for the first time, propelling the future nation into a regrettable trajectory of white supremacy; an ideology whose scars remain in the social fabric even after 400 years (Elliott and Hughes 2019). In the decades prior to, and immediately after the American Revolution, plantations that profited from slave labor were largely concentrated along the Southern coasts. As indigenous peoples were forcibly removed from inland areas and more valuable farmland acquired by White Americans, a “Black Belt” emerged by the 1850s in the Deep South – a double entendre reflecting the rich soil of the Piedmont and the alluvial floodplains around the Mississippi-Yazoo Delta and the high concentration of African-origin slaves working the plantations in these areas (Figure 8) (Ayers, Madron, and Ayers 2021). In the aftermath of the Civil War, most emancipated Blacks remained closely tethered to rural, southern farms, often working as sharecroppers on White-owned cotton fields. Despite the constant attempts from White

Southerners to subvert their newfound political rights and freedoms through overt terrorism or covert, discriminatory legal machinations (Coates 2014), these Black Americans often did not migrate; they did not have the economic means to do so, and the Deep South only became well connected to the North via railroads in the 19th century (Ayers, Madron, and Ayers 2021).

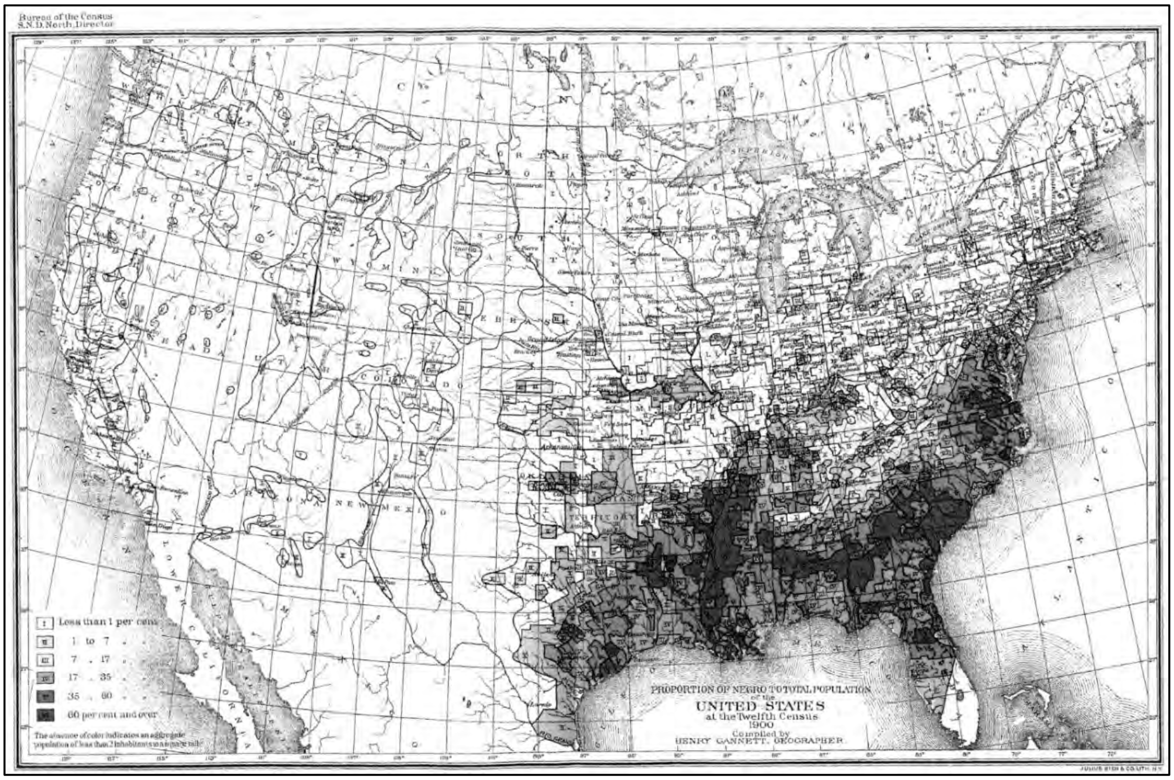

Figure 8. Black population in the US, circa 1900 (Gannett 1904)

2.1.1. The Great Migration and Initial Exclusionary tactics

Beginning in the early part of the 20th century, the spatial geography of Black Americans began to shift. The outbreak of the boll weevil crop pest, followed by the economic devastation of the Great Depression, and mechanization in harvesting crops, wreaked havoc on the livelihood of southern Black sharecroppers, prompting a "Great Migration" of African-Americans from southern fields, through the expanding rail network, into northern and later western cities in search of factory work (Lemann 1991). As Black families began settling in northern cities, they had newfound political liberties, but were nonetheless confronted with hostilities not altogether alien to those they confronted in the Jim Crow south, particularly when Black families unwittingly disrupted the prevailing opinion that neighborhood stability depended on racial homogeneity. To preemptively segregate arriving Black migrants from White neighborhoods, cities first used racial zoning ordinances as an exclusionary tactic. This practice was short-lived, and deemed unconstitutional in 1917, because of its overt discrimination (and lack of nexus with the powers vested with cities to "zone" for land uses), and so following that, many property owners placed racial covenants on their deeds to effectively achieve the same results albeit more covertly. This exclusionary practice became widespread in White communities; the Mapping Prejudice project at the University of Minnesota, for instance, has found over 20,000 deeds in Hennepin County with racial covenants issued prior to 1948, the year they were struck down as unconstitutional by the Supreme Court (Kaul 2019; University of Minnesota Libraries n.d.). The National Association of Real Estate Boards promoted neighborhood exclusivity and, amongst its broker members, actively discouraged sales to minority groups, believing that integration would erode property values [2] (Rothstein 2017).

2.1.2. The Home Owners' Loan Corporation and "Redlining"

The professionalization of the real estate industry and its coalescence into a powerful lobbying group quickly led discriminatory practices to be adopted by the federal government. As part of the range of programs created by the New Deal to help Americans contend with the effects of the Great Depression, the HOLC was established by the federal government to help homeowners refinance their mortgages and avoid defaulting. Shortly after its inception, roughly

[2] From the ethics handbook of the National Association of Real Estate Boards, 1924: "A Realtor should never be instrumental in introducing into a neighborhood a character of property or occupancy, members of any race or nationality, or any individuals whose presence will clearly be detrimental to property values in that neighborhood" (Kaul 2019).

between 1935 and 1940, agents of the HOLC devised a grading system to evaluate “residential security” – essentially a proxy for the lending risk a bank would assume. Within most major American cities, neighborhoods were carved up into A, B, C, and D categories, with associated colors of green, blue, yellow and red. The “A” category (green) equated to the “best” housing, the “B” areas (blue) meant “still desirable”, “C” (yellow) represented “definitely declining” and “D” (red) meant “hazardous” (Jackson 1987; Nelson, et al. n.d.). The rating system accounted for a variety of factors that customarily accompany real estate appraisal in defining its categories, such as the type and age of construction, but also added extraneous factors like the racial and ethnic composition of neighborhoods as part of the grading rubric. Pockets of Black neighborhoods were almost uniformly given C and D ratings within cities, effectively barring them from access to loans. The red borders that demarcated the D zones led to the pejorative term “redlining” for any type of racially discriminatory land use or housing-related practice based on a community’s demographics[3]. The urban historian Kenneth Jackson (1987) summarized the situation thusly: The HOLC “devised a rating system that undervalued neighborhoods that were dense, mixed, or aging…[and] applied these notions of ethnic and racial worth to real-estate appraising on an unprecedented scale” (Jackson 1987, 197). While the HOLC maps have become notorious, grading neighborhoods for underwriting was also common

[3] Descriptions of each designation were written by HOLC agents to help local lenders and give an unadulterated vantagepoint into their mentality. A “hazardous” D zone in Minneapolis was assigned as such because:

> At the present time, many Jews and Scandinavians and negroes reside in the easterly half of this area. The westerly half has many of the shifting populations occupying the cheap apartments and rows. Down in the southeast corner of the area near the Adams school there is a considerably large negro settlement. The whole area is close to the business center of the city, it contains many rooming houses occupied by salaried employees and laboring people because of the nearness to the business district. The age is 20 to 50 years. (Nelson, et al. n.d.)

practice by banking institutions and other government lenders, such as the FHA[4] (Hillier 2003). The interlocking levels of discriminatory lending practices meant that the stratification of 1920s cities started to become ossified in the urban landscape, as there was a special pattern already emerging: inner-city areas, near the core, often received C and D ratings, while peripheral areas transitioning to suburbs, received A and B designations. Figure 9 shows this radial type of pattern in Minneapolis and Baltimore, where risk is diminishing as one moves outward from the center city.

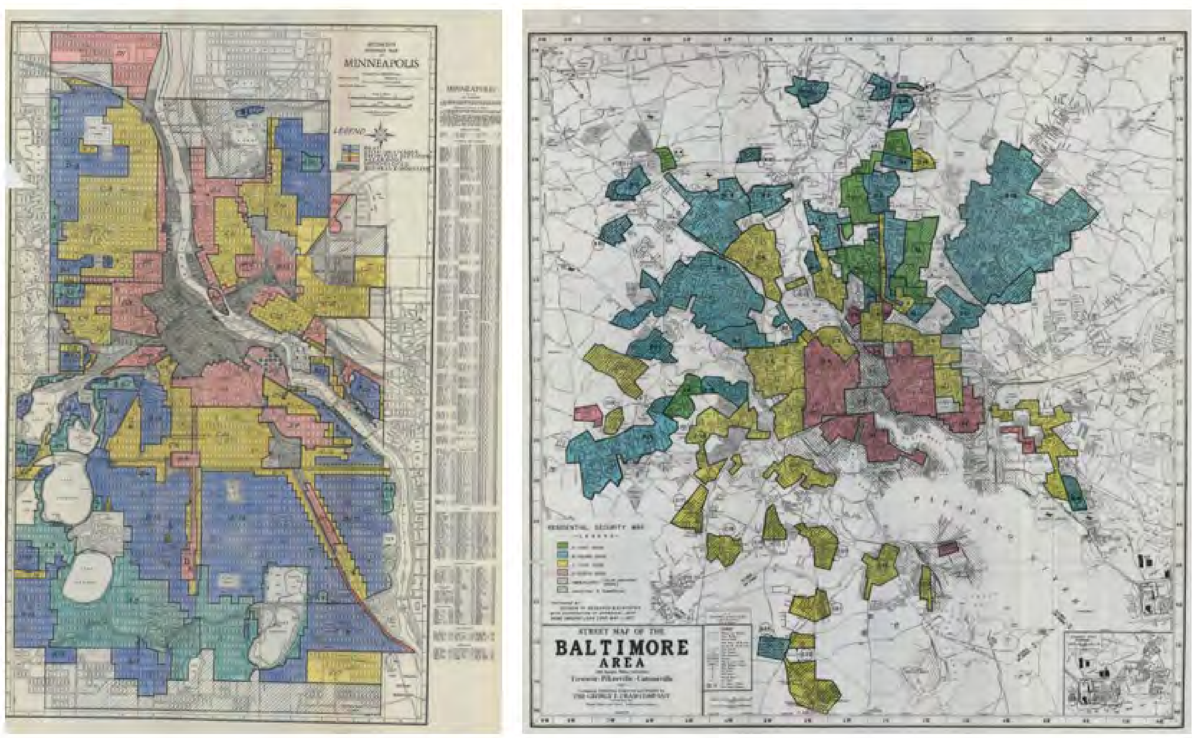

Figure 9. HOLC maps from Minneapolis and Baltimore (Nelson, et al. n.d.)

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[4] In instructing the creation of maps to assess appraisal and risk throughout the US, staff economist of the FHA, Homer Hoyt, explained:

> 'The maps, if prepared carefully according to the suggestions now to be given, should lay the groundwork for the rating of neighborhoods,'… [and then] instructed staff responsible for creating the maps to draw lines in specific colors around certain types of areas. In the first set of maps, red was to be used to mark off areas with concentrations of an "undesirable element" such as distinct racial, national, or income groups. (Hillier 2003, 402)

2.1.3. Suburbanization and the Rise of Single-Family Zoning

The disparagement of dense, inner-city, minority neighborhoods by federal underwriting manuals coincided with a championing of single-family detached homes in peripheral suburban areas. These were typically located in the areas of cities that HOLC and FHA maps graded "best" or "still desirable" areas, and appraisers often noted legal protections like the presence of racial covenants or exclusionary local zoning ordinances as reasons for banks to extend credit and assume low risk. While the Supreme Court had determined that it was illegal to explicitly discriminate through zoning in the early 1900s, planners quickly sought to effectively achieve the same results through physical criteria, like minimum lot sizes, and an extremely limited range of permissible land uses (Kahlenberg 2019). By explicitly prohibiting nearly every type of land use other than single-family homes on large lots from swaths of the city, a de-facto segregation emerged, as the types of homes lower-income residents could afford, like duplexes, triplexes, and rental apartments, were expressly prohibited. Since barriers to economic opportunity often meant non-White racial populations were low-income renters and could not afford to purchase single-family homes, these exclusionary practices were upheld in courts despite yielding the same effects as the explicit discrimination deemed unconstitutional. They spread quickly to zoning codes throughout the country[5] where they came to "protect the neighborhood character"

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[5] The landmark Supreme Court case that upheld zoning, Euclid v. Ambler, discussed apartment buildings as follows:

> …very often the apartment house is a mere parasite, … interfering by their height and bulk with the free circulation of air and monopolizing the rays of the sun which otherwise would fall upon the smaller homes, and bringing, as their necessary accompaniments, the disturbing noises incident to increased traffic and business, and the occupation, by means of moving and parked automobiles, of larger portions of the streets, thus detracting from their safety and depriving children of the privilege of quiet and open spaces for play, enjoyed by those in more favored localities – until, finally, the residential character of the neighborhood and its desirability as a place of detached residences are utterly destroyed (Justice Sutherland, US Supreme Court 1926).

of large swathes of the peripheral areas of most cities, not to mention their suburbs, from the encroachment of higher-intensity uses and the unseemly demographics associated with them (Figure 10) (Rothstein 2017). Zoning ordinances, therefore, often worked in tandem with the mortgage lending practices to completely alter the 19th-century urban fabric of major cities[6]. They had the effect of simultaneously suburbanizing White residents into homogenous communities and consolidating Blacks and other minority groups into denser, urban ghettos without access to loans (Rothstein 2017; Hirsh 1998).

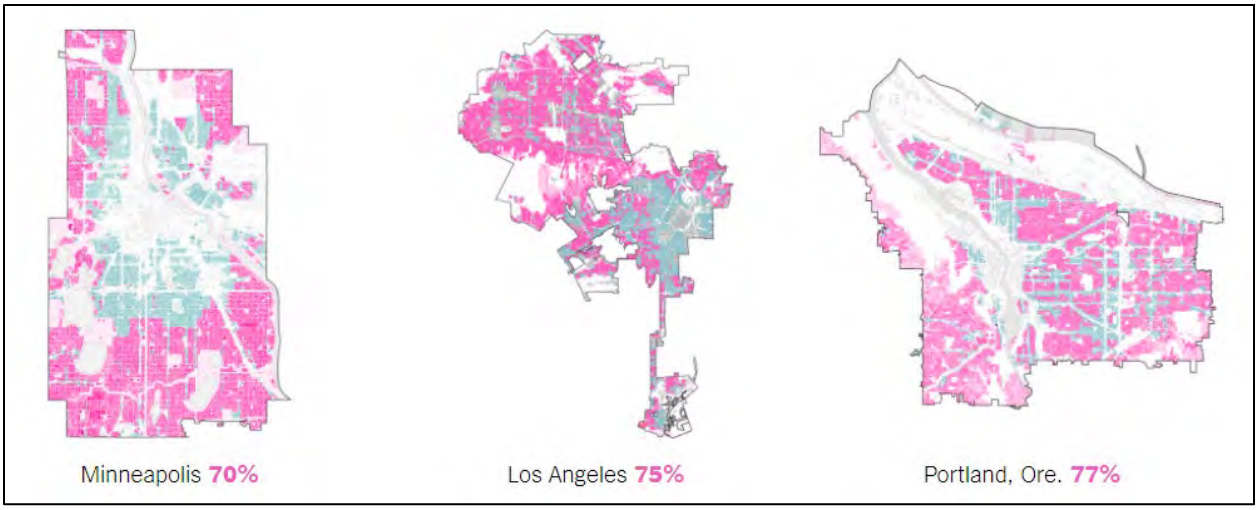


Figure 10. Land zoned for single-family homes in select US cities (Bui and Badger 2019)

2.1.4. Slum Clearance, Urban Renewal, and Suburban Mortgages

The Housing Act of 1949 was landmark federal legislation that accelerated these divisive urban and suburban trends in three primary ways. First, Title I of the bill granted federal monies towards slum clearance in urban renewal projects designated by US cities (Committee on Banking and Currency, US Senate 1949). These areas were often designated in lower-income, minority communities and were used for a variety of functions, such as to reinvest in new civic

[6] In *The Color of Law*, Richard Rothstein notes that "the FHA had its biggest impact on segregation, not in its discriminatory evaluations of individual mortgage applicants, but in its financing of entire subdivisions, in many cases entire suburbs, as racially exclusive white enclaves. (Rothstein 2017, 70)"

amenities (such as Lincoln Square in New York, as shown in Figure 11), to build middle-class housing (such as Stuyvesant Town in New York), to construct highways, (particularly after the Federal Highway Act was passed in 1956), and to construct public housing (in concert with Title III funding through the same legislation) (Rothstein 2017; Hirsh 1998). Even where families were not displaced by urban renewal transformations, their effects could be pernicious; highways, for instance, often divided previously vibrant minority neighborhoods, causing a vicious cycle of economic and social side effects. Figure 11, for example, shows Interstate 95 being cut through Tremont in the Bronx (Avila 2014; Caro 1973). Title II of the Housing Act expanded the mortgage insurance program which, coupled with the discriminatory lending practices and exclusionary zoning, expanded home-ownership opportunities for mostly White citizens by offering securitized down payments and low-cost mortgage rates (Rothstein 2017).

Figure 11. Images showing highway-building (Tremont, Bronx, 1949) and other urban renewal impacts in NYC (Lincoln Square, Manhattan, 1969) (lbennett 2019; Williams 2017)

2.1.5. Separate and Unequal

In the decades after World War II, as returning veterans sought to start families, this policy armature was in place and ushered in modest suburban enclaves throughout the nation and lifted millions of Americans into the middle class by securitizing their appreciating home assets (Jackson 1987). Yet for Black Americans, a dramatically different narrative emerged; they were locked out of the lending markets, barred from this federally subsidized wealth accumulation, and confined to certain areas of the city where the limited housing supply left them dependent on public housing or vulnerable to unscrupulous landlords[7] and predatory lending schemes like contract housing. Early post-war suburbs like Levittown, NY, on Long Island, as shown in Figure 12, were affordable to returning veterans through the GI Bill. However, despite federal underwriting, they still included racial covenants barring Black owners (Sheidlower 2020).

Factors such as overcrowding, minimal maintenance from absentee landlords (whether private or public entities), and neglect from city administrators, often led to slum conditions in Black neighborhoods, and Black residents were stigmatized as the initiators rather than the victims of this circumstance. Public housing projects like Pruitt-Igoe, in St. Louis, also shown in Figure 12, had little money budgeted towards maintenance and operation, and so slum conditions emerged from disrepair (Newman 1976). This, in turn, made White enclaves more biased against integration, fearing slum conditions would follow Black residents (Rothstein 2014). Real estate agents preyed on these White fears, and used a tactic called “block-busting” to acquire properties at a lower price from White sellers for fear of Black residents, and then resold them to Black

[7] Ta-Nahesi Coates (2014) explains: “In Chicago and across the country, whites looking to achieve the American dream could rely on a legitimate credit system backed by the government. Blacks were herded into the sights of unscrupulous lenders who took them for money and for sport. ‘It was like people who like to go out and shoot lions in Africa. It was the same thrill,’ a housing attorney [gloated]... ‘The thrill of the chase and the kill.’”

families at much higher prices as contract housing (where no equity was obtained), as families were so desperate to leave the ghetto (Rothstein 2017; Coates 2014).

Figure 12. Different trajectories stemming from the Housing Act of 1949 (Levittown, NY, 1950s, and Pruitt-Igoe, St. Louis, 1960s) (Sheidlower 2020; Newman 1996)

As the Great Migration continued in earnest, with five million Black Americans migrating between the 1940s and 1970s, the multi-level, discriminatory government policy framework was in full force and intensified the burgeoning schism. Attempts to course-correct, such as through Civil Rights legislation, and the Supreme Court mandated desegregation of school districts, prompted swift reaction from White suburbanites (Figure 13), and the lofty ambitions of the 1960s Great Society began to fade as this cohort became an important voting bloc. In what would become one of the last bold moves for suburban integration, President Nixon’s Secretary of the Department of Housing and Urban Development (HUD), George Romney, proposed denying federal investments in sewers, water projects, parks, or other redevelopment in White suburbs unless exclusionary zoning tactics were repealed and subsidized low- and moderate-income housing accepted (Lamb 2005; Rothstein 2015). In a foreshadowing of the dramatic shift in the Republican Party platform, Romney was dismissed, and the integration policy reversed in order to mollify Nixon’s [perhaps not so] “silent majority”

(Jackson 1987). Figure 13 shows White Bostonians protesting the court-ordered desegregation of schools and White suburbanites in Warren, Michigan, a suburb of Detroit, protesting HUD Secretary Romney's proposed suburban integration plan (Detroit News 1970). Romney was familiar with inner-city strife as he was the Governor of Michigan during the 1967 race riot in Detroit, and suburban residents were also familiar with him.

The exodus of White people from inner city areas to the suburbs – "White flight" – continued into the 1970s and 80s, and as their associated wealth fled with them, the tax bases of many cities plummeted, spurring a decline in the quality of municipal services. As crime rose, schools and other municipal services deteriorated, and soon a vicious cycle emerged wherein people of means left the city, leaving municipalities to grapple with more problems with fewer resources, which in turn spurred further decline and exodus (Hirsh 1998). Drug epidemics in the 1980s and 90s further crippled these disenfranchised communities. Reciprocally, suburban resources increased in a virtuous cycle, as the leafy, low-crime oases with high-performing schools beget more transplants, aided by new federal highways, and a steady migration of businesses and manufacturers to cheaper exurban land (Sugrue 2005).

Figure 13. Images of White suburbanites resisting integration
(Hannah-Jones 2019; Detroit News 1970)

In 1967, while the National Guard had been called in to quell a race riot in Detroit, a Commission was assembled by President Johnson to try and understand the underlying psyche leading to the string of rioting and looting being incited primarily by young Black men in cities throughout America. While many expected an indictment of the Black "agitators", the Kerner Commission instead laid the blame squarely on White America, bluntly stating that the reason for economic strife and social discontent amongst the Black in inner-city ghettos was a direct consequence of the White privilege concentrated in the suburbs:

> Our nation is moving toward two societies, one black, one white – separate and unequal…What white Americans have never fully understood – but what the Negro can never forget – is that white society is deeply implicated in the ghetto. White institutions created it, white institutions maintain it, and white society condones it (The National Advisory Commission on Civil Disorders 1968, 1).

Over fifty years later, the warning of the Kerner report remains largely unheeded, and nearly every new episode of violence in Black communities reignites a probe into the underlying structural inequality dividing Black and White America. Understanding the pernicious side effects of redlining and other discriminatory tactics in American cities is vitally important if progress is to be made in desegregation, and this thesis aims to contribute to that knowledge - base.

2.1.6. New York Backdrop

New York is heralded as a bastion of liberal politics and progressive policies, but beneath this veneer, the city has struggled with race for centuries.

Central Park, one of the largest municipal infrastructure projects ever contemplated, is one of the city's most defining features. Yet, when the Olmstead and Vaux plan was selected as the winning entry to steer the park's design in the 1850s, the northern portion of the land to be condemned was home to a thriving Black community, Seneca Village, whose residents had sought refuge there to escape persecution further downtown. The residents, who had constructed roughly fifty homes, three churches, and a cemetery, were displaced entirely by 1857 (The Central Park Conservancy 2018).

Less than a decade later, during the American Civil War, the city's working-class, mostly immigrant residents in Lower Manhattan rioted over being conscripted to fight in the war, and in the process, the event degenerated into race riot, with mobs burning the homes, and inflicting violence and death on innumerable Black residents. While this obviously was not the result of a particular land use policy, it represented the largest insurrection in American history to that point – apart from the Southern secession itself. The violent racism of its residents instilled such fear and horror that many Black residents relocated to other parts of the city (Foner 1988).

In the late 1800s, a new Black enclave emerged on the fringes of the vice district of the day, the Tenderloin. In 1900, a race riot emerged when a police officer was struck and killed by a Black man intervening in the arrest of a Black woman for soliciting. White gangs burned down Black homes and attacked Black residents. Within a decade, the city condemned four blocks housing predominantly Black populations to construct its second rail station, Pennsylvania (Penn) Station, displacing residents to other Black enclaves in the city (Jonnes 2008).

In the 20th century, a discussion of New York's planning narrative, and the intersection of federal and local policies, would not be complete without invoking Robert Moses and Jane Jacobs. Moses, a city and state bureaucrat, embodied top-down urban planning, making sweeping urban changes to the city without the input of those impacted, while Jacobs, an activist, represented a bottom-up approach, where officials would make informed decisions from community participation (Gratz 2010). Their powerful, and often opposing ideologies, have not only had a lasting influence on the city, but embody a shift in larger planning mentalities over time.

Robert Moses' life and contribution to the city – both for good and ill – have been meticulously documented by his biographer, Robert Caro. The emergence of government infrastructure investment programs like the Works Progress Administration during the Great Depression created a perfect scenario for this visionary, realpolitik power broker to rise through the ranks of state and city governments. Moses was a fixture in nearly every agency involved with physical planning in the region without ever being elected to office. He ran the Parks Department, was a City Planning Commissioner, and otherwise operated as an infrastructure czar, overseeing the construction of bridges, parkways, highways, stadiums, and public housing (Caro 1973). This authority gave him an outsized influence over urban renewal policies and their on-the-ground manifestation across the city, and he is known for his callous displacement of minority communities[8] (Boeing 2021; Caro 1973).

His decrees were not always implemented. Between the 1940s and 60s he issued several plans for a Lower Manhattan Expressway that would connect the Holland Tunnel on the west side with the Manhattan and Williamsburg Bridges on the east side (Figure 14). While this would efficiently connect New Jersey with Brooklyn and, through other highways, Queens, and greater Long Island, it would displace residents in SoHo, Little Italy, the Lower East Side, and Chinatown. Nearby residents in Greenwich Village would also be impacted, and activists like Jane Jacobs (Figure 14) made resistance a cause célèbre (Chatelain n.d.).

[8] In response to Robert Caro's seminal biography, and the criticism of his legacy, Moses said: "I raise my stein to the builder who can remove ghettos without moving people as I hail the chef who can make omelets without breaking eggs" (Boeing 2021, 1).

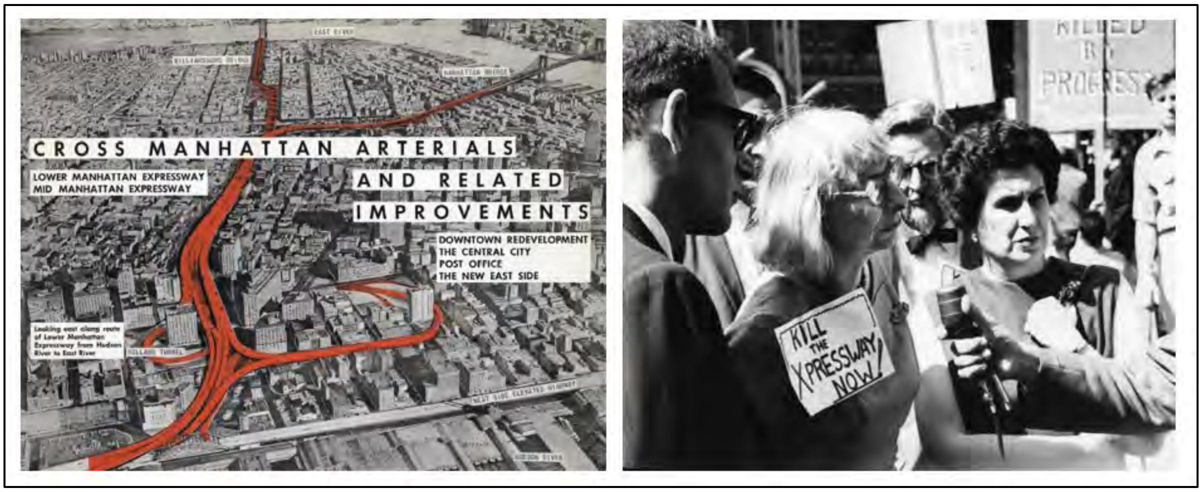
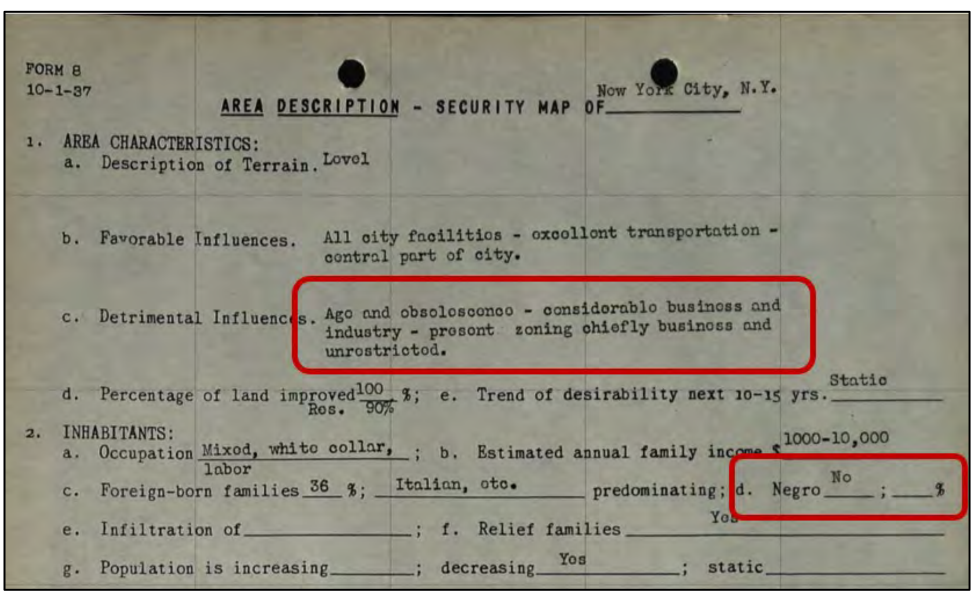


Figure 14. Proposed location of, and protest against, the Lower Manhattan Expressway (Sagalyn 2016; Seamon 2019)

The South Village also had a Slum Clearance and redevelopment plan proposed by Moses under the auspices of the Title I of the Housing Act of 1949, wherein several blocks south of Washington Square Park would be cleared for housing projects (The Committee on Slum Clearance Plans 1951). Jacobs, in her seminal *Death and Life of Great American Cities,* which is a foundational book for urban planners, delivered a blistering critique of monolithic superblocks, and the banal residential architecture characterizing many urban renewal redevelopments. Instead, she championed four principles that underpin a healthy neighborhood: a mix of uses to encourage day-round vitality; short, walkable blocks; a varied building stock of old and new buildings; and a healthy density to stimulate interactions (Jacobs 1961). The underlying anecdotes that grounded her practical urban sociology were largely derived from her home in the Village and were deeply critical of not just the urban renewal in her neighborhood, but what she saw as a mistaken pedagogy of urban planning in general.

The narrative of Jane Jacobs' success in stopping Robert Moses' plans in the Village is a well-trodden David versus Goliath type of story, which fueled a new generation of community activism to try and shape local land-use politics (Gratz 2010). What is less explored in the literature is the reasonings for targeting the Village for renewal in the first place. While significant areas of the Upper East Side, the West Village, SoHo, and Lower Manhattan around the CBD are some of the most affluent zip codes in the nation today, they were redlined in HOLC maps and subsequently designated for slum clearance because the primary building stock were aging tenements that possessed substandard access to light and air. Figure 15, for example, shows a description from the West Village and one from Bedford-Stuyvesant (Nelson, et al. n.d.). Notably, there are no "Negro" inhabitants in the West Village; instead, inhabitants are comprised of a mix of white and blue collar, foreign-born and native-born, White residents. The detrimental influences are simply the age and obsolescence of the building stock and lax zoning regulations. This contrasts with the "infiltration" by African Americans in central Brooklyn.

Little literature has explored the connection between redlining maps, the slum clearance proposals (such as in Figure 16), the actual racial composition, and how White communities that were redlined have fared in subsequent decades contrast to Black or other minority communities that were redlined.


FORM 8
10-1-37

AREA DESCRIPTION - SECURITY MAP OF New York City, N.Y.

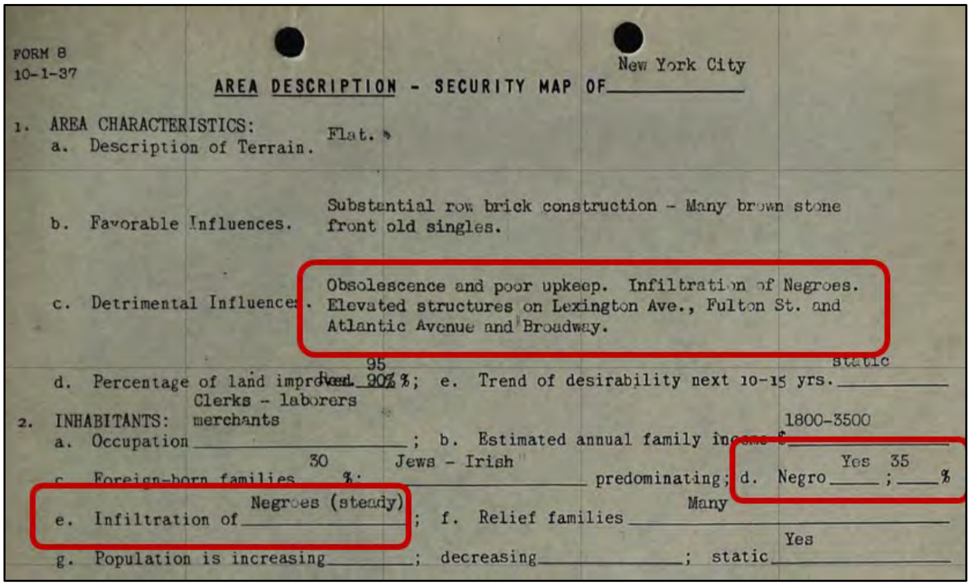
1. AREA CHARACTERISTICS:
a. Description of Terrain. Level

b. Favorable Influences. All city facilities - excellent transportation - central part of city.

c. Detrimental Influences. Age and obsolescence - considerable business and industry - present zoning chiefly business and unrestricted.

d. Percentage of land improved 100 Res. 90% %; e. Trend of desirability next 10-15 yrs. Static

2. INHABITANTS:
a. Occupation Mixed, white collar, labor; b. Estimated annual family income $ 1000-10,000
c. Foreign-born families 36 %; Italian, etc. predominating; d. Negro No ; ___ %
e. Infiltration of ___; f. Relief families Yes
g. Population is increasing ___; decreasing Yes; static ___



FORM 8
10-1-37

AREA DESCRIPTION - SECURITY MAP OF New York City

1. AREA CHARACTERISTICS:
a. Description of Terrain. Flat.

b. Favorable Influences. Substantial row brick construction - Many brown stone front old singles.

c. Detrimental Influences. Obsolescence and poor upkeep. Infiltration of Negroes. Elevated structures on Lexington Ave., Fulton St. and Atlantic Avenue and Broadway.

d. Percentage of land improved 95 %; e. Trend of desirability next 10-15 yrs. static

2. INHABITANTS:
a. Occupation Clerks - laborers merchants ; b. Estimated annual family income $ 1800-3500
c. Foreign-born families 30 %: Jews - Irish predominating; d. Negro Yes ; 35 %
e. Infiltration of Negroes (steady) ; f. Relief families Many
g. Population is increasing ; decreasing ; static Yes

Figure 15. HOLC D area designation writeup for West Village (top) versus Bedford-Stuyvesant (bottom) (Nelson, et al. n.d.)

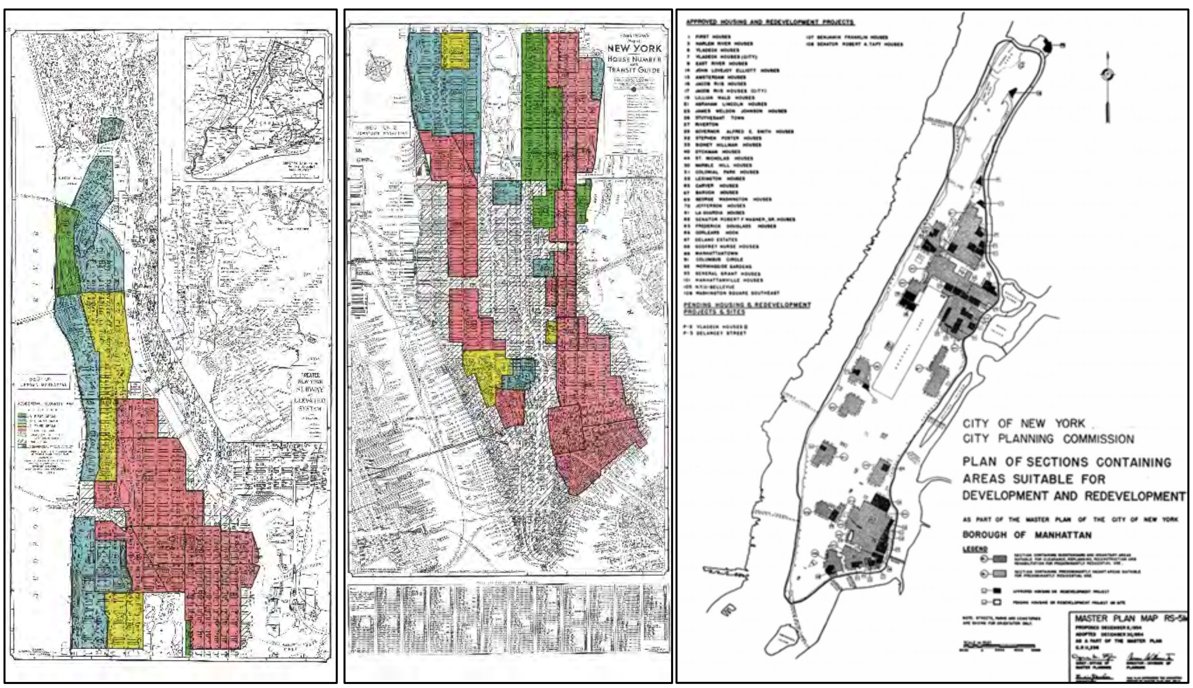


Figure 16. HOLC maps of Manhattan compared with the Slum Clearance boundaries (Nelson, et al. n.d.; Laurence 2006)

NYC's Zoning Resolution is one of the principal planning tools of the Department of City Planning (DCP). The Department's 1961 Zoning Resolution was a comprehensive rewrite of the 1916 Zoning Resolution and was decades in the making. It sought to vastly simplify the districting framework of its predecessor while also reducing the overall zoned capacity and increasing open space (NYC DCP 2018). However, because the Zoning Resolution was the result of decades worth of planning work, the underlying presumptions characterizing development allowances, height, and setback regulations, and nearly all building bulk regulations, were generally that of the 'tower-in-a-park' campuses typified by urban renewal plans. This large-scale, super block framework, with towers set far from the street amidst open space, contrasted in nearly every way with the existing character of most transit-adjacent neighborhoods, where the building stock was defined by more granular 25-40' wide tenement buildings that were comparatively squat and hugged the sidewalk (NYC DCP 2018).

As urban renewal became reviled, accelerated by the growth of the historic preservation movement (particularly after the loss of Penn Station in 1963), piecemeal modifications to the Zoning Resolution were adopted in the form of alternative zoning districts, called "contextual districts." As the name suggests, these rules sought to ensure new development would mimic the built pattern of well-established neighborhoods and differentiated themselves from the original 1961 zoning districts by having fixed height limits and a squatter built form (NYC DCP 2018).

While the negative reaction by community activists to urban renewal, and its zoning affiliates, was legitimate, problematically, as the acuteness of government overreach diminished, and the propensity to raze neighborhoods waned, the affinity for these contextual districts has persisted. Over several decades, different coalitions of affluent and privileged stakeholders became increasingly vocal about *any* change, saying "not in my backyard" about new construction (Adams 2022). These NIMBY-ists were intent on preserving the "character" of a neighborhood by shrink-wrapping the code around its existing form. Contextualization, at nearly every density, has been one of the major themes to zoning amendments after 1961, especially as district tools became more widely available in the late 1980s (NYC DCP 2018), and has been a tool used by the Department as readily as communities themselves (Laskow 2014). Perhaps unsurprisingly, as layers of land use regulations have increased, and more limitations on where new housing can be built have been added, housing prices in New York have drastically increased.

The Zoning Resolution has been amended a dizzying number of times (NYC DCP 2018). This fact, combined with the complexity of the code, and difficulty in teasing out definitively whether a modification increased or decreased zoned capacity, by changing the zoning map or the zoning text, makes it difficult to evaluate if changes that have occurred to the Zoning Resolution have disproportionately benefited White communities. For example, have legislative changes in White affluent areas led to an outsized reduction in development capacity (by virtue of a reduction in zoned rights (a "downzoning")? Reciprocally, if housing supply is heavily restricted in these affluent White areas, but demand to live in New York persists, has this led to a disproportionate reliance on lower-income minority neighborhoods for shouldering a disproportionate share of growth? Acknowledging housing supply is complex, and there are exogenous inputs impacting NYC, including regional housing supply, there is little research connecting the genesis, and effects of zoning modifications (e.g., the elasticity in housing supply) with race and privilege.

The 2020 Census shows drastic demographic shifts in traditional Black communities like Harlem, Crown Heights, and Bedford Stuyvesant, as can visually be seen in the maps in Figure 17. The loss of Black population in these neighborhoods corresponds very closely with corresponding White gains. Overall, there was nearly a five percent loss in the Black population between 2010 and 2020 (NYC DCP 2021) .

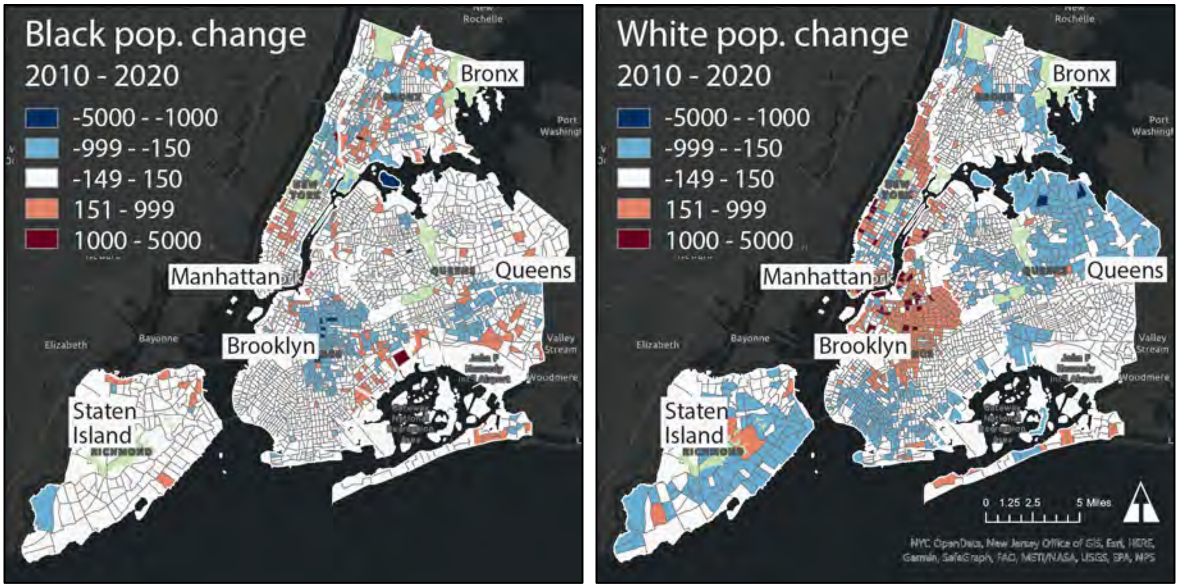


Figure 17. Change in Black and White population between 2010 and 2020

Given the tremendous loss of Black residents in the last ten years, despite the growth of the city, consideration must be made for one of the more controversial urban phenomena of the twenty-first century – gentrification. This phenomenon most traditionally involves wealthier residents moving into lower-income areas, and, because they bring greater disposable incomes, they accelerate neighborhood change (Freeman 2006). Retail store fronts change (with higher priced goods), rents can be raised, and soon lower income populations are often undergoing housing stress and at risk of being displaced (Freeman 2006).

In cities across America, this trend has more recently involved a racial component – White residents moving into traditionally Black neighborhoods – as part of the renaissance many cities have experienced since the late 1990s (Chronopoulos 2020). The trend is sometimes doubly painful in cities like New York because it is occurring within the very same neighborhoods that Whites abandoned in the 1960s and 70s (Chronopoulos 2020). While a cursory glance at census data might reveal a seemingly integrated neighborhood, it could be cloaking a prolonged segregation that is now in transition and masking Black displacement.

While gentrification has certainly received considerable attention, there has been little research at a granular level that seeks to connect the correlation of planning policies in these recent demographic shifts; exploring whether these land use regulations are new covert stand-ins for overt segregation in housing policy 100 years ago, with a similar callousness in perpetuating displacement.

2.2. Literature review

Several pieces of prior research informed different portions of this thesis; literature was surveyed to inform the background understanding of planning policies and pertinent variables to assess, while other literature informed the spatial research methods.

2.2.1. Literature Informing the Historic Backdrop and Variable Selection

The disparate treatment of Black population segments in American cities is a topic that has spawned considerable discussion by other researchers. Many authors have researched the very tactile repercussions of spatial segregation in the urban landscape, particularly homing in on and quantifying the disparity between Black communities and other neighborhoods. Accessibility studies have shown unequal access to quality schools, park space, mass transit, healthcare, and jobs, while public health literature has documented higher prevalence of obesity due to insufficient fresh food access and higher rates of asthma due to proximity to highways.

Tracking the perniciousness of housing policies and land use regulations on Black communities is perhaps more difficult, as it requires sufficient knowledge of their historical arc, and interactions with local regulations, institutions, and prominent individuals. Because of this, much of the literature is difficult to communicate sufficiently in a paper; the core texts are often substantial volumes.

A significant amount of literature is devoted to examining the origins of segregation in the American city and the role various government policies played. This backdrop is important to understand the complexity of race in the American city, but also to ensure the appropriate variables are being considered for their role in explaining neighborhood segregation.

Kenneth Jackson, in his seminal book *Crabgrass Frontier* (1987), was the first scholar to rediscover the discriminatory HOLC maps, connect this lending risk assessment to FHA home financing, and assessing the power these tools collectively had in shaping the post-war American city. Richard Rothstein, in his the equally important *Color of Law*, explores the cumulative effect of redlining, zoning ordinances, restrictive covenants, urban renewal designations, and other racist government practices in shaping the Black experience. These texts are vital to this research for their tremendous historical sweep and topical range.

Many authors have addressed singular topics concerning the plight of Black Americans in the 20th-century city. Charles Abrams (1955) and Arnold Hirsh (1998) have written extensively on mid-20th-century housing policy and the evolution of New Deal era policies into hyper-segregated federal housing projects. Charles Lamb's (2005) research extends the arc of this housing lens from the Fair Housing Act of Johnson's Great Society into the Nixon era, and the slow unraveling of Johnson's Great Society's laudable goals. David Freund (2007) explores the sociological shift in suburban mentality that enabled this – the suspension of disbelief where one could simultaneously embrace civil rights, but oppose integration in their own backyard. Ta-Nehasi Coates (2014) discusses the rapacious tactics of real estate brokers in blockbusting White neighborhoods, and reselling homes to Black residents through predatory lending practices like contract housing. Massey and Denton (1998) tell the historical sweep of these policies, their contribution to segregation, and even ‘hyper-segregation’ and detail the sobering sociological implications for the Black community.

Many authors have also discussed the racial and exclusionary issues embedded within zoning regulations. Charles Haar (1989) describes the origin of zoning regulations in the United States, and the diverse range of issues that advocates of zoning sought to resolve. While some reformers legitimately sought to protect the interests of the city’s most vulnerable by ensuring basic rights like access to sunlight and fresh air in the dense immigrant enclaves of New York or separate validly incompatible uses under the guise of public safety, other influential forces tried to use zoning as an exclusionary device to protect property values, couching the protection of the city’s tax base as a valid public purpose (Haar and Kayden 1989). Christopher Silver (1997) discussed the increasing boldness of abusing zoning in the late 1800s and early 1900s, from California’s prohibitions on Chinese laundromats as a means of discriminating, to the eventual explicit prohibition of persons of color from certain sections of cities through racial ordinances. Interestingly, Silver notes that while racial zoning was struck down by the Supreme Court in 1917, many Southern cities continued to adopt and enforce new legislation afterwards; Birmingham, Alabama illegally enforced their code as late as 1951. Other literature has made some of the more covert exclusionary zoning practices, like single-family zoning and minimum lot sizes, so well-connected with their racist history that some planning departments and local politicians are summoning the courage to repeal them, and communicate their historical missteps (DC Office of Planning 2020; Bureau of Planning and Sustainability 2019).

Urban renewal policies relating to highway construction have also been addressed topically. Eric Avila has written on the disproportionate targeting of low-income neighborhoods for slum clearance and highway construction and unsuccessful community mobilizations and protests to stop the destruction of communities of color (Avila 2014). Robert Caro (1973) has chronicled similar histories in New York under the supervision of the powerful urban planner Robert Moses, and in detailing the construction of the Cross-Bronx Expressway detailed the singular commitment to removing minority residents, even when less destructive and cheaper options were available. In evaluating slum clearance designations in five cities, Miles Miller suspects racist motivations for slum clearance designations for similar reasons; neighborhoods acquired through eminent domain routinely exceeded slum standards, and often had higher property values than surrounding areas (Miller 2018). David Karas has similar conclusions as Miller, that while the Interstate Highway System ushered in tremendous growth, a tepid approach to civil rights by the Eisenhower administration allowed the blatant targeting of Black communities for highways (Karas 2015).

Lastly, literature discussing the origins of urban rioting in the late 1960s is useful in understanding the practices that led to civil unrest. Thomas Sugrue explored the conditions that led to the 1967 race riot in Detroit, finding that housing prejudice, deindustrialization, automation, shifting access to capital and job discrimination all played a role (Sugrue 2005). The Kerner Commission similarly explored the race riots of the late 1960s and found the origins of urban crises for Black Americans were the economic opportunity, social equity, and public safety that was systematically deprived to them by White racism (The National Advisory Commission on Civil Disorders 1968).

While many of this literature will use examples or anecdotes to make a particular point, or underscore a particular injustice, there are few examples that concretize the cumulative effects of decades of racist, or otherwise exclusionary policies in a particular location, and examine the transformation, or persisting segregation, at a neighborhood scale.

2.2.2. Literature Informing Spatial Research Methods

2.2.2.1. Related research methods

Notwithstanding this rich literature on racist government land use and lending practices, there is little research devoted to understanding how their spatial implications continue into the present. The digitalization of HOLC maps, by the University of Richmond's Digital Scholarship Lab, as part of the Mapping Inequality project (Nelson, et al. n.d.), offers a significant opportunity to analyze the spatial impacts of redlining in cities across the US, but since its vintage is 2015, it is still a relatively new resource. In an interesting working paper released in fall of 2020, Fishback et al., digitized 1930 Census maps in ten northern cities and compared these to the HOLC maps, which were created between 1937 and 1940. They found that 97 percent of Black individuals and 95 percent of Black-owned homes existing in 1930 were captured in the D designations and argue that the maps were not necessarily the genesis of the spatial segregation within cities, but rather, they were documenting an already fragmented metropolis (Fishback, et al. 2020). Amy Hillier (2003), in researching the influence of HOLC maps on redlining practices in Philadelphia, came to a similar conclusion – that the HOLC maps in and of themselves were not causing redlining and disinvestment in cities. She noted that bank lenders were denying loans to Black residents prior to HOLC maps, real estate agents were acutely aware of the demographic patterns even without the maps and could steer buyers without them, and that the HOLC maps were not dispersed widely to local real estate agents and lenders [9]. If there was a longer research arc, investigating other primary source materials with spatial

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[9] In discussing the HOLC maps, Hillier writes:

> "…the map provides evidence that ecological and infiltration theories, racial prejudice, and real estate and appraisal industry codification of all these sentiments in combination with federal endorsement and promotion of them—not the maps, themselves—caused urban decline. The

implications, such as racial zoning ordinances, racial restrictive covenants, and other legal instruments that would have begun segregating cities prior to HOLC maps, would be an important research component.

Regression tools have been utilized to connect the role of historic HOLC maps to present-day disparities in quality-of-life metrics. White, Guikema and Logan (2021) surveyed 13 US cities and using logistic regression and K-means clustering techniques, tried to discern the correlation between historic HOLC boundaries and present health, employment, education, and income measures. They consistently found that the inequities etched in the modern-day urban fabric align with the historic spatial boundaries of discrimination. Comparing the green, A-rated areas with the red, D-graded areas, they found that the population presently associated with the historic A areas in all 13 cities had better health outcomes, and reciprocally, the D areas in all cities had higher poverty rates and lower high-school graduation rates. The population in D areas in 12 of 13 cities had lower health insurance coverage rates, while 10 of 13 had higher unemployment rates.

Regression analyses have also been utilized to discern explanatory variables for segregation. Yu and Wu (2013) used Landsat, remote-sensing imagery to extract biophysical and textural information, in particular, vegetation, impervious surface, and soil conditions, which in turn were used to interpolate an array of land uses. For example, pixels where vegetation is low and imperious surface most strongly correlate with commercial areas, so that land use might be assigned depending on the specific mix. The authors then used the derived land use cover to seek to explain segregation patterns in Milwaukee with OLS and geographically weighted regression

HOLC maps are probably the clearest, most accessible, and most dramatic evidence of this collusion, but that does not make them the most influential. (Hillier 2003, 413)”

(GWR) techniques. The GWR analysis found a large presence of high-density land cover and a small presence of low-density land cover to be the strongest explanatory variables in predicting the spatial concentration of Black people. Ogneva-Himmelberger, Pearsall, and Rakshit (2009) similarly explored the relationship between land cover and socio-economic status in Massachusetts using GWR and found higher amounts of impervious surfaces were a strong predictor of higher percentages of both minority population and households living in poverty; they also found, somewhat reciprocally, that smaller amounts of imperviousness predicted higher home values.

Several authors have explored the correlation between housing supply, land use constraints, and housing affordability, both in New York and across the US more broadly. Glaeser and Gyouko (2003), for instance, studied housing markets throughout the US, and found that the majority of regional markets behaved as one would expect, with housing sale prices only slightly exceeding construction costs. In a few urban markets, however, disproportionately clustered on the east and west coasts, sale prices vastly exceeded construction costs, and in probing further they found a high correlation between housing prices and overly burdensome land use regulations (Glaeser and Gyourko 2003).

Glaeser, Gyouko, and Saks (2005) further explored affordability in the context of Manhattan, where severe land constraints necessitated high-density towers long ago. While this makes construction much more expensive than a single-family home, they note an important distinction: land preparation costs in multi-family construction, including excavation and foundation costs, only need to be done once, so in a perfect economic model, a developer would add the marginal cost of adding an additional floor until the building rose to a height where the sale price per square foot slightly outpaced costs, to ensure profitability. However, paradoxically, they found that the percentage of residential buildings over 20 stories that have been constructed in Manhattan has steadily dropped since 1980, suggesting another factor artificially reducing building height, and indirectly, housing supply. The authors place this blame squarely on the rise of community activism in clamoring for shorter buildings and more restrictive land use regulations (Glaeser, Gyourko, and Saks 2005).

While correlations between land cover and uses have been correlated with race, and zoning correlated with price, there seems to be research gaps in directly exploring the relationship between zoning designations and segregation. Moreover, there also seems to be a literature gap exploring, through regression analyses, the cumulative extent to which government policies – directly or indirectly – explain the current spatial distribution of minority communities within select cities. Similarly, there is little literature exploring, at a quantitative level whether there are other interlocking factors, like economic status, social preferences, urban structure, and mobility patterns, at play in determining residential housing patters, as Clark (1986) contended. Perhaps more importantly, there are few studies that have embraced the scope of evaluating how spatial patterns have ebbed and flowed through time. Lastly, while progressive leaders have made attempts at undoing the more infamous types of government interventions – removing highways (Popovich, Williams, and LuMay 2021), removing single-family zoning ordinances (Bui and Badger 2019), or demolishing public housing – there is little literature on the effectiveness of these restitutionary interventions in reducing segregation. These gaps all present promising pathways to contribute novel research and analysis.

2.2.2.2. Studies of population patterns

Spatial autocorrelation analyses, at their core, invoke Tobler's first law of geography, that nearer things are more closely related than further things (O'Sullivan and Unwin 2010). These analyses can be conducted in a global sense – where values in a given feature class are compared across an entire study area, or in a local sense, comparing values against those of neighboring polygons. Each has their own value, as a global study helps benchmark values of concentration, which helps understand the degree of localized deviation higher or lower than that level (O'Sullivan and Unwin 2010).The global Moran's I test (Spatial Autocorrelation in ArcGIS Pro) is a global test of spatial autocorrelation, and can be used to determine if the concentrations of values in polygons are statistically significant. The outputs are entirely numerical and involve evaluating p-values and Z-scores. P-values indicate the probability that the results are random – lower resulting values indicate a lower probability that the result is random and greater probability that the result is statistically significant (values less than 0.1 have a 90% confidence, values less than 0.05 have 95% confidence and less than 0.01 have 99% confidence). Z-scores are standard deviations from what result would be predicted under a random distribution. Results with high or low Z-scores are at the ends of a normal bell curve and would exhibit statistically significant clustering or dispersion (Esri n.d.). The analysis also outputs a Moran's Index value, where a positive value indicates clustering, and a negative value indicates dispersion. Since this is a global test, there is one value output for the study area.

The Getis-Ord Gi* test (Hot Spot Analysis tool in ArcGIS Pro), is a local measure of spatial autocorrelation that allows one to reconceptualize the spatial relationship between neighbors and determinines if an there are 'hot spots' – areas of statistically significant clustering – occuring within the subject study area (Esri n.d.). Based on the p-values of and z-scores of an areal unit and its neighbors, the tool generates a map showing not only hot spots of clustering, but also cold spots of dispersion, as well as areas that are not statistically significant and more randomized. Within the hot and cold spots, there are confidence levels at 90, 95, and 99%

thresholds that the results are statistically significant, depending on the p-value. Another local test, the federal Moran's I test (Cluster and Outlier Analysis tool in ArcGIS Pro), takes the premise of a Moran's scatterplot, and depicts relationships between an areal unit and its neighbors as high-high, low-low, or clusters and dispersions again, and importantly, also shows outliers – units that have low-high or high-low values relative to their neighbors (Anselin 1995). A high-low outlier designation, for example, would mean that the particular areal unit has a high Moran's I value relative to the surrounding units.

2.2.2.3. Segregation studies

Measuring segregation has long been a topic of inquiry for sociologists, economists, geographers, and other social scientists to understand the effects of the striation of people in different settings, and its intersection with access to quality educational, employment, health outcomes and other socio-economic opportunities. Indices have been developed over time to try and grapple with the core issues underpinning segregation, and its deleterious impacts in civil society, in order to quantify them in localized settings. Most of the segregation research has grappled with residential segregation by race, but segregation has also been assessed based on income, age, religion, gender, language or numerous other characteristics, in the context of schools, workplaces, and other physical locations (Oka and Wong 2019).

Prior to the 1950s, there was no prevailing approach to measuring segregation amongst social scientists. Duncan and Duncan (1955) changed this, by convincing demonstrating that the index of dissimilarity captured much of the information offered by other indices, ushering in over 20 years of relative academic consensus (Massey and Denton 1988). The index of dissimilarity measures the evenness of population groups across a study area, and the index values interpreted as the proportion of the population that would need to move to obtain an even distribution (Duncan and Duncan 1955). This was upended, indirectly, in the mid-1970s with a critique of the dissimilarity index by Cortese, Falk, and Cohen (1976), which, instead of mustering debate on the index itself, reopened the larger narrative of appropriate measures. The sociologists Massey and Denton (1988) offered a pivotal framework after over a decade of spirited debate. They analyzed over 20 different indices and determined that segregation has 5 major dimensions: 1) evenness, the relative distribution of population groups across a space; 2) exposure between major and minor groups; 3) concentration, the physical space occupied by a population group; 4) centralization, the degree to which a group is near the geographic center of an area; and 5) clustering, the degree to which areal units occupied by minority groups adjoin one another (Massey and Denton 1988). In this framework, evenness and exposure were aspatial dimensions (even though they invoked areal units with an implied spatiality), and concentration, centralization and clustering were more explicitly spatial (Reardon and O'Sullivan 2004).

Reardon and O’Sullivan (2004) posited that aspatial dissimilarity indices are often fraught, as they fail to account for the arrangement of population within an areal unit, and in relation to its neighborhors, invoking not only the modifiable areal unit problem (MAUP) but also the “checkerboard problem”. The MAUP is invoked when point data is arbitrarily aggregated into larger areal units, potentially masquerading more granular patterns. In this case, a census divison could aribtrarily divide a cluster of a minority, but because it is fragmented, and diluted with other population groups, the pattern might be concealed (Reardon and O'Sullivan 2004). The checkerboard problem, as shown in Figure 18, refers to a situation wherein a completely segregated hypothetical grid would generate the same dissimilarity index as a more integrated checkerboard, because it is failing to account for the pattern of its neighbors (Reardon and O'Sullivan 2004).

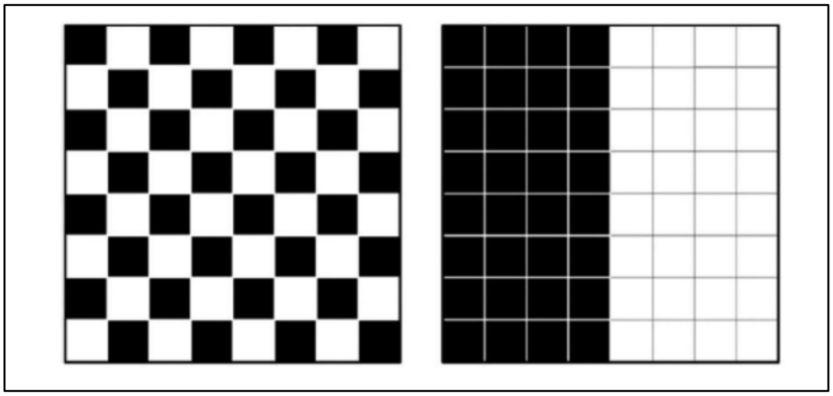

Figure 18. Illustration of the checkerboard problem (Katumba, et al. 2021)

Building on the idea that every segregation measure should be spatial, they proposed a modification to the five Massey and Denton dimensions, simplifying it to two major dimensions. They argued that aspatial evenness and spatial clustering addressed the same issue and were better characterized as two ends of a single spectrum instead of two separate indices. To this they layered in Massey and Denton's isolation and exposure dichotomy, but in a spatial manner, and built a conceptual matrix of evenness (clustering) and exposure (isolation) shown in Figure 19. The top right quadrant, with evenness and exposure, represents an idealized integration while the bottom left, with clustering and isolation, represents larger segregation (Oka and Wong 2019).

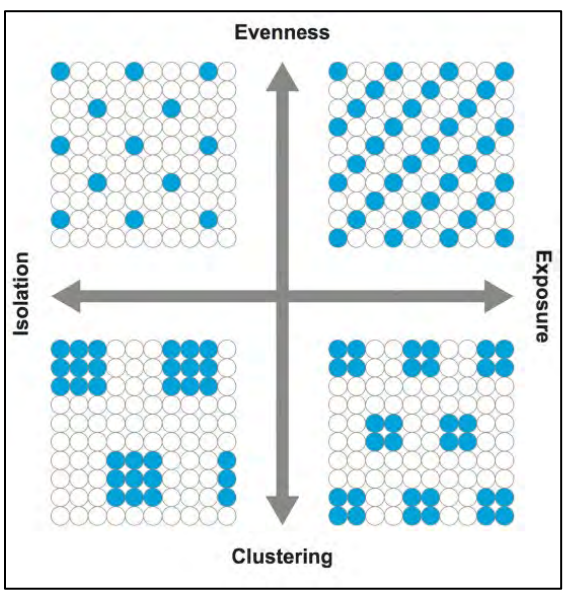

Figure 19. Dimensions of spatial segregation (Oka and Wong 2019)

Reardon and O’Sullivan also proposed spatialized versions of several existing measures, including the spatial dissimilarity index (D), the relative diversity index (R), the spatial information theory index (H), and an exposure / isolation index (P*). Evaluating these and other indices through a series of conceptual and mathematic rubrics, they determined the spatial information theory index (H) and the spatial exposure / isolation index (P*) to be most faithful to their ideas. The spatial information theory index measures the level of local diversity relative to the total population of the region, a type of evenness measure; maximum segreation would be equal to 1, while complete integration would be 0 (Reardon and O'Sullivan 2004). The spatial exposure / isolation index tabulates the relationship of a particular race to other races (e.g. white to white, white to black, black to white and black to black) to determine if localized populations of a population are segregated and spatially isolated from other races, or if they are integrated and exposed.

O’Sullivan worked with Hong in devising an R package which allows these spatial segregation measures to be tabulated with relative ease by inputing demographic data and a spatial geometry (Hong, O'Sullivan, and Sadahiro 2014). This package, in turn, has enabled greater usage of segregation tools in an array of applications. Katumaba, et. al. (2021) for instance utilized these spatial segregation measures to evaluate whether policy changes in post-apartheid South Africa have had a meaningful difference in integreation. They found that since 1996, residential segregation has steadily declined, and exposure of Whites to Black Africans has increased.

These spatial segregation measures proposed by Reardon and O’Sullivan are all global measures – they generate a singular set of values for a study area. While this is useful for comparing the relative segregation of cities or other bounded areas, it does not produce local calculations which might allow intra-urban assessments. Wong (2002) introduced local measures of spatial segregation, as conceptually similar to local measures of spatial autocorralation developed by Anselin (1995). Oka and Wong (2014) have practically applied these measures, to evaluate localized segregation levels in Washington, D.C., St. Louis and Chicago, through a local spatial dissimilarity index and local spatial isolation index, in order to correlate with public health indicators. These local indices, however, do not have an associated R package, and despite the similar (or greater) potential for cross-disciplinary utlization, there has been limited application.

Chapter 3 Methods

This thesis had two principal research questions: 1) to what degree have Black populations clustered and been segregated from White populations within the City of New York from 1910 to 2020? and 2) what variables might explain any identified patterns of clustering and segregation in three time-windows: 1960, 1990 and 2020? Intrinsic to each of these two questions was a spatio-temporal query as to how these patterns have changed over time.

The methods employed to answer these questions are two-fold. The first task was more investigatory. Spatial autocorrelation tools were deployed to find hot spots of Black residents, while spatial segregation indices were calculated to determine the level of integration between racial and ethnic groups. These cluster and segregation analyses were completed decennially beginning in 1910 to discern overarching spatial trends, pivotal time periods, and outlier geographies, all of which can validate and further inform regression variables.

The second task was to analyze the factors that predict population clusters using regression analyses. This included querying the effects of historic boundaries of the HOLC maps, urban renewal legacies like public housing concentrations and highways, zoning district typologies, and historic districts. It then compared the influence of these government-oriented variables in explaining Black and White population patterns with more organic market forces for population concentration, like proximity to a subway station or distance to a CBD. This second task was conducted longitudinally, in 30-year intervals, beginning in 1960, to determine how the influence of different variables has shifted over time. It was conducted using a variety of different Black and White population metrics as response variables to compare and contrast the influence of the different planning-related explanatory variables.

3.1. Data Description and Preparation

A series of clustering and segregation metrics were chosen as dependent variables to test a series of independent, planning-related variables. The thought was that each would provide unique insight into different relationships between explanatory variables that other response variables didn't fully elicit. Independent variables were comprised of a series of federal and local planning-related factors, based on the literature, which evaluate their influence on the relative clustering and segregation of the New York population. This section describes these variables and the data that represent them, as well as the necessary preparation of the data for usage in the research tasks is also described.

3.1.1. Dependent Variables

All of the measures of the dependent variables began with population data from the 1960, 1990, and 2020 census. This historical census data, from the IPUMS National Historic GIS database, included spatial and tabular census tract information for the entire nation, so preparation included clipping the datasets to NYC, joining the spatial data with tabular data (conveniently using the 'GISJOIN field'), and then changing the projection from a continental projection – the USA Contiguous Albers Equal Area Conic projection – to a more localized State Plane projection.

New York's State Plane coordinate system takes into account its wide east-west dimension, and, to minimize distortion, subdivides the state into East (3101), Central (3102) and West (3103) zone, each of which uses a transverse Mercator projection. A fourth zone, the Long Island zone (3104), which encompasses NYC and two other counties of Long Island (Nassau and Suffolk), accounts for the fact this geography is largely an appendage at the southern end of the state, and so uses a different projection method, a Lambert Conformal Conic projection (The

Legislature of the State of New York 1995). All data was projected to use this Long Island State Plane projected coordinate system (PCS), specifically, NAD 1983 StatePlane New York Long Island FIPS 3104 (US Feet).

The data sources, their original type and projection, are all included in Table 1. Each of these population-oriented variables is further described after the table, along with the process of preparing the data.

Table 1. Response variables in regression analyses

Criteria	**Source**	**Type**	**Original projection**
Black and White population density, by census tract	US Census Bureau National Historic GIS Data Finder (IPUMS National Historical GIS n.d.)	Generated from tabular demographic data and joined to polygon census tract shapefiles	USA Contiguous Albers Equal Area Conic
Black and White population percentage, by census tract	US Census Bureau National Historic GIS Data Finder (IPUMS National Historical GIS n.d.)	Generated from tabular demographic data and joined to polygon census tract shapefiles	USA Contiguous Albers Equal Area Conic
Black and White population density change, by census tract, in thirty-year intervals	US Census Bureau National Historic GIS Data Finder (IPUMS National Historical GIS n.d.)	Generated by intersecting previously joined tabular and spatial data.	USA Contiguous Albers Equal Area Conic
Black and White local spatial dissimilarity index	US Census Bureau National Historic GIS Data Finder (IPUMS National Historical GIS n.d.)	Generated from geoprocessing and mathematical formula, then joined to polygon census tract shapefiles	USA Contiguous Albers Equal Area Conic
Black and White local spatial isolation index	US Census Bureau National Historic GIS Data Finder (IPUMS National Historical GIS n.d.)	Generated from geoprocessing and mathematical formula, then joined to polygon census tract shapefiles	USA Contiguous Albers Equal Area Conic

Race has long been reported in the decennial census, but has gotten increasingly complex over time. In 1960, there were three race categories “White”, “Negro” and “Other races”. In 1990, these had expanded to five categories: “White”, “Black”, “American Indian”, “Asian or Pacific Islander” and “Some other race”. By 2020, the basic categories had slightly changed to “White”, “Black or African American”, “American Indian or Alaska Native”, “Asian”, and “Native Hawaiian or Other Pacific Islander”, and “Some other race” (IPUMS National Historical GIS n.d.). These 2020 categories were caveatted in a couple important ways, reflective of a more plurasitic society. First, cohorts like White and Black populations could have Latino or non-Latino ethnicity, and these basic categories were for individuals that identified as a singular race alone – multiracial individuals could now identify as “Two or More Races” (IPUMS National Historical GIS n.d.). To reflect the 1960 limited categories, this analysis used three basic race categories, “White”, “Black” and “Other”. In 1990 and 2020 data, this meant aggregating several races into the third category. It also used the White alone and Black and African American alone categories from the 2020 census, and was agnostic to Latino heritage.

The first response variable evaluates the population density of Black and White cohorts within the city’s census tracts. A density metric, as opposed to raw population numbers, was thought to better normalize the data for better comparisons between tracts. It was created first by divvying the respective Black and White populations by the area of the census tract. However, since the square footage units associated with the PCS result in high numbers, population per acre was used as the density metric.

The maps in Figure 20 show that White density in 1960 is largely following the subway lines, well into the outer Boroughs. In the 1990s the White population held in Manhattan south of 96th Street but largely vacated the South Bronx and central Brooklyn. The pattern in 2020 mimics this, but new areas on the Brooklyn waterfront are densifying. Black population density, in Figure 21, is much more static, expanding and intensifying with White exodus in the 1990s but de-densifying somewhat by 2020.

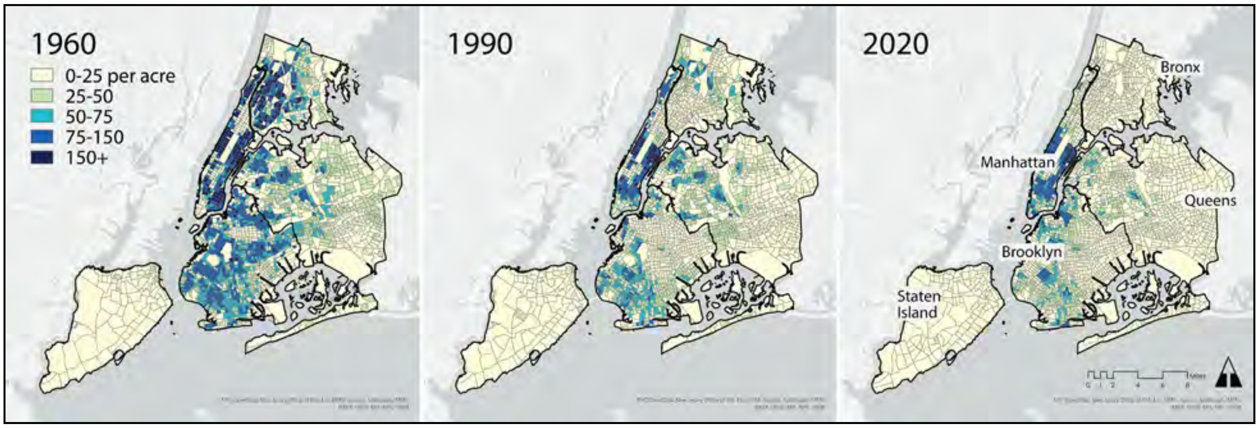

Figure 20. White population density per acre: 1960, 1990, and 2020

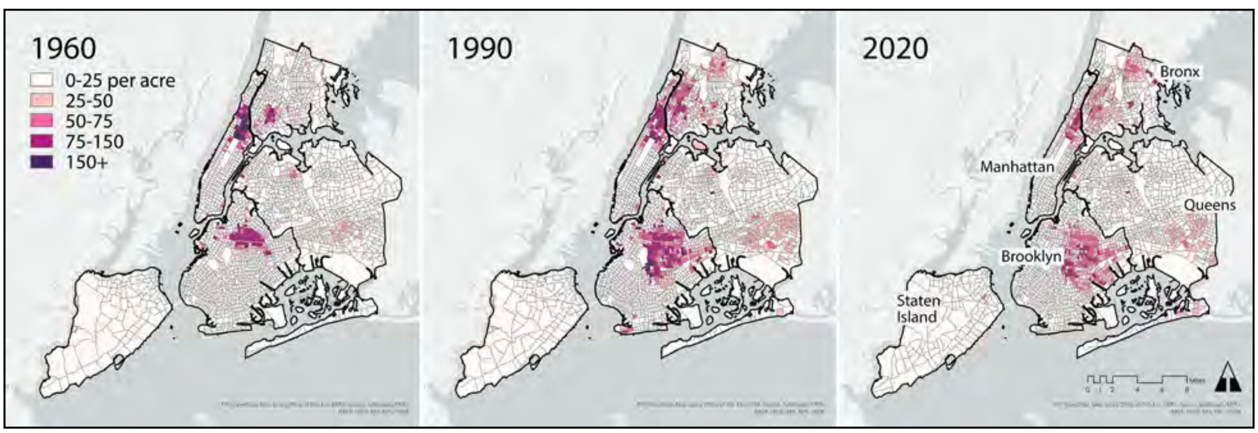

Figure 21. Black population density per acre: 1960, 1990, and 2020

The relative population density in New York has an extremely wide spectrum, with the maximum density exceeding 300 persons per acre and the minimum being fewer than one person per acre. Because of these extremes, a simple percentage metric was deemed worthwhile as a second response variable, in order to ensure that patterns occurring in areas with high Black concentrations, but at a lower density, such as Hollis and St. Albans in southeastern Queens, were not being overlooked. This dataset was generated similar to the density analysis, but the percentage of Black or White population, respectively, as a percentage of the total population per census tract (inclusive of White, Black and Other populations) was calculated.

The maps in Figure 22 show how New York went from a largely White city in 1960 to a more a racially diverse one over time. It also shows how dispersed White population is compared to the clustered Black segments in Figure 23.

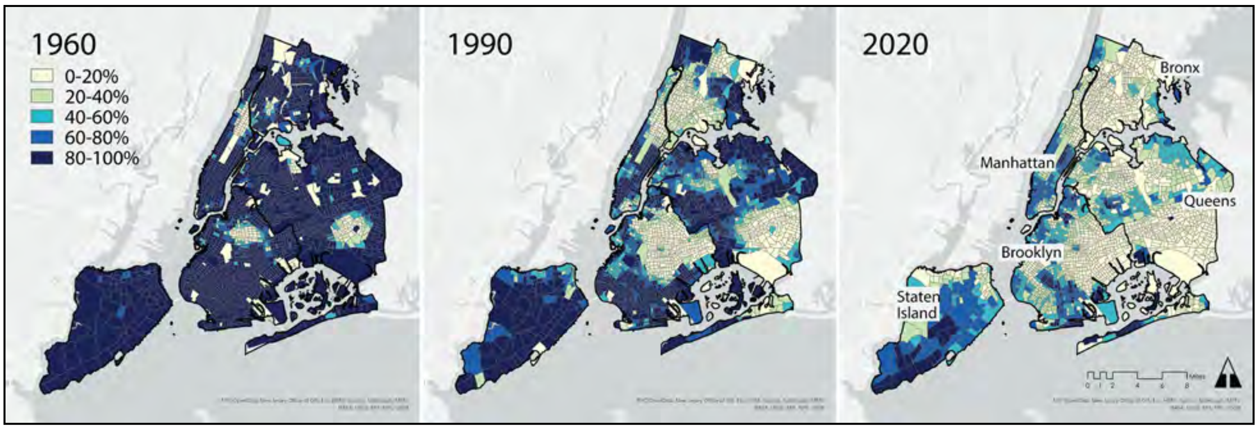

Figure 22. White percentage of population of census tract: 1960, 1990, and 2020

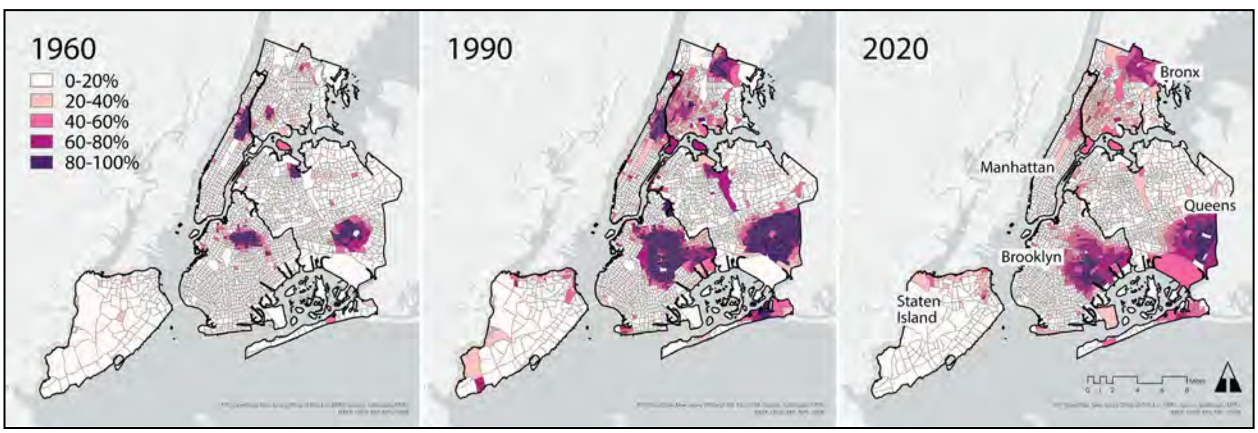

Figure 23. Black percentage of population of census tract: 1960, 1990, and 2020

The first two metrics evaluated the influence of the planning-related variables at static moments in time – 1960, 1990, and 2020. The decades between these benchmarks were full of widely shifting demographic change however, so it was deemed worthwhile to try and determine if the variables exerted influence on this change, positive or negative. For instance, were urban renewal and public housing patterns of the 1950s influencing population shifts themselves? Has the uptick in contextual rezonings spawned housing pressures, fueling gentrification?

To generate this dataset, the subject population dataset for census tracts in each specific interval was intersected with the same dataset for the period 30-years prior (including one for 1930 for the 1960 dataset), and the resulting comparisons of polygon size differentials for split census tracts exported to Excel. In this program, the percentages associated with each portion of the split census tract could be determined, and an estimated population count for the prior period derived. This was done by assuming an even population distribution over the census tract (implausibly, but necessarily because of the limited availability of more granular data) and attributing to each portion of the split the same percentage of population it occupied in the split (i.e.., a 60 / 40% split in land area would also receive a 60 / 40% split in population). After generating density changes in the two census tracts, the tabular data was rejoined in ArcGIS Pro.

The maps in Figures 24 and 25 show clear White population losses between the 1960s and 1990s corresponding largely with Black gains in Harlem, the South Bronx, and Bedford-Stuyvesant. There are also tracts with population loss and no corresponding gains in certain portions of these neighborhoods, a result of urban crises, where property abandonment and municipal service shrinkage led to swathes of neighborhoods being reduced to rubble by fires (Flood 2011). By 2020 White gains and Black losses were emerging, particularly in central Brooklyn and Harlem.

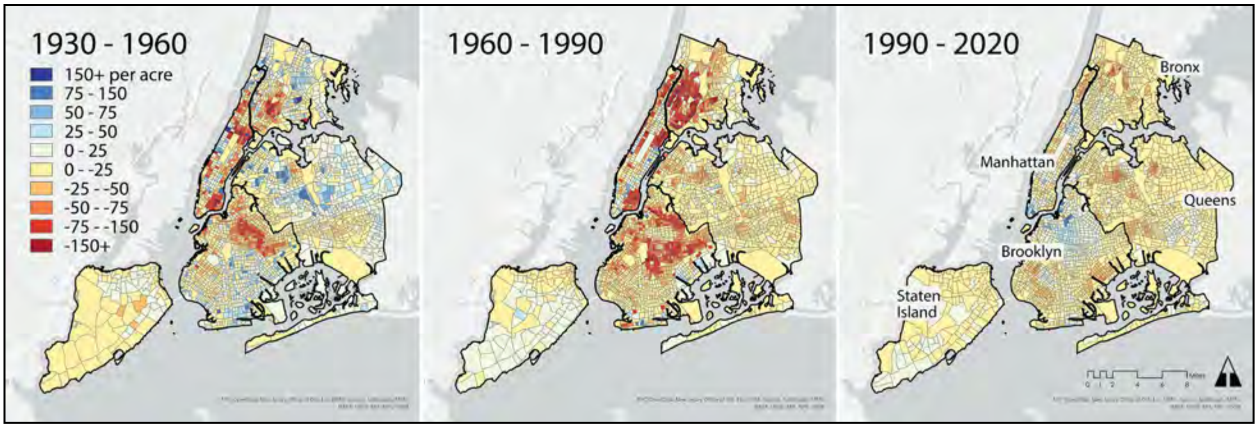

Figure 24. White population change per acre: 1930-1960, 1960-1990, and 1990-2020

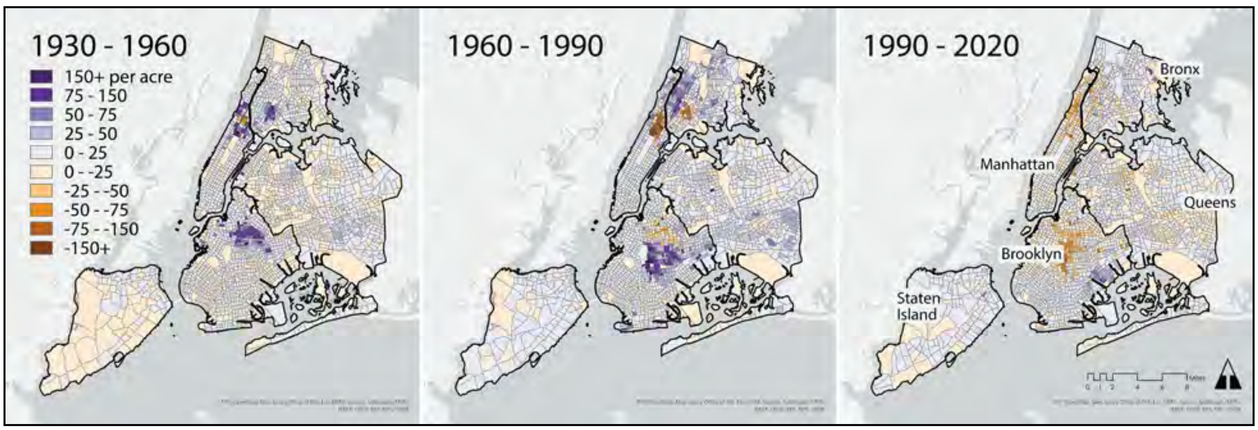

Figure 25. Black population change per acre: 1930-1960, 1960-1990, and 1990-2020

Two local segregation indices were also included as response variable to test, one measuring evenness of population distribution through the local spatial dissimilarity index, and the other measuring relative exposure and isolation through the local spatial isolation index. As mentioned, there is no R package to devise these local spatial segregation measures. These indices were generated through the following steps.

Both indices account for the population characteristics of their neighboring tracts, beginning to address the MAUP, by utilizing a ‘composite’ population count. This composite count is created through a spatial weight matrix, similar to a local spatial autocorrelation analysis. By using the Generate Spatial Weights Matrix tool in ArcGIS Pro, a ‘Queen’ contiguity-based matrix was generated from each subject year's census tract shapefile. The Queen case matrix identifies neighbors of an areal unit with a common edge or vertex, as opposed to a Rook case which only includes neighbors with a common edge. This Queen-based matrix, and associated field IDs for every adjacency were exported into a table form. In Excel, using VLOOKUP tools, the field IDs of a principal census tract and each of its neighbors could be paired with their respective Black, White and Other population counts in separate tallies, and the summed to generate the composite count for each tract. Unlike a traditional spatial weight matrix, no 'weight' was assigned to populations in neighboring tracts – if they abutted the subject tract, the full sum of their populations was aggregated. After generating the segregation indices, the tabular data was joined to the spatial census tract polygons in ArcGIS Pro.

Local spatial dissimilarity indices were generated for both Black and White populations pursuant to the formula in Figure 26, where cw_i and cb_i are the composite population counts of an areal unit *i*, *CW* and *CB* are the composite population counts of Whites and Blacks, respectively, over the entire study area, ct_i is the composite count of the total population of areal unit *i* and *CT* is the composite population count of the total population of the entire study area (Oka and Wong 2014). In these calculations, total population counts were inclusive of White, Black and all other races.

White–others dissimilarity ($SD_{i^{*}wo}$)

$$SD_{i^{*}wo} = \left| \frac{cw_i}{CW} - \left(\frac{ct_i - cw_i}{CT - CW} \right) \right|$$

Black–others dissimilarity ($SD_{i^{*}bo}$)

$$SD_{i^{*}bo} = \left| \frac{cb_i}{CB} - \left(\frac{ct_i - cb_i}{CT - CB} \right) \right|$$

Figure 26. Formula for local spatial dissimilarity indices (Oka and Wong 2014)

The resulting spatial patterns, which became response variables, are shown in Figures 27 and 28, for White – others, and Black – others, respectively. Because the formula uses the absolute value in determining segregation values, the localized index value is high in instances where the subject population group constitutes a very high percentage of the composite count and is also high when that group's absence is particularly acute. In the Black – other dissimilarity index, for instance, Bedford-Stuyvesant in Brooklyn and Hollis and St. Albans in southeastern Queens have high index values because of the high Black population, but the Upper East and Upper West Sides of Manhattan, along with southern Staten Island are high because of the high prevalence of other population groups and the absence of Blacks.

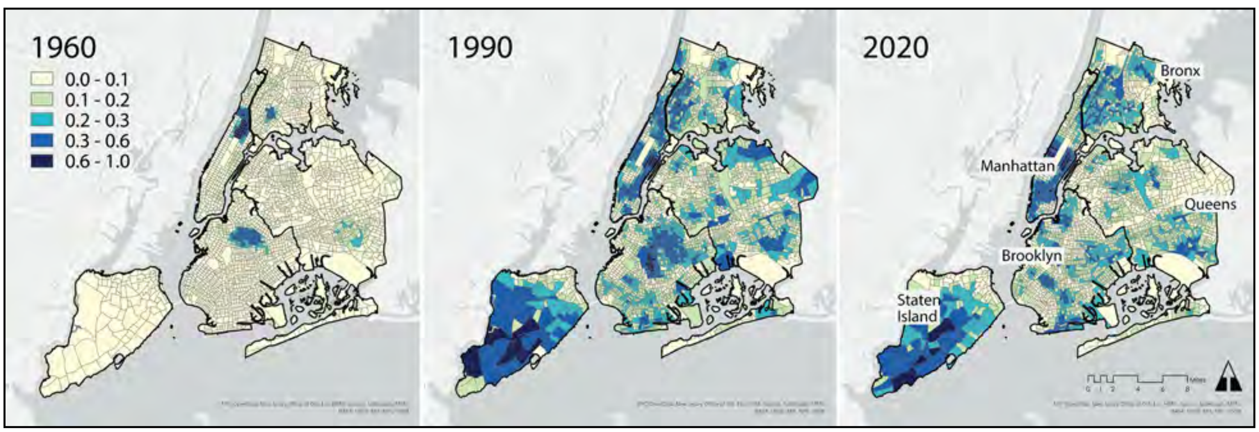

Figure 27. White – others dissimilarity, by census tract: 1960, 1990, and 2020

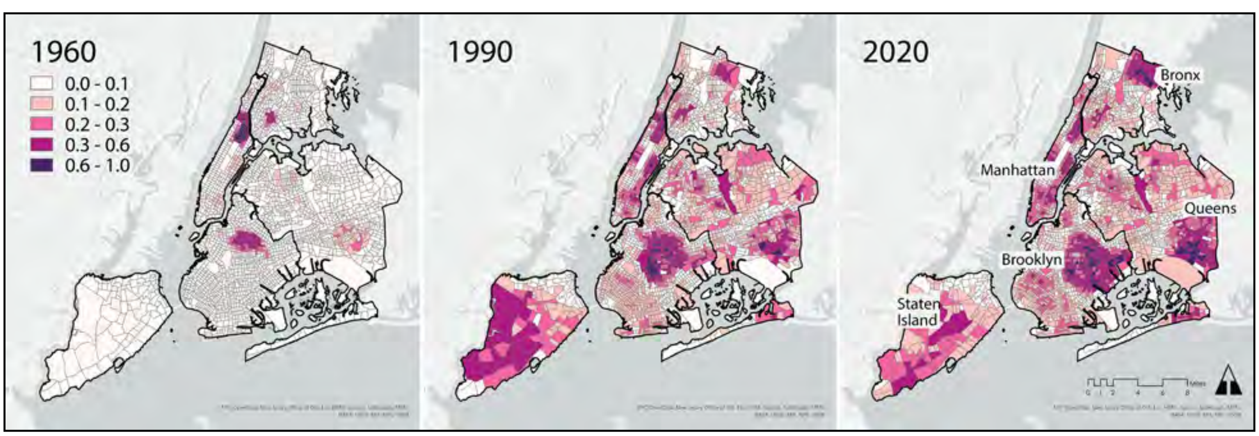

Figure 28. Black – others dissimilarity, by census tract: 1960, 1990, and 2020

The local spatial isolation index was calculated pursuant to the formula in Figure 29 for both the Black and White population groups, where cg_i is the composite population count of a particular segment, group G in census tract i, G is the population count of group G for the entire study area (not the composite), and ct_i is the composite population count of the total population in census tract i (Oka and Wong 2019). As in the prior analysis, the total population counts are inclusive of White, Black and all other races.

$$SI_i = \frac{cg_i}{G} \times \frac{cg_i}{ct_i}$$

Figure 29. Formula for local spatial isolation index (Oka and Wong 2019)

Figures 30 and 31 show the maps generated from calculating White and Black isolation, respectively. White isolation was widespread in 1960, while Black isolation limited, because of the small, clustered populations. Since 1960, White isolation has entrenched in Manhattan south of the 96th Street, southern Staten Island, and shifting areas of Brooklyn and Queens.

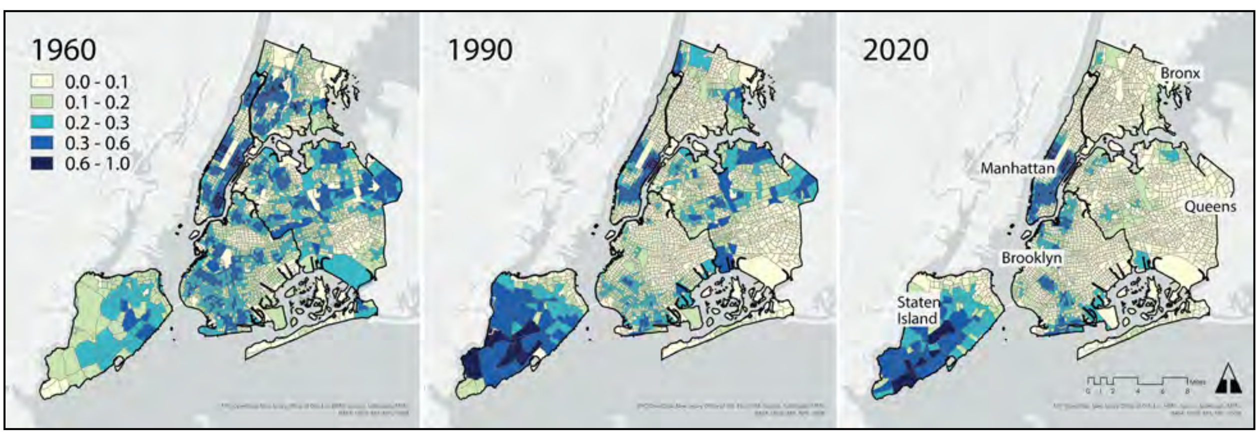

Figure 30. White isolation, by census tract: 1960, 1990, and 2020

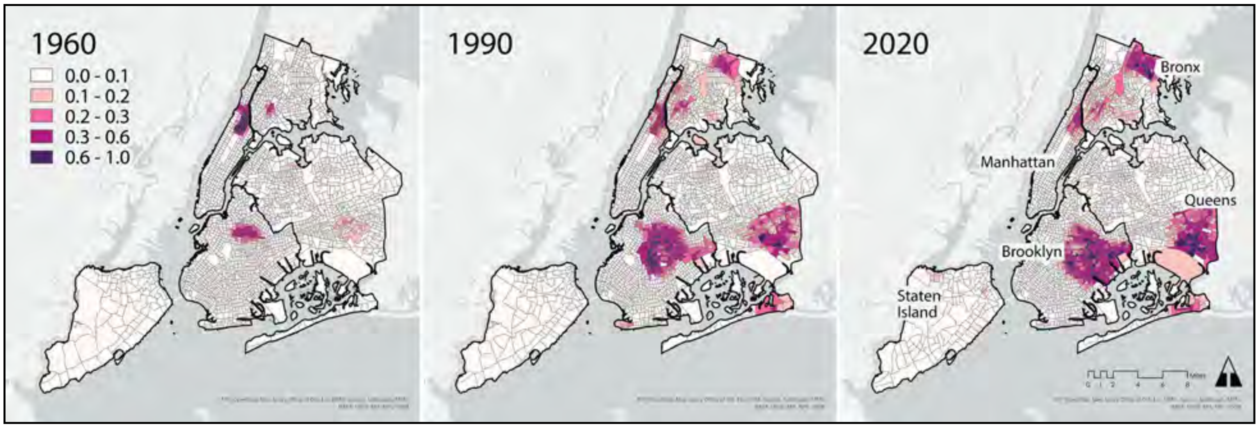

Figure 31. Black isolation, by census tract: 1960, 1990, and 2020

3.1.2. Independent Variables

The independent variables being evaluated to test their influence on the response variable are largely comprised of generations of federal and local land use regulations that would implicate the built environment, but also include a couple of market-driven factors, to compare to as a baseline. Like the dependent variables, wherever a source dataset had a different PCS (or lacked one altogether) its projections was changed to NAD 1983 StatePlane New York Long Island FIPS 3104 (US Feet). National datasets were clipped to the NYC extents.

New York was a thriving center of commerce long before the emergence of HOLC maps in the 1930s, and already had a strong spatial pattern. Housing markets responded to the pronounced demand exerted by immigrants and then internal migrants, with the construction of high-density housing in the most opportune areas. While reform-minded politicians began regulating this free market with increasing health and safety parameters after the 1850s, to curb the most scrupulous developers from warehousing immigrant families (Plunz 2016), traditional market drivers, like transit access and distance to the regions core, often predicted where housing units would be located.

In New York, Manhattan is the epicenter of the city's (and regions) economic activity. In earlier eras of the city, density tracked close to job hubs; tenements in the Lower East Side, housing immigrants, for instance, was in close proximity to sweatshops in SoHo. Within Manhattan, the majority of jobs, premier institutions and amenities are concentrated in Midtown and Lower Manhattan, the city's two CBDs. Even today, unparalleled access remains a significant factor underpinning Manhattan's residential neighborhoods high demand and associated costs. Without market intervention (in the form or government regulations and other factors), one might expect the highest natural density to agglomerate in the middle of the two, and so, a dataset was generated that measured the distance from a center point between the two CBDs to the centroid of each census tract as a means of evaluating if there is disparity in access between Black and White population segments.

While the subway system is overseen by the state controlled Metropolitan Transportation Authority (MTA) today, the initial lines were constructed by private entities, and only later consolidated into one system. Many lines, or segments thereof, predated the development of outer borough neighborhoods. Early 20th-century housing development largely followed this infrastructure, facilitating some relief to overcrowding in immigrant enclaves in Manhattan (Plunz 2016). This variable is thus seen as a proxy for market-driven growth that typified the city's development, apart from government influence vis-a-vis urban renewal, zoning or risky mortgage lending boundaries. It was used to evaluate the percentage of a census tract that is within a quarter mile of a mass-transit station, a traditional measure of walkability, and evaluate whether traditional urban growth measures explained Black or White clustering.

After these market-driven variables, government policies were evaluated. These can be largely split into three different epochs – federal-led HOLC designations, federal and local mixtures of urban renewal era interventions, and local zoning and historic districting.

HOLC area designations have garnered much criticism for the explicit references to minority groups in assessing higher risks in the red-colored, D areas. However, all categories were deemed worthy of evaluating, as A and B areas may be positively correlated with White populations and used as an initial tool in buttressing their privilege. To generate the dataset, the HOLC boundaries for NYC were obtained from the University of Richmond's Mapping Inequality project. The initial shapefiles were initially borough-specific and so combined into one citywide shapefile. They were then split into A, B, C, and D areas, and intersected with the census tracts to determine the percentage of each tract, if any, that was allocated to these designations. Since the HOLC maps were created in the 1930s, which was before the city had been built out, a fifth category consisting of the percentage of tracts with areas that were not designated, was also generated. This could be more highly associated with suburban areas on the periphery, so may have a strong racial association as well.

Urban renewal era variables include the highway proximity, the public housing density, and the percentage slated for acquisition and disposal by the city.

The first of these, highway proximity, utilized primary and secondary road classifications from the US Census Bureau Tiger data within New York State. From this, those segments within NYC were clipped and projected. The percentage of a census tract that is within proximity (within 250 feet, a standard block width interval) of a primary or secondary highway was tabulated by constructing a buffer, clipping the buffer to the extents within the shoreline, and using that revised area in the calculation. This factor helped determine if Black neighborhoods were disproportionately sited for highway construction. Calculating the number of dwelling units within that proximity was considered, especially as a counterbalance to low-scale suburban areas but piecing together the number of units in a building at the historic junctures of 1960 and 1990 was deemed infeasible.

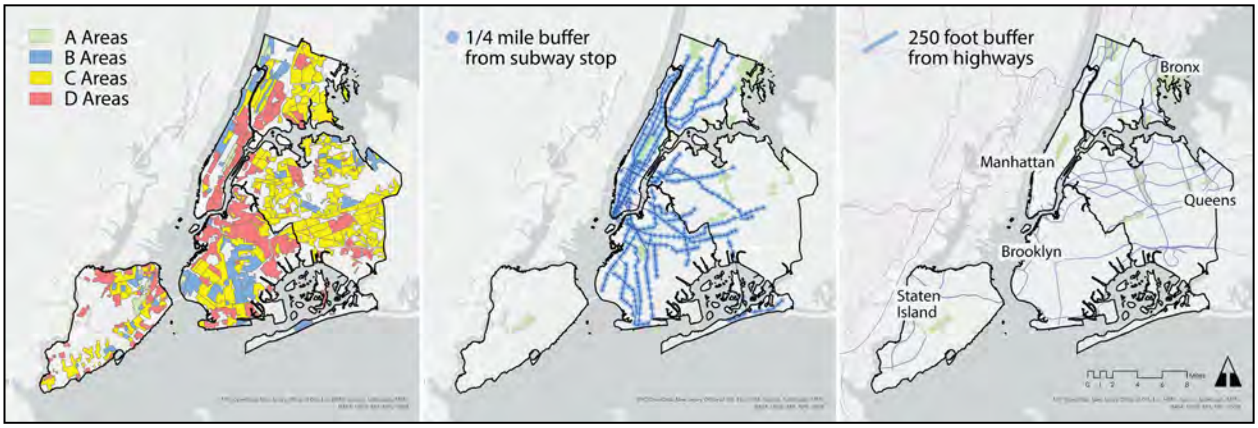

Figure 32. HOLC areas, subway adjacent areas, highway adjacent areas

Public housing began as a means for government-sponsored housing to meet a supply shortage for working and lower-middle class Whites borne of the Depression and World War II. Only after the Housing Act of 1949, the emergence of the FHA mortgages, and the suburbanization of middle-class Whites did public housing become associated with housing lower-income Blacks in segregated silos. The public housing during and after the 1950s was often the result of Slum Clearance policies associated with urban renewal, and ironically, integrated neighborhoods were torn down and replaced by segregated silos (Rothstein 2017; Blumgart 2017).

HUD has a database with all public housing buildings, including the year built and number of units. This database helped assess the number of total units in a census tract that had been constructed at a given point in time. The first public housing was associated with the Housing Act of 1937, but funding and projects expanded dramatically with the Housing Act of

1949. While the Nixon administration placed a moratorium on public housing construction in 1974, and programs largely shifted to vouchers, facilities can be altered, and replacement housing has been constructed in small amounts since then (National Low Income Housing Coalition 2019). Looking at Figure 33, the distribution of public housing looks plainly concentrated in historically minority neighborhoods, like Bedford-Stuyvesant, Bushwick, Brownsville, Harlem, the South Bronx, and the Lower East Side. The majority of Queens and Staten Island are without public housing.

To generate this variable, the national dataset was first clipped to the NYC boundary, and then split into three different data layers based on whether they were in existence on the target dates of 1960, 1990, and 2020 by using the construction year field. Then, for each dataset, the number of units within public housing buildings was isolated and summarized within each census tract. Lastly, the number of units of public housing was then normalized by the acres of land area in the census tract to generate, in effect, a public housing density.

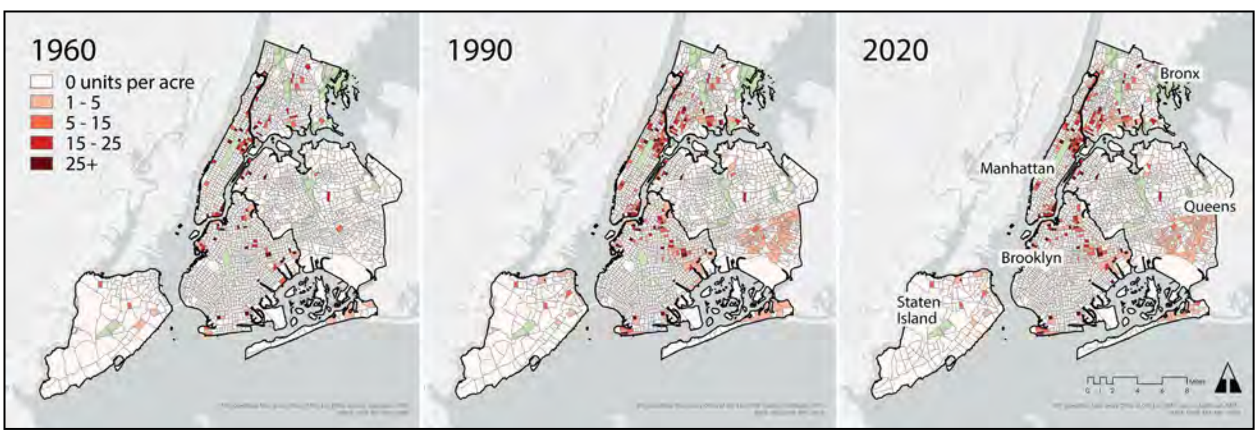

Figure 33. Public housing density: 1960, 1990, and 2020

Urban Renewal Law allows the City to acquire and dispose property within Urban Renewal Area (URA) boundaries. New York has dozens of plans, enacted over several decades by the city's Department of Housing Preservation and Development (HPD), and its agency predecessors. Sometimes plans laid out the usage of eminent domain, the relocation of current residents, the demolition of building stock, and the preparation of the site. Other plans emerged when a neighborhood was already under duress, and a cluster of properties were abandoned by their owners (or were in significant tax arrears), and the building stock unsafe or hazardous. In all cases, the plans govern the land uses when the site had undergone land disposition for redevelopment, and covenants typically run with the land (HPD n.d.). The scale and prevalence of URA designations in minority neighborhoods, and notoriety in the literature makes their study worthwhile.

This variable evaluated the percentage of parcels in a given census tract that have historically been slated for renewal. The dataset was somewhat tedious to generate. Many older plans include an overall project area boundary, but this is something of a misnomer because oftentimes only select properties within that boundary were acquired (Figure 34). The University of Richmond Digital Scholarship Lab, Renewing Inequality project is compiling digital shapefiles for URAs across the country (ed. Nelson and Ayers n.d.), and was the first data source. In New York, its data sources were compiled by the advocacy group, 596 Acres, through a Freedom of Information Law (FOIL) request from HPD (596 Acres n.d.). This generated the project names and property designations throughout the city. Next, this database was paired with a DCP database that had cruder digitization (overall project boundaries instead of individual parcels) but that included the dates for enactment. This was cross-validated with a Urban Renewal project plan database on HPD's website, which includes scanned copies of most of the historic plans (HPD n.d.).

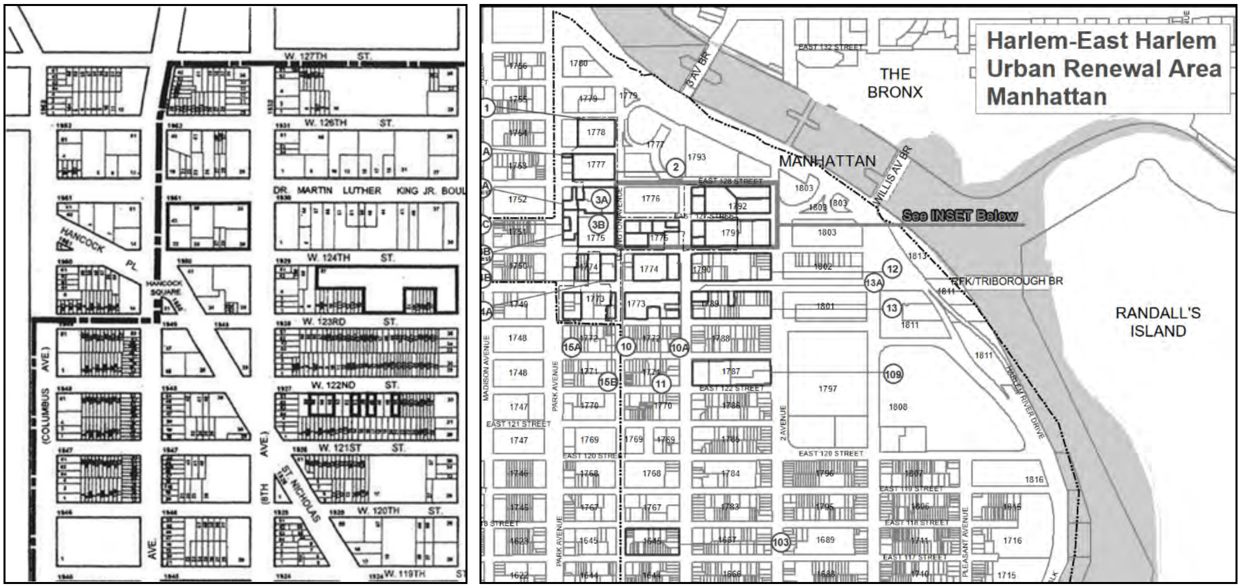

Figure 34. URA plan examples in Harlem

With the database assembled, with both the digital boundaries and active dates, they could be cut by those active in 1960, 1990, and 2020, to glean a sense of their influence in population clustering in each era.

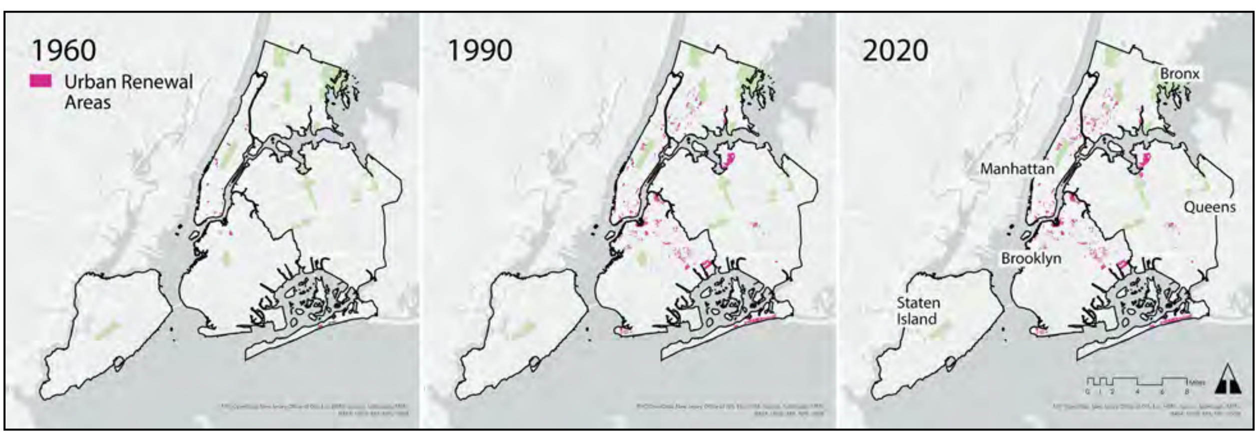

Figure 35. Urban renewal areas: 1960, 1990, and 2020

Several variables were derived from their district categorizations from the NYC Zoning Resolution, which is administered by the NYC DCP. Since there are hundreds of different individual zoning designations in New York, they were batched into pertinent representative categories: single-family districts, two-family districts, multi-family ‘contextual’ districts, multi-family non-contextual districts, districts that permit residential towers, districts emerging from former industrial areas and purely non-residential areas.

Zoning district designations in New York come in three major district typologies, residence, commercial and manufacturing, and on maps are designated by an R, C or M. Appended to each of these letters is a number which implies the associated density or intensity of the district. Residence districts, for example, range from R1 at the lowest density and R10 at the highest; manufacturing districts with an M1 are lower intensity than the M3 reserved for the most noxious uses. Additional letter or number suffixes after the first letter / number combination denote additional nuance in regulations, with number typically referring to differing parking regulations and letters signifying ‘contextual’ rules. A diagram showing the general spectrum of the districts that permit residences is in Figure 36.

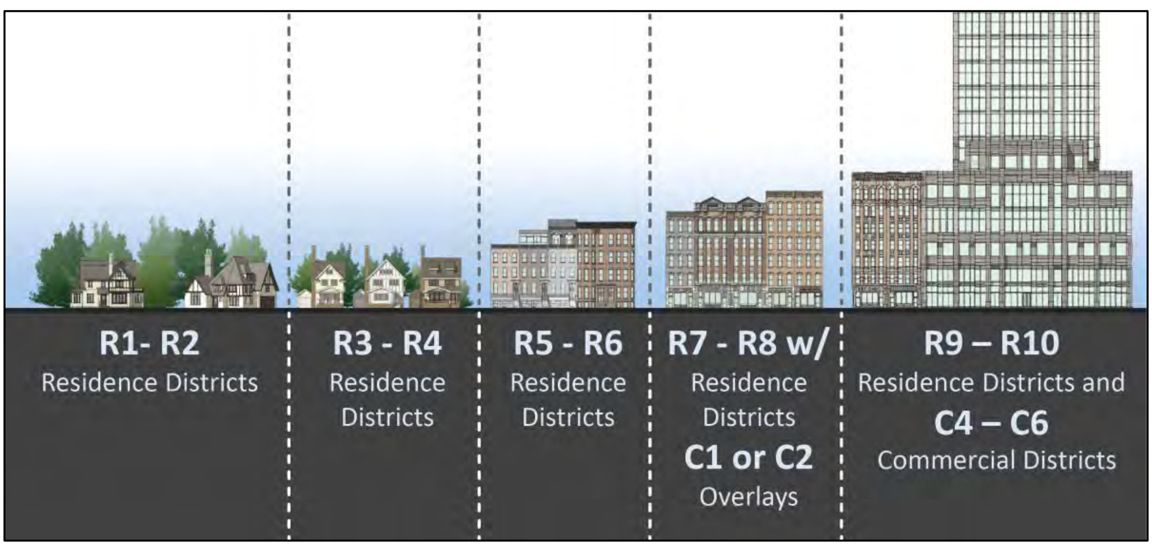

Figure 36. NYC zoning district spectrum (NYC DCP 2018)

In the original 1961 NYC Zoning Resolution, areas with zoning designations of R1 (including R1-1 and R1-2) and R2, permitted only single-family homes, while R3-1 districts permitted single and two-family homes. Over time, the range of districts, has dramatically increased (single family districts like R1-2A, R2A, and R2X were added in the 1980s through DCP zoning amendments, as well as more two-family districts, including R3A, R3X, R4-1, R4A, R4B, and R5A districts). The extent of the area mapped with these districts has also dramatically increased, particularly the latter. Single-family zoning is a well-documented exclusionary zoning tactic to buttress White privilege, and has come under tremendous scrutiny in the past several years. In New York, two-family districts have become much more prevalent than their single-family counterparts over time. While they certainly have an exclusionary undertone, they were initially created to permit semi-detached homes, or detached homes on much smaller lots, typologies often associated with the working or lower-middle class (for example, the television show ‘All in the Family’ depicted the home of Archie Bunker, a blue-collar patriarch prone to bigotry as a semi-detached home in Queens; the actual home is zoned as a two-family, R4-1 district today, and is shown in Figure 37. Because the 1961 zoning framework made zoning district distinctions between where single-family homes on large lots and two-family homes on smaller lots would be appropriate, the districts were evaluated individually. This district split would help determine if the income striation being accommodated also had racial undertones.

Figure 37. Semi-detached homes in Queens (Google 2022)

In 1961, the majority of the original residence district zoning designations allowed multi-family housing and employed a tool called a height factor devised by DCP to optimize the balance of open space and building height, and mimic the "tower-in-a-park" ideal of Stuyvesant Town, under the guise that entire blocks would similarly be razed and recreated in the same fashion (NYC DCP 2018).

In the years following the 1961 zoning's enactment, when programs like urban renewal became controversial, federal funding dried up, and trends like suburbanization went into full swing in the post-war years, the potential for wholesale urban redevelopment became increasingly impractical. Beginning in the 1980s, new zoning districts were created by DCP in medium and high-density areas to respond to the building incompatibility problems produced by small infill developments using zoning regulations intended for large-scale urban renewal on multiple blocks (NYC DCP 2018).

These 'contextual' multi-family zoning districts are recognizable on a zoning map by having an A, B, D or X suffix attached to the R5 through R10 district base district (e.g., R7A instead of R7). Their emergence also led the initial districts to be dubbed, somewhat contemptuously, as 'non-contextual' districts. Unlike the original suite of districts, contextual districts have strict, predictable height limits, and have been increasingly mapped – at the urging of local communities – to limit what is viewed as incompatible development: taller buildings than their older neighbors (NYC DCP 2018). A comparison of the forms derived from buildings in non-contextual versus contextual districts is shown in Figure 38 (NYC DCP 2018).

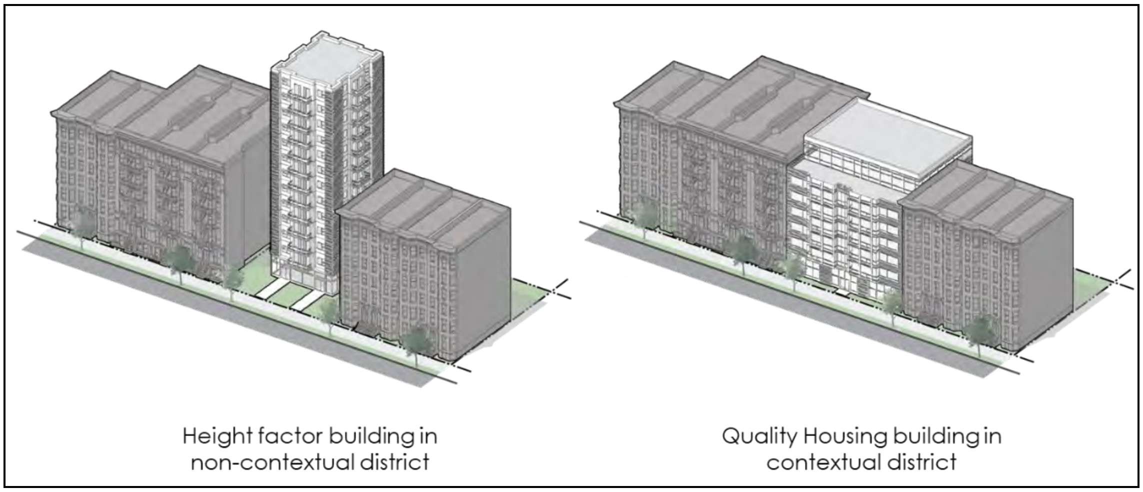

Figure 38. Comparison of potential built form in non-contextual versus contextual districts

Because these districts required a zoning map amendment to establish though, the distribution of the contextual districts may be disproportionately allocated to vocal neighborhoods with political clout and have ripple effects on housing production and racial dynamics. Glaeser et al. (2003, 2005) have discussed the impact of onerous height limits on affordability and exclusivity, particularly in central locations like Manhattan.

What complicates contextual districts, however, is that they became the *de riguer* type of zoning district to map when undertaking DCP-led rezonings, with intent to facilitate both growth and preservation – sometimes simultaneously on different streets in the same rezoning area (Laskow 2014). The Bedford-Stuyvesant rezoning (shown in Figure 39), for example, designated large swathes of the neighborhood as R5B and R6B districts, with the intent of preserving the existing built form. These mappings did not increase the zoned capacity so much as set prescriptive height limits to prevent development that would be taller than existing buildings. Along a few principal corridors however, like Fulton St., denser districts like R7D and its commercial district corollary, C4-5D was mapped, planning for substantial redevelopment (NYC DCP n.d.).

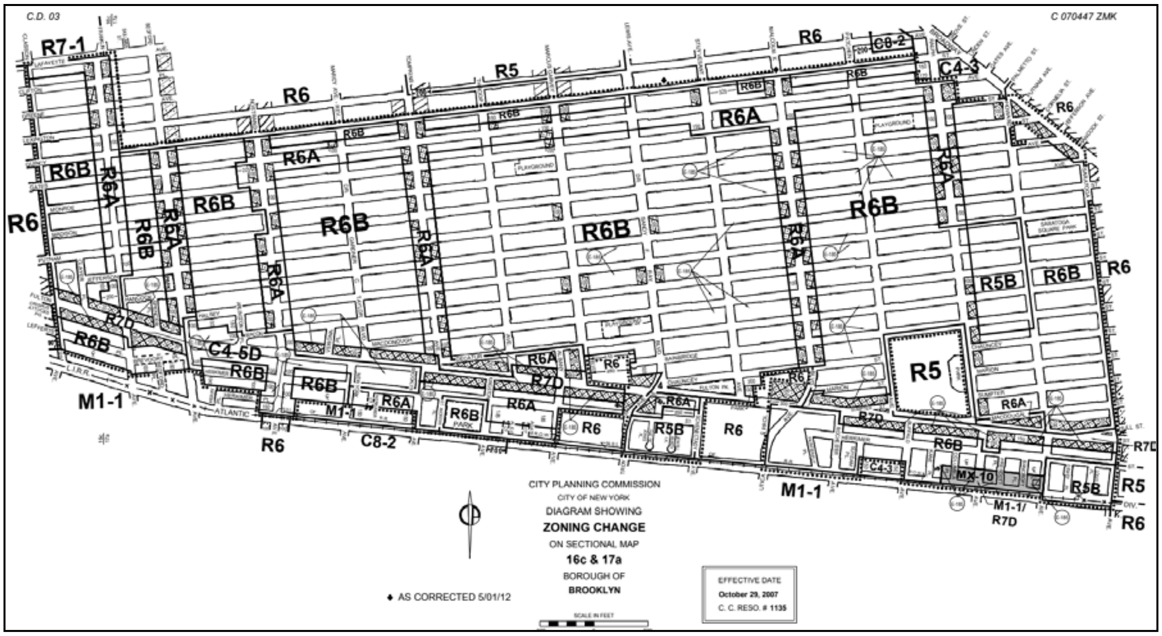

Figure 39. Rezoning map for the 2007 Bedford-Stuyvesant rezoning

This example rezoning also implicates the role of rezonings in demographic transformation, as sweeping development has occurred in the wake of the rezoning. Whether directly correlated or not, the two Neighborhood Tabulation Areas (NTAs) that the rezoning area straddles saw a gain of over 30,000 White residents between 2010 and 2020 and a loss of over 20,000 Black residents (NYC DCP 2021).

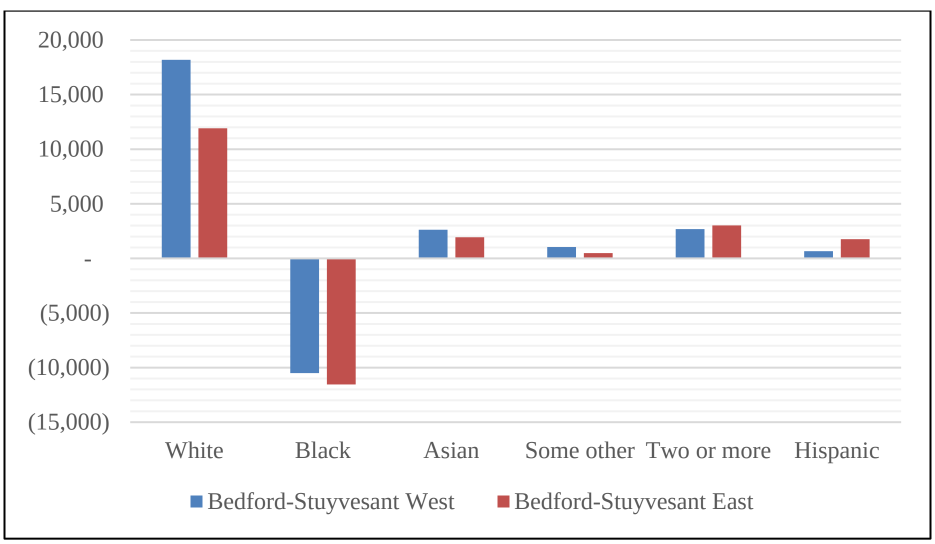

Figure 40. Demographic change, 2010-2020 in Bedford-Stuyvesant NTAs

Tumultuous trends like this, particularly those that result in the substantial loss of minority residents, are certainly suggestive of potential displacement from gentrification, and have connected rezonings as a pejorative term in many neighborhoods (Stremple 2019).

Since contextual districts have been the vanguard tool for these rezonings – every single new district mapped in Bedford-Stuyvesant was contextual – testing for correlation with population change seemed a worthwhile venture. It also seemed prudent to evaluate the areas that remain non-contextual districts to probe at reasons for not having been contextualized – for instance, is the building stock in those areas really without any prevailing context, or is it that the designation has remained, in part, as a byproduct of being a neglected minority community.

The predecessor to the New York's 1961 Zoning Resolution, the 1916 Resolution, was very liberal in its allowance for residential towers – nearly any lot in the city could allocate up to 25% of its lot and rise in perpetuity (Vorhees, Walker, Smith & Smith 1958). This was a theoretical allowance, but in practice it was not heavily utilized because other construction codes dramatically increased costs after 5-6 stories (e.g., because sprinklers and elevators became required) and the local market dynamics could rarely offset these costs with higher rents (Plunz 2016). In partial acknowledgement to these realities, the 1961 Zoning Resolution only permitted tower construction in two residential zoning district types, R9 and R10, and their commercial district equivalents, and limited those geographies exclusively to Manhattan below 96th Street.

Zoning districts that allow residential towers were seen as worthwhile to evaluate for correlations with demographic and segregation trends for a few reasons. First, in evaluating the HOLC maps for the most exclusive areas of the city, only one area that was not suburban warranted the A designation – the high-density apartment towers that march up the east side of Central Park. Since the 1960s, new crops of towers have come each generation, with new calls for height caps and greater protections to protect the sunlight reaching the park and the neighborhood (Oser 1989). Despite much consternation from some civic organizations (Municipal Art Society 2013), since the mid-aughts, a new crop of supertall towers emerging two blocks below the park has been the local symbol of ostentatious wealth, with W. 57th Street, being dubbed 'Billionaires' Row' (Hughes 2018). Between the continued exclusivity of areas around the park, and the expansion of tower districts to other Borough business districts, like Hudson Yards, Downtown Brooklyn, and Long Island City through high-profile rezonings, the ability to construct towers seemed a worthy subject to evaluate exclusivity in and of itself.

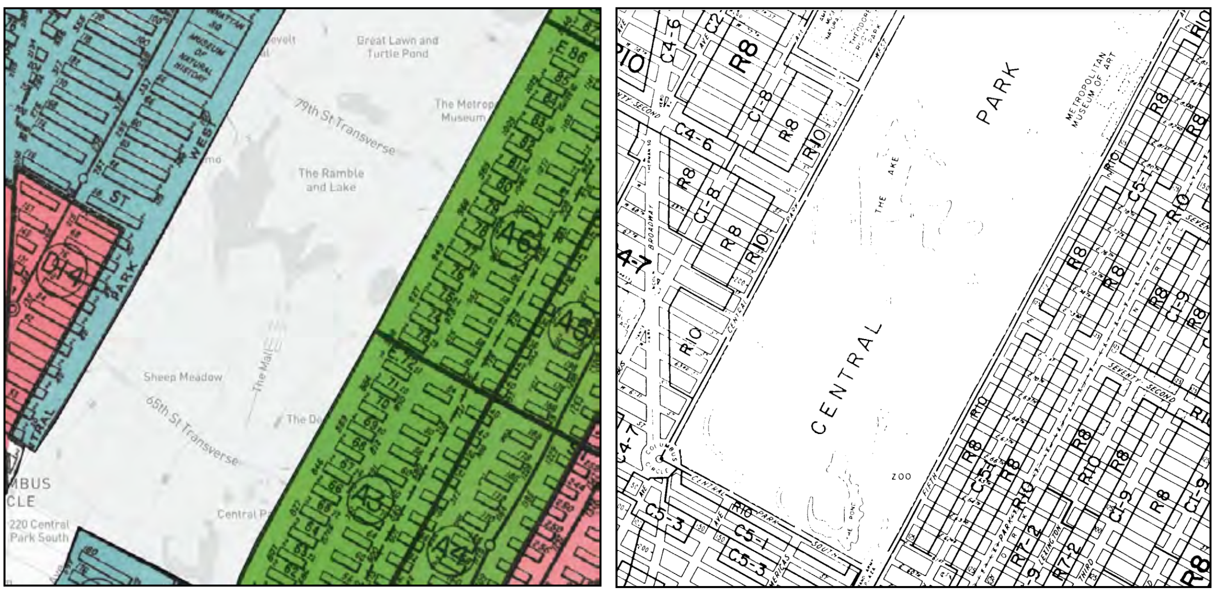

Figure 41. HOLC A and B areas around Central Park compared with R10 zoning

In the NYC Zoning Resolution, areas zoned C8 or M1, M2, or M3 are semi-industrial or manufacturing districts that do not permit new residences to be constructed. Unlike the exclusive residence districts, these districts have generally not been expanded over time, as the reduction in areas zoned with these designations has largely tracked with the reduction of the manufacturing sector's influence in the local economy.

Like many other facets of the zoning resolution, there have been policy shifts in this regard as well. The planners of the 1950s were overzealous in mapping manufacturing districts, thinking that in order to retain the manufacturing sector, large swathes of the city would need to be razed and converted to low-slung housing. To effectuate this, they mapped districts not only over existing industrial and vacant land, but also over nearby worker housing. This created non-conformances with the zoning, which made lending and re-investment extremely difficult. As the manufacturing aspirations did not materialize, the city generated special tools to address these types of situations, first in the form of 'D' suffix districts, and then in Special Mixed-Use Districts. In Manhattan, districts with an 'A' and 'B' suffix were created as tools to allow artists to have live-work spaces in older garment loft buildings in and around SoHo (Haughney 2010). Districts utilizing these new tools were seen as worthwhile to evaluate separately from the original manufacturing districts as they may represent a skewed demographic privilege in bringing zoning conformance and neighborhood investment.

The various zoning datasets discussed above were established by taking the range of districts and extent existing at the time of the analysis (e.g., 1960 versus 2020), and determining the percentage of each census tract allocated to these district types.

Digital versions of the NYC zoning map designations are updated monthly and extend back to June 2009 in an archival database available from the NYC DCP. The Department also has an archival digital shapefile of the initial 1961 zoning map. However, because there is nearly a 50-year gap between these available datasets, an interstitial map was sought to better understand trends more fluidly.

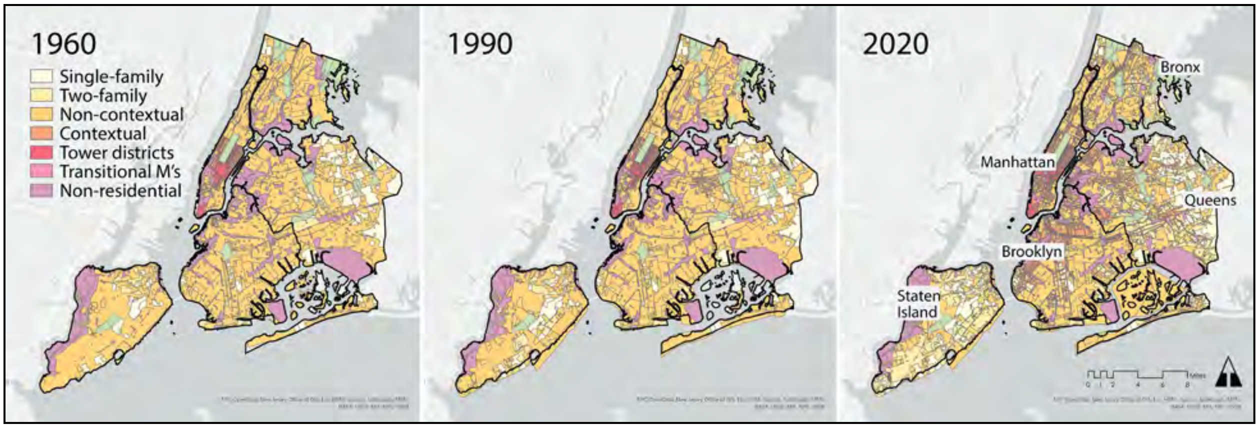

Figure 42. Zoning designations: 1960, 1990, and 2020

A 1990 zoning map was created that depicted the city's zoning on December 31, 1990. To do this, the earliest available digital shapefile from June 2009 was used, and historical print versions of each individual zoning map were assessed to compare the versions, evaluate which areas had been rezoned between 1990 and 2009, and to essentially "undo" those rezonings digitally. Usually, this involved recategorizing several smaller contextual districts that had been created in the early to mid-2000s into the same non-contextual affiliate, and then merging them into one polygon. A series of R3X and R3A districts, which permit one- and two-family homes in detached and semi-detached homes for instance, as shown in the 2009 zoning map on the right in Figure 43, had previously all been R3-2 districts in the 1975 zoning map on the left, which permits multi-family homes.

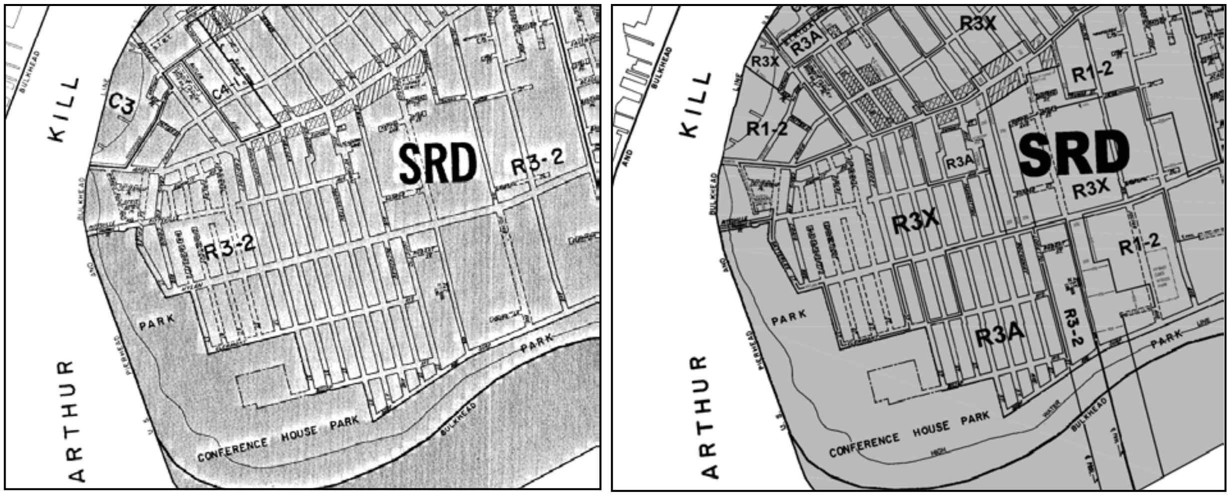

Figure 43. Example of zoning changes in South Richmond, Staten Island, 1975 and 2006

The pattern of the 1990 zoning map is interesting; if today's zoning map is associated with a granularity from multiple rezonings, and the 1961 map is notable for broad swathes of a singular district, 1990 is a clear juncture between these eras; the first contextual zonings have occurred and introduced moments of that granularity as islands in a still large sea of non-contextual districts. The example in Figure 44 highlights this with initial contextual rezonings in Astoria, Queens (and the Upper East Side) on the left in 1990, and the same stretch in 2020 on the right. This shows the importance of having this mid-step in the analysis.

Figure 44. Example of zoning changes in Astoria, Queens, 1990 and 2020

In the Zoning Resolution, special regulations contained within a special purpose district set forth a unique plan for a specific neighborhood or geography through modifications to the underlying use, height or parking regulations. In 1961, there were no special purpose districts – the first was established by DCP in Lincoln Square in 1969, and since then dozens more have been established, typically as part of DCP-led rezonings. These special overlays are denoted in grey tones on the zoning map and have special chapters in the Zoning Resolution. Their existence in a certain location may equate to disparate levels of political power and privilege, or simply with representative case studies for significant policy shifts.

Like the zoning districts themselves, a digital shapefile of special purpose districts extends back to June 2009, and so a similar process was necessary to recreate the range of Special purpose districts existing at the end of 1990. These have been created, repealed, and recombined over time, so assessing their geographies also involved cross-validating their time sequences in the special district time series tables of Appendix B of the Zoning Resolution.

Figure 45. Special purpose districts: 1960, 1990, and 2020

After the demolition of Penn Station in the mid-1960s, the Landmarks Preservation Commission was established to review design modifications to landmarked buildings and new construction in historic districts. Since that time, the number of historic districts has grown vastly. Several authors (Glaeser, Gyourko, and Saks 2005) have written on how the added time and risk associated with an agency's discretion in making approvals, not to mention the soft power of a vocal community, adds significant project costs. This squarely layers into discussions on artificial housing-supply constraints, often in the areas best suited for growth. This variable aided in evaluating whether historic districts are disproportionately clustered in White neighborhoods as a means to protect against new development, and if that in turn has had implications on Black population dynamics.

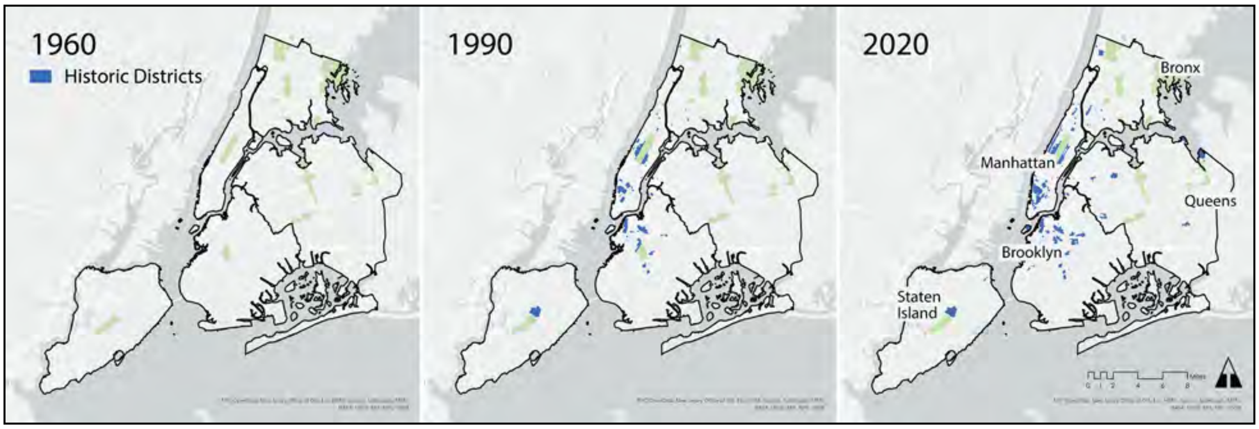

Figure 46. Historic districts: 1960, 1990, and 2020

The data sources for these independent variables, their original data type and projection, are all included in Table 2. Also included is the influence anticipated in the various regression models.

Table 2. Independent variables to investigate in regression analyses

Criteria	Data Source	Type	Original projection	Anticipated influence
Distance to core	Utilized census tracts centroids and the center of the Lower Manhattan and Midtown Special Districts as a proxy for CBD boundaries.	Geoprocessing generated a distance field in the attribute data.	N/A	The influence of this variable may shift over time, due to suburbanization in White segments. In recent years it may positively affect White

				cohorts, as a proxy for the wealth gap between the racial groups.
Percent Subway Proximate	NYC Open Data, MTA	Point data for subway stations, from which buffers were drawn.	GCS of WGS 1984; no projection	This variable may behave similar to distance to core, and disproportionately explain Black density in the eras of peak White suburbanization.
Percent HOLC A, B, C, D areas Percent non-HOLC areas	University of Richmond Digital Scholarship Lab, Mapping Inequality project (Nelson, et al. n.d.)	Polygon data	GCS of WGS 1984; no projection	A and B areas were favorable ratings, so they may be positively correlated with White neighborhoods and negatively with Black, particularly the former. The influence of C and D areas may be more balanced between the racial segments.
Percent Urban Renewal Areas	596 Acres, through a Freedom of Information Law (FOIL) request with the HPD (596 Acres n.d.)	Polygon data	NAD 1983 StatePlane New York Long Island FIPS 3104 (US Feet)	Urban renewal areas may explain Black population density loss in some areas, as neighborhoods were razed, and gain in others, as affordable housing was developed on abandoned lots.
Public housing density per acre	HUD data portal (HUD 2021)	Point data, summarized by counts into census tract polygons	GCS of WGS 1984; no projection	This variable may disproportionately explain Black population density, and the absence of White cohorts.
Percent highway proximate	TIGER / line highway datasets by state from US Census Bureau (US Census Bureau n.d.)	Line data, from which buffers were drawn	GCS of NAD 1983; no projection	This variable may verify the disproportionate concentration of highways in Black neighborhoods but may also explain vehicular-oriented suburban White neighborhoods.
Percent allocated to different zoning designations (single-family,	NYC DCP (NYC DCP 2021)	Polygon data with district designations for 1960 and 2020. For the newly	NAD 1983 StatePlane New York Long Island	Different zoning districts likely impact White and Black segments differently. Single-family districts

two-family, contextual multi-family, non-contextual multi-family, residential tower, former manufacturing, and non-residential districts)		created 1990 map, digitized archival zoning maps were utilized.	FIPS 3104 (US Feet)	and contextual districts may disproportionately explain White population patterns by virtue of their restrictive nature and / or the political capital exerted to generate zoning changes. Other districts may have a more even impact.
Percent special purpose district	NYC DCP (NYC DCP 2021)	Polygon data. For the newly created 1990 map, digitized archival zoning maps were utilized.	NAD 1983 StatePlane New York Long Island FIPS 3104 (US Feet)	Special purpose districts may benefit White populations more by virtue of the political capital involved in undertaking the rezoning and establishment of special rules.
Percent historic district	Landmarks Preservation Commission (NYC Landmarks Preservation Commission 2021)	Polygons	GCS of WGS 1984; no projection	Like special districts, this variable may speak to political privilege and thus explain White populations more than Black

3.2. Research Design

The research in this thesis can be broken into two larger parts: exploratory spatial analyses and comparative regression analyses. Exploratory spatial analyses consisted of studies of population patterns and global segregation analyses while regression analyses involved ordinary least squares, and then additional models to address spatial dependence and heterogeneity. The results of each informed the findings and conclusions. A summary diagram for the methods in this thesis is included in Figure 47.

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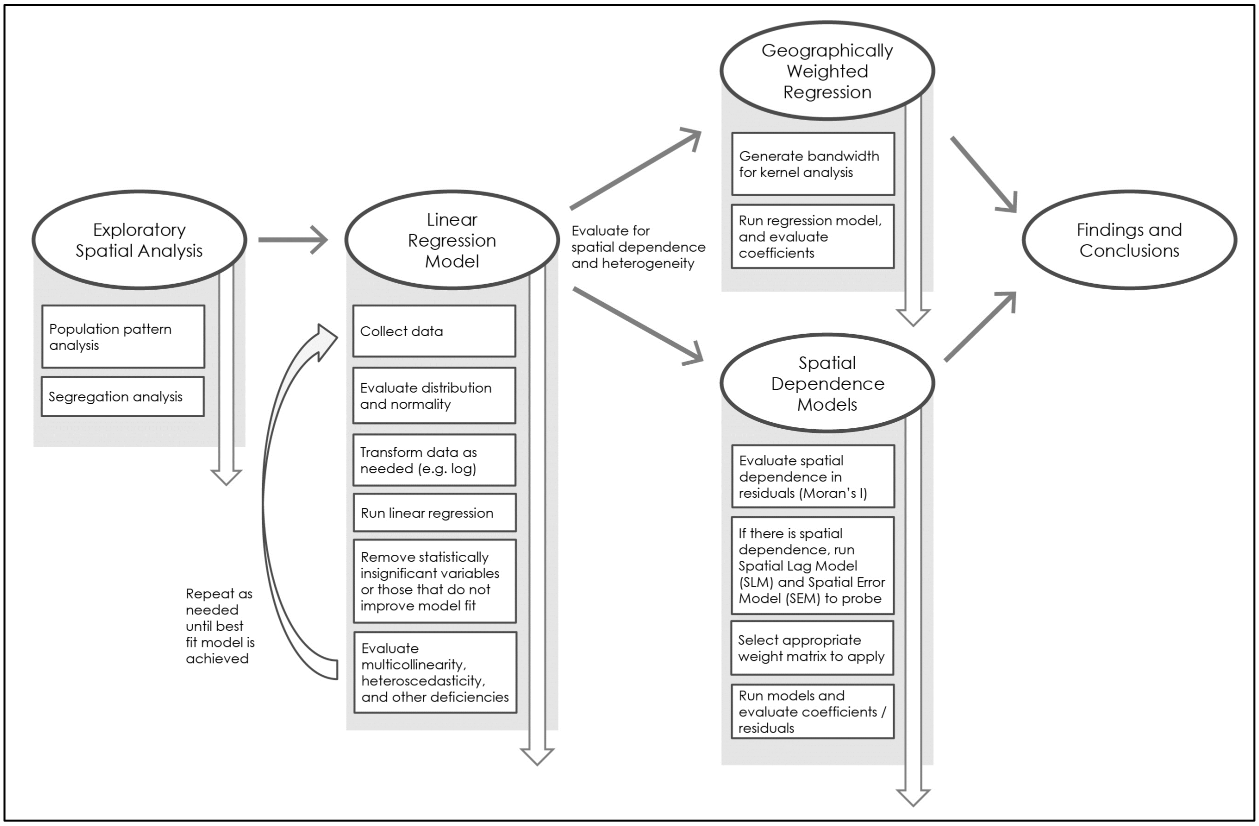


Figure 47. Process diagram for thesis methodology

3.2.1. Exploratory Spatial Analyses

Exploratory spatial analyses in this study included population pattern analyses, and segregation analyses.

3.2.1.1. Population pattern analyses

For this study, data from the US Census Bureau's decennial census counting the number of Black and White residents within each census tract of the city was used to determine significant concentrations – both at the citywide level, and in localized areas. This was done not only for the 2020 census, but also for historical decennial census data, going back to 1910 (the earliest date that spatial and tabular data are available for NYC (IPUMS National Historical GIS n.d.)).

Both global and local spatial autocorrelation measures were undertaken. The Spatial Autocorrelation (Global Moran's I) tool in ArcGIS Pro outputs a single index value evaluating the strength of autocorrelation of a phenomenon amongst areal units in a study area. In this case, the tool was evaluating the density of Black population amongst census tracts to determine if the pattern of distribution was random or exhibited a spatial pattern of clustering or dispersion such that the null hypothesis of randomness could be rejected.

Two local measures evaluating spatial autocorrelation were also undertaken. The Getis-Ord Gi* test (Hot Spot Analysis in ArcGIS Pro) was used in the same decennial time period as the Moran's I, and was used to visualize localized areas of statistically significant Black population concentration or dispersion, through hot spots and cold spots color-coded on a census tract map. The local Moran's I evaluation was also conducted, mainly to inspect outlier relationships in the local relationships between the Black population densities of neighborhing units – the low-high and high-low relationships, as this was the most novel information not already captured by other analyses.

In both global and local measures of spatial autocorrelation, the spatial weights matrix chosen to assess relationships between neighboring polygons matters considerably and has a large influence over the results. Essentially, the choice of relationship between neighbors allows the algorithm to compute the influence it will exert.

The relationship between neighboring units generally falls into two categories – contiguity-based, or distance-based (Chi and Zhu 2019). Contiguity-based matrices evaluates neighbors based on whether they physically touch each other, and variations in methods involve the type of abutment; the "Rook's case" (or 'Contiguity edges only' in ArcGIS Pro) for instance, includes neighbors with a shared boundary, while the "Queen's case" (or 'Contiguity edges corners' in ArcGIS Pro) includes both shared boundaries and vertices (Chi and Zhu 2019). In NYC, the irregular census boundaries generated by the various river courses and the coastline limits the viability of these continuity-based approaches; many islands are orphaned without neighbors, and several river-abutting tracts have limited neighbors, even if the distance over the river is marginal, and readily traversable via bridges. Even if there were no shoreline conditions to contend with, the irregularity of certain polygon features, like census tracts, and the vast range of shapes and sizes, can make continuity-based approaches problematic.

To overcome some of these issues and have a more rational outcome, distance-based approaches can be utilized. These generally evaluate neighbors based on a distance from a polygon centroid, and similarly have a few variants in approaches. 'Fixed distance' approaches, as the name suggests, capture all the areal units whose centroid falls within a particular distance. The abruptness of this approach – which does not consider the influence of neighbors outside the band, even those immediately outside – leads many to consider the 'zone of indifference' approach, which accounts for neighbors' values beyond the distance band, but just with a lessening influence (Esri 2009). Distance bands can be chosen based on numerous methods, such as the distance where the z-score is the highest in the global analysis. The Incremental Spatial Autocorrelation tool, which calculates the global Moran's I iteratively over a range of distances, was used to evaluate the peaks of z-scores in the 1930, 1960, 1990, and 2020 Black population per acre clusters. As Figure 48 shows, the peak z-scores for each year interval occur at different distances – 6,000 feet in 1930; 12,000 feet in 1960; 14,000 feet in 1990; and 16,000 feet in 2020. This variance makes this approach problematic.

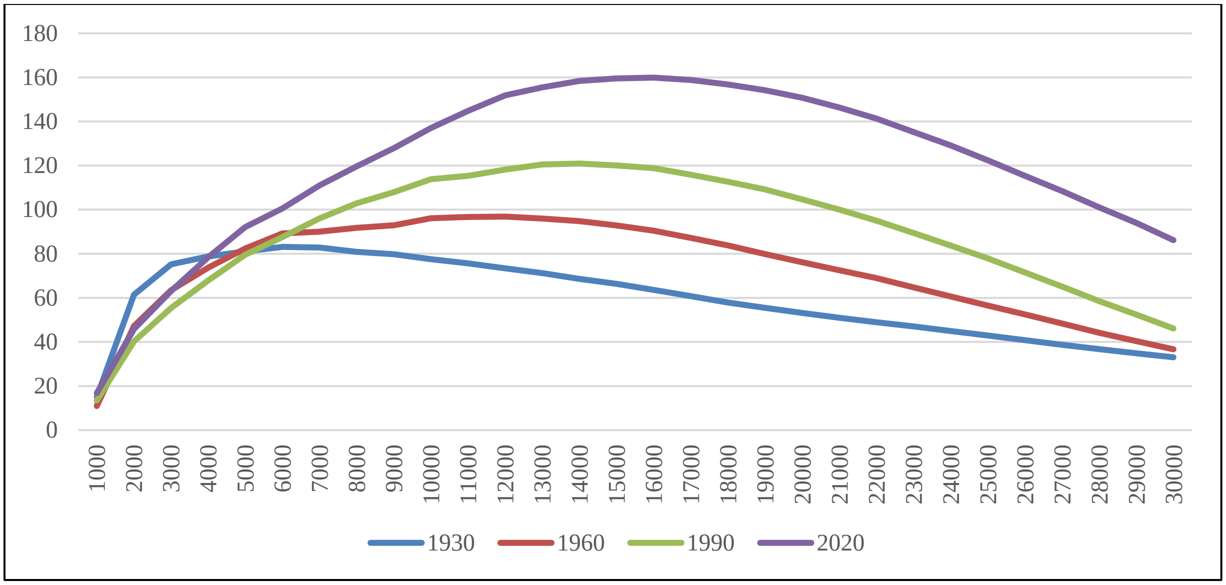


Figure 48. Z-scores resulting from Incremental Spatial Autocorrelation tool

The Manhattan Grid was established in 1811 by the Commissioner's Plan, and at its core parcelized the island in the north-south direction into modules consisting of 200-foot-deep blocks (for 100-foot-deep tax lots) divided by streets of 60-foot width. Roughly every tenth street a wider, cross-town avenue was mapped, which, at 100 feet, added an additional 40 feet to the standard width, so that every 20 blocks was an even mile (Ballon 2012). The cross-town avenues also coincide with major transfer points between express and local subway lines. Given the regularity of the 1-mile interval , this was chosen as the distance band, and the 'zone of indifference' was chosen as the evaluation method.

3.2.1.2. Segregation analyses

Segregation indices have long been utilized to evaluate population patterns in cities and regions with more nuance. A spatial autocorrelation analysis might show high concentrations of Black residents in a neighborhood of NYC, for example, but until it is compared against other racial and ethnic groups and their total respective populations, it is difficult to discern if the population pattern is segregated from or integrated with other groups.

To address this knowledge gap, global spatial segregation measures like the spatial dissimilarity (D), relative diversity (R), spatial information theory (H) index, and exposure / isolation index (P) proposed by Reardon and O’Sullivan (2004), and available through ‘seg’ package of R Studio, were conducted. Evaluating the segregation in census tracts through the same decennial time series gave a baseline window of whether segregation increased or decreased through time.

In addition to plotting the raw global values, the ‘seg’ package of R Studio has the ability to plot resulting population density maps, smoothing the values from census tract centroids with a kernel density estimator (Hong, O'Sullivan, and Sadahiro 2014). This analysis compares the population densities for different population cohorts being evaluated, in a side-by-side manner to visualize their spatial differences (and begin to understand the spatial segregation). These were output for the years 1930, 1960, 1990, and 2020, to obtain a cursory understanding of the spatial pattern which could be probed deeeper with local segregation tools in the regression analyses.

3.2.2. Comparative Regression Analyses

The spatial autocorrelation and segregation tests help answer the “where” question of the analysis – where Black households are inordinately segregated within NYC. The next round of analyses seek to answer “why” this might be occurring. Regression analyses take the topic issue, the spatial pattern of various Black and White population metrics, and try to understand their spatial phenomena through other, independent variables. Like the prior analyses, these are done at the census-tract level and conducted through different time intervals to have a spatio-temporal understanding of the persisting or waning influence, if any, of these variables on segregating the city.

Running the linear regression analyses twice, with Black and White population metrics as the dependent variable, was critical to this analysis. It was thought that severable variables may exert difference influences, or even opposite influences over their respective population distributions. The literature notes a propensity for urban renewal to displace Black populations, and cluster them in public housing. Separately, literature notes the exclusionary nature of some zoning tools, like single-family housing, and its historical usage in the bulwarking of White privilege. Understanding the influence of each of these variables simultaneously, with the opposite population cohort, was compelling. Comparing the regression coefficients between the two groups identified disparities in the concentrations of their respective population sets.

3.2.2.1. Time intervals: 1960, 1990, and 2020

This evaluation was be done in 30-year intervals beginning in 1960. 1960 was chosen as it represented the oldest decennial year that would reasonably correlate with the 1961 Zoning Resolution. While the 1961 Zoning Resolution was adopted by the Board of Estimate on December 15, 1961, its vestiges trace back earlier. The district types and preliminary mappings were published in the 1958 *Zoning New York City* by Vorhees, Walker, Smith and Smith (Vorhees, Walker, Smith & Smith 1958). The year 1990 was chosen as the intervening year because it represents the stabilizing period after decades of sustained population loss, and it also corresponds with a substantial policy shift in the DCP towards mapping contextual zoning districts, with fixed height caps. This policy shift, and subsequent contextual rezonings began in earnest after citywide text amendments in 1987 and 1989 for medium / high-density and low-density districts, respectively (NYC DCP 2018). The choice of a 30-year gap, and three overall time windows was largely a produce of time availability; a narrower gap, of 20 or even 10 years may have been more ideal but would have necessitated the digital creation of zoning maps for each intervening window.

3.2.2.2. Ordinary least squares and diagnostics

Ordinary least squares (OLS) regression analysis is a common tool for helping understand the explanatory variables for a particular phenomenon in an area. One of the principal outputs are coefficients, positive or negative, for each individual explanatory variable. These coefficient values represent the expected change in the response variable for an additional unit of the explanatory variable (Chi and Zhu 019); for example, if evaluating the influence of the percentage of a census tract allocated to an HOLC D area on the Black population density, a coefficient of 2.5 would mean that for every additional percentage of HOLC D area, one would expect 2.5 more Black residents per acre. The model also outputs the p-value for the individual variable, denoting if it is statistically significant in explaining the response variable. The overall adjusted R-squared value of the model helps explain the degree to which a set of variables might influence the dependent variable and are expressed as a decimal from 0 to 1. An R-squared value of .5 for instance, would explain 50% of the model's behavior (Esri n.d.). Much of the labor of running linear regression models, however, involves preparing the data, and evaluating the residuals, to ensure the model is properly fitting the data.

In order to prepare data for the regression model, one first needs to evaluate if there is a linear relationship between the x and y variables. One method is to plot them on a scatter plot, and visualize if the variables have a relationship, and if so, whether they fall roughly into a straight line. One can also employ more technical measures, such as evaluating the skew or kurtosis in each of the variables to ensure they are normally distributed. Where nonlinear relationships occur, and variables are not normally distributed, one should employ a transformation to the variables, such as a logarithmic or cube root transformation.

A linear regression should avoid independent variables that are highly correlated, the phenomenon of multicollinearity. This can often occur with demographic or socioeconomic factors; if trying to explain why food deserts occur in certain urban areas, for example, race and income might be highly correlated with one another. A common test for multicollinearity is the Variance inflation factor (VIF) which indicates a level of multicollinearity, the higher the value the greater the cause for concern. Values of 1 suggest no influence while values between 1 and 5 suggest increasing levels of moderate influence, and those between 5 and 7.5 begin to be highly correlated, and could exert influence on the model (Esri n.d.).

These data preparation and checks allowed a first run of the OLS model, but other typical linear regression assumptions also needed to be met to ensure the model's viability. One standard assumption in a regression model is that the residual values are characterized by homoscedasticity – meaning they have a similar range of variance from each other throughout the regression plot. If there is heteroscedasticity, the residuals will often become more pronounced in a cone pattern at one end of the plot. More rigorous tests to evaluate this include the Breusch-Pagan (BP) test, which evaluates the variance of the residuals and determines their significance. If the p-value is higher than 0.05, the residuals are random and equally varied, and thus homoscedasticity is present. However, if the p-value is lower, the null hypothesis can be rejected, and heteroscedasticity is present with unequal variation (Statology 2020).

Another assumption in a regression model is that residuals will be normally distributed. This can be checked relatively easily by plotting the residuals through a Q-Q plot and ensuring that they roughly follow a straight line. If one end of the distribution curves upward, this would indicate outliers, and a log transformation of the independent or dependent variable may be necessary. More rigorous statistical tests like the Jarque-Bera test evaluate a dataset for skew and kurtosis, signs that a dataset is not normally distributed. Here, one can run it against the residuals of the linear regression models to determine if they violate the normality check – the higher the x-squared value and lower the p-value, the more likely the residuals are not normally distributed (Statology 2019).

A third assumption is that residuals should be independent of one another, and not autocorrelated. Spatial autocorrelation can be tested by running a global Moran's I on the residuals – if the p-value is statistically significant, there is autocorrelation occurring. A more sophisticated test is the Lagrange multiplier (LM) test. This test can determine whether there is spatial lag (SLM) or spatial error (SEM) in the model, and whether it is statistically significant; if so, then it foreshadows the appropriate type of spatial regression model to run next.

R Studio was used to conduct this linear regression work, and three OLS runs were employed, to incrementally improve the model's fit. Model fitness is generally measured by an Akaike information criteria (AIC) or Bayesian information criteria score; the lower the score, the better the model fit. Step functions were added that evaluate each variable's contribution to model fitness and drop any variable that, when removed, lowers the score were utilized. Similarly, removing any statistically insignificant variables incrementally bolstered the model's fit and gives confidence that the chosen variables are properly explaining the phenomenon being queried (Esri n.d.).

3.2.2.3. Spatial dependence

Where the OLS model does not pass diagnostic tests for homoscedasticity, normality and autocorrelation in the residuals, there is likely spatial dependence occurring in the model. If this occurs, more sophisticated models that account for spatial dependence in the data, including the spatial lag and spatial error models need to be employed.

The SLM helps assess how neighboring response variables might positively or negatively be influencing each other. It is similar to a linear regression model, but in addition to evaluating the relationship between explanatory variables, and residuals, it evaluates the spatial lag in the response variable through a new coefficient, Rho, and by applying a spatial weights matrix to the model. The SEM is used to account for spatial dependence in the residuals, or the error units, which occurs when there is a spatial autocorrelation occurring between unidentified explanatory variables (Chi and Zhu 2019) . Like the SLM, a spatial weight matrix is applied, but this time it is applied to the error term, and a new coefficient, Lambda, is added to measure the degree this influence exerts in the model.

This analysis' regression models all used population data as a response variable, which, particularly in an urban setting, is prone to spillover effects and spatially dependent variables (Chi and Zhu 2019). In fact, every OLS model run resulted spatially autocorrelated residuals, necessitating the spatial regression models to be an added component to each model.

Like the OLS regression, these spatial regression models were constructed and run in R Studio. In constructing the spatial weights matrix, a Queens-based approach was utilized, capturing the influence of every abutting census tract. The best model fit was derived by comparing the resulting AIC values. Residuals were also be tested for autocorrelation, as viable models will not have statistically significant p-values after running a Moran's I or LM test.

3.2.2.4. Spatial heterogeneity

While the previous models have tested for spatial dependence within the dataset, other models can test for spatial heterogeneity. This emerges in datasets when X and Y values vary across a study area, and therefore have localized fluctuations between their influence. For example, if HOLC redlining boundaries are significant to explaining clusters of segregated Black communities, the degree to which it explains the clustering may be stronger in some areas of the city than others – while some neighborhood clusters may, hypothetically, coincide perfectly with former D zones, others may not, as the D zone may have been designated over dilapidated building stock near nuisances at the time, for instance, like railroads and waterfronts, that are no longer perceived as such, and could even be highly desirable areas. The nature of the population datasets being used lends itself to heterogeneity, as the population density varies dramatically in the city as it transitions from high-density Manhattan to mid-density inner core neighborhoods in outer boroughs to suburban areas in the peripheries.

To evaluate spatial heterogeneity in a model and determine how the variables that have been contemplated and isolated through the linear regression analyses might interact with the dependent variable differently through space, a geographically weighted regression (GWR) can be utilized. This analysis did not utilize GWR for every variable in every time period, but instead isolated specific variables for spatial heterogeneity analysis based on interesting, or potentially counter-intuitive behavior in other regression models.

This analysis was conducted in R Studio. Since this is a local analysis, there is a spatial weights matrix to consider here as well. The outputs of this tool were exported to Excel, brought into ArcGIS and joined with the shapefile. The visualizations of different coefficients can display the spatial differences in the influences they exert throughout the study area. Collectively they can show the complex relationships between different variables.

Chapter 4 Results

The first component of this section discusses the results of exploratory spatial analyses and the second details the comparative regression analyses. Collectively they show how the city is segregated, and the impact of government policies on spatial segregation.

4.1. Exploratory Spatial analyses

Results for the exploratory spatial analyses include population pattern assessments and global segregation analyses.

4.1.1. Population Pattern Analyses

Conducting Getis-Ord Gi* (Hot Spot) analyses for each decade showcased statistically significant hot spots and cold spots. Sequencing these analyses in a time series revealed interesting patterns in densification, de-densification, as well as intra-city migrations and shifts over-time.

Figure 49 shows the sequenced results of Black hot spots in the city for the decennial years of 1910, 1920, and 1930. In the early 20th century, the Black population in the city was extremely modest. Small communities were clustered throughout much of Manhattan’s west side, with the largest community in Harlem in northern Manhattan. Between 1910 and 1930 two interesting phenomena occurred – the Black cluster south of Central Park, in the modern-day Garment District, disappeared, and a new cluster in Bedford-Stuyvesant in Brooklyn emerged rapidly.

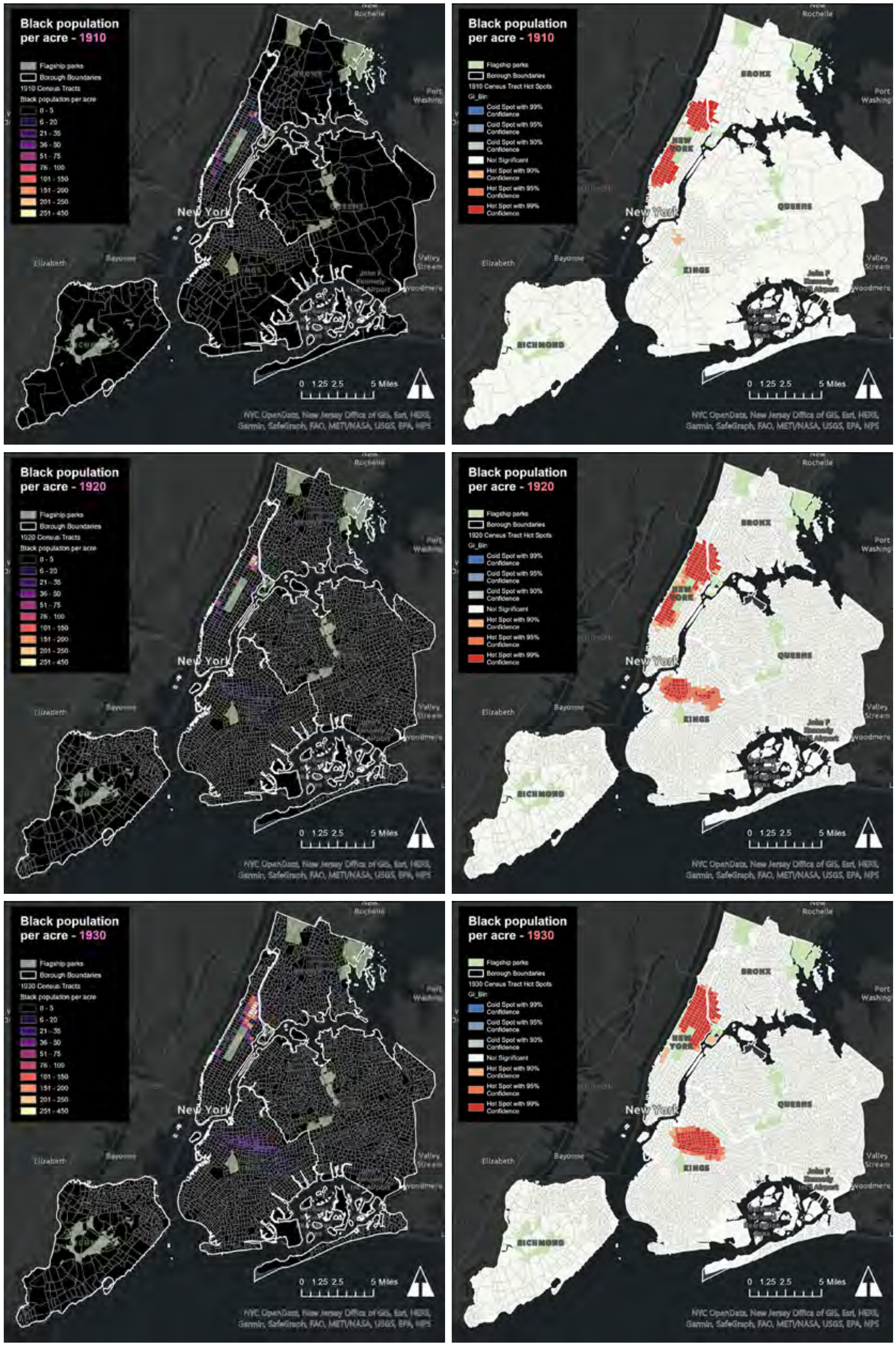
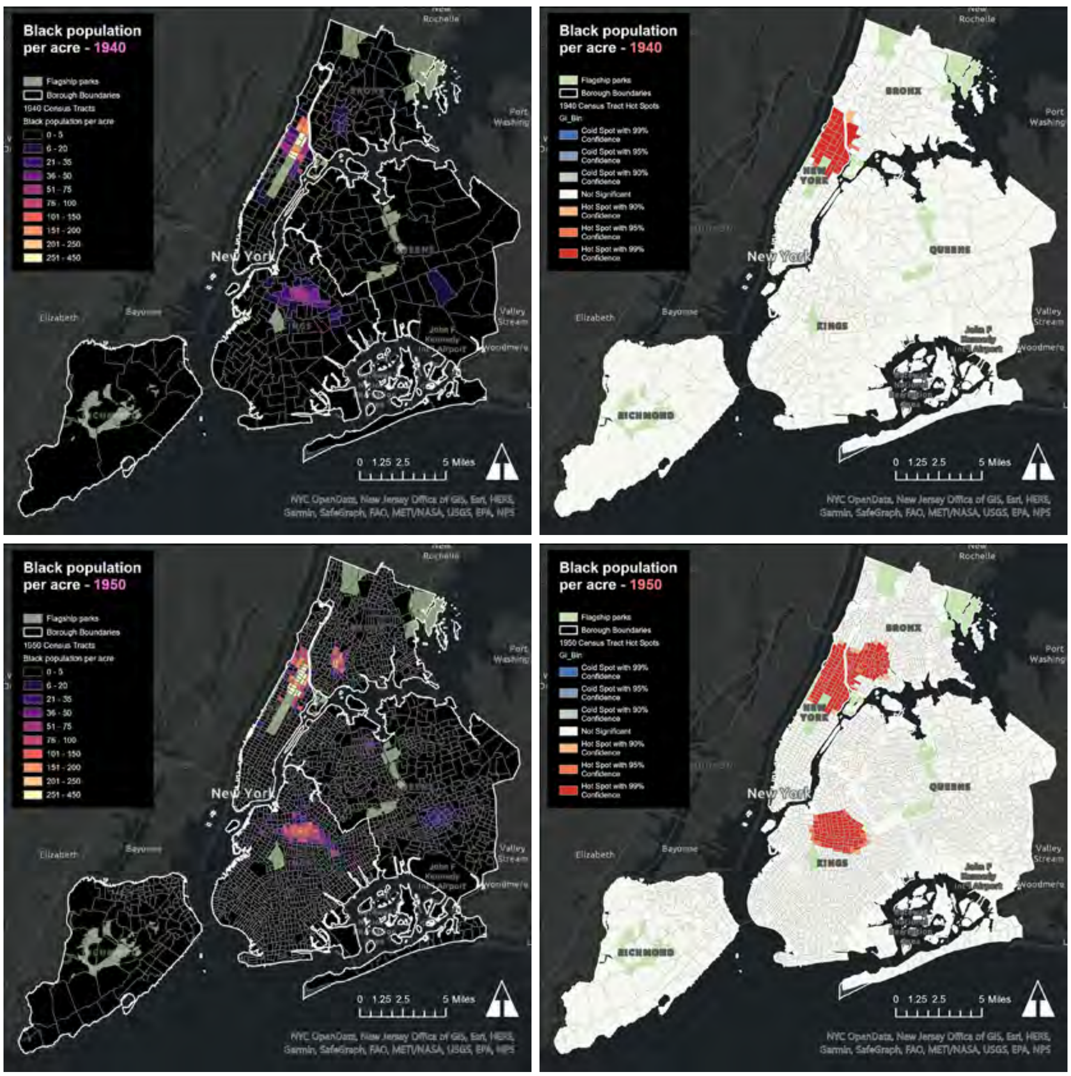


Figure 49. Black population density (left) and hot spot analysis (right), 1910 – 1930

Figure 50 shows the next sequence of hot spot analyses for the decades of 1940, 1950, and 1960. In the middle of the 20th century, which coincided with the greatest growth in Black population, the pre-existing Black population clusters continued to grow. Clusters in Harlem pushed northward into the South Bronx, while hot spots in Bedford-Stuyvesant pushed eastward towards Brownsville. In 1960, the continued development of the outer boroughs, and the suburbanization of the periphery, resulted in the initial cold spots in the spatial pattern of Black density. The Black suburban enclave in southeast Queens was also beginning to emerge.



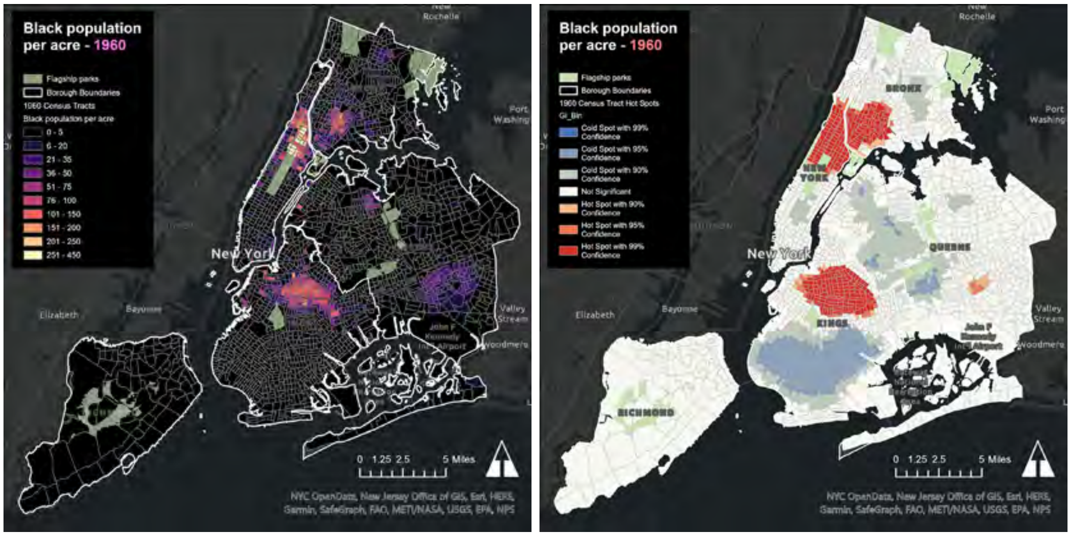
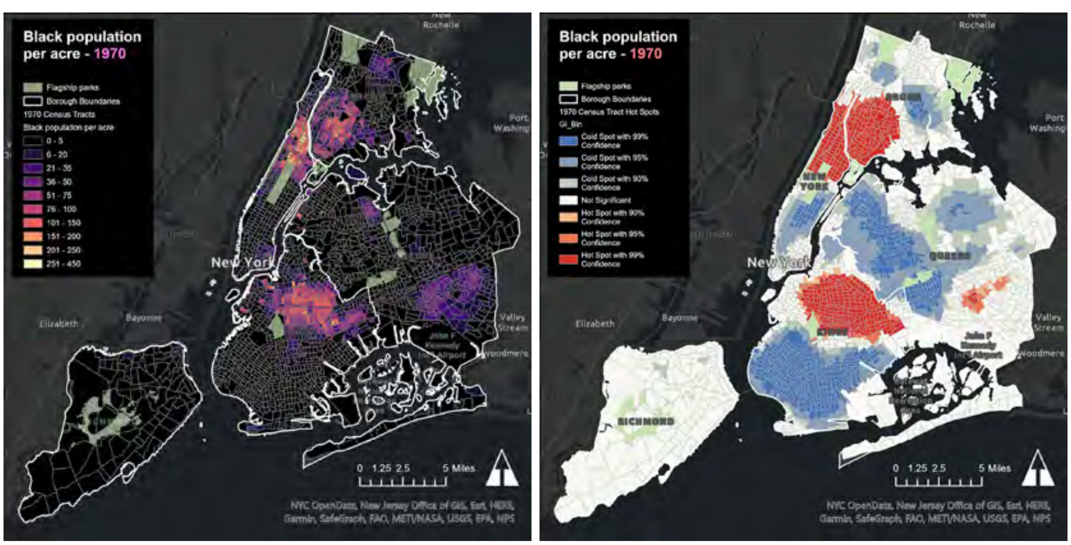


Figure 50. Black population density (left) and hot spot analysis (right), 1940 – 1960

Figure 51 shows the third sequence of decennial clusters – 1970, 1980, and 1990. This period largely coincided with “White flight” and fiscal difficulties for the city. The cold spots in these decades intensified, presumably as White residents fled the perceived crime in minority neighborhoods for suburban enclaves or Manhattan south of 96th Street. As they abandoned edge neighborhoods, Black residents moved in; the hot spot in Bedford-Stuyvesant expands westward and begins to wrap Prospect Park while the Harlem cluster wraps into Morningside Heights and the Upper East Side.



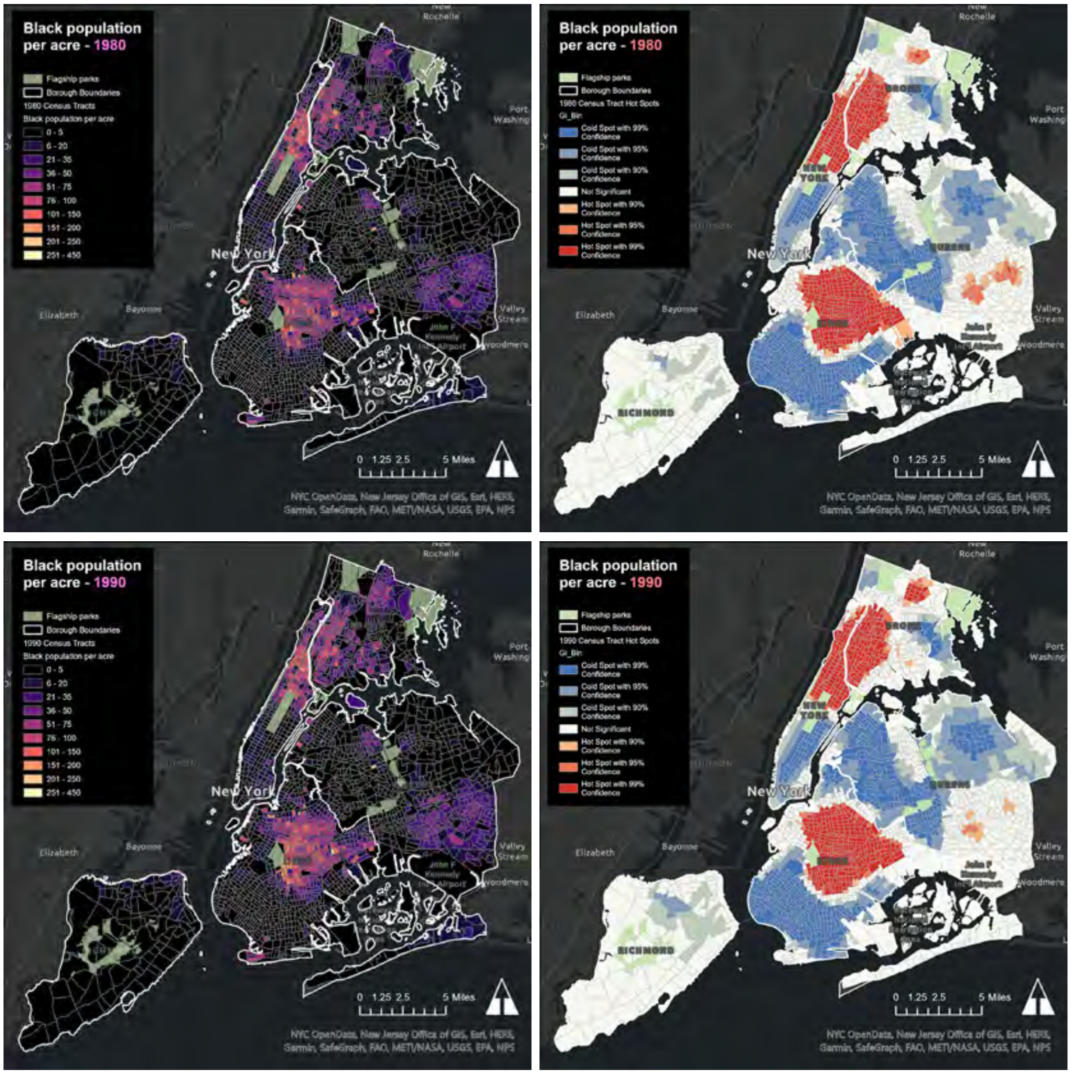


Figure 51. Black population density (left) and hot spot analysis (right), 1970 – 1990

Figure 52 shows the final sequence of hot spot maps for the years 2000, 2010, and 2020. As the city reversed its population loss, pressure has emerged on where and how the city should grow. Popular, transit-accessible neighborhoods saw tremendous pressure, and expanded outwards, encroaching into these very same minority neighborhoods. In the 2000s, the Brooklyn hot spot has pushed eastward, while the Harlem and Bronx hotspots have pushed northwards, further from the CBDs, into less accessible areas.

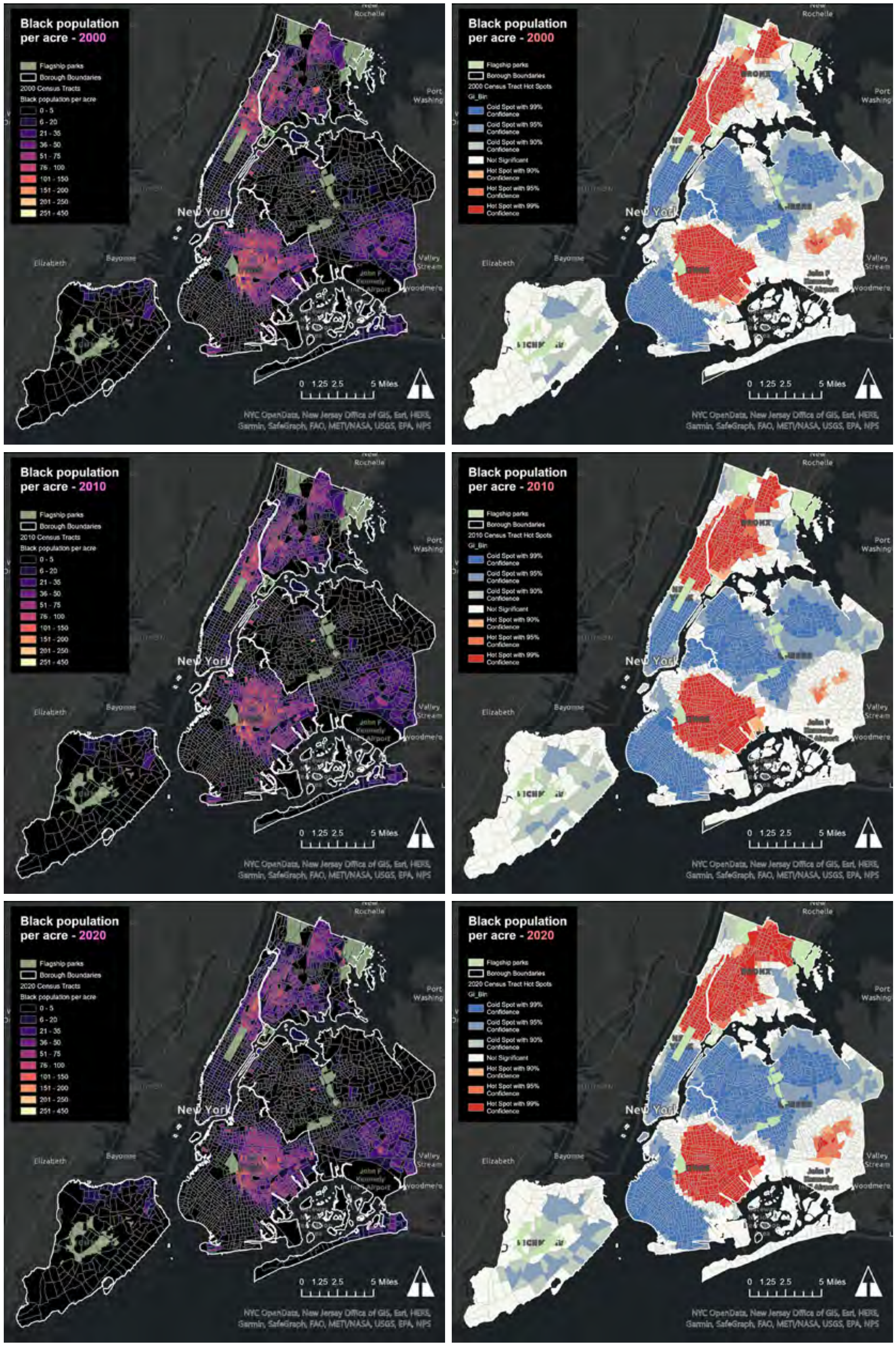


Figure 52. Black population density (left) and hot spot analysis (right), 2000 – 2020

Global Moran’s I (spatial autocorrelation) measures were conducted over time to determine the changes in the intensity of clustering. The index value indicates the strength of clustering; the stronger the cluster, the closer the index gets to a value of one. The values are shown in Figure 53 and are compared with overall population changes in Figure 54. The changes in Moran’s I seem to track closely with the overall population of NYC. In periods of growth, clustering of Black residents increased, while in the aftermath of population loss, there was in fact de-densification. This pattern did not abate in the 21st century.

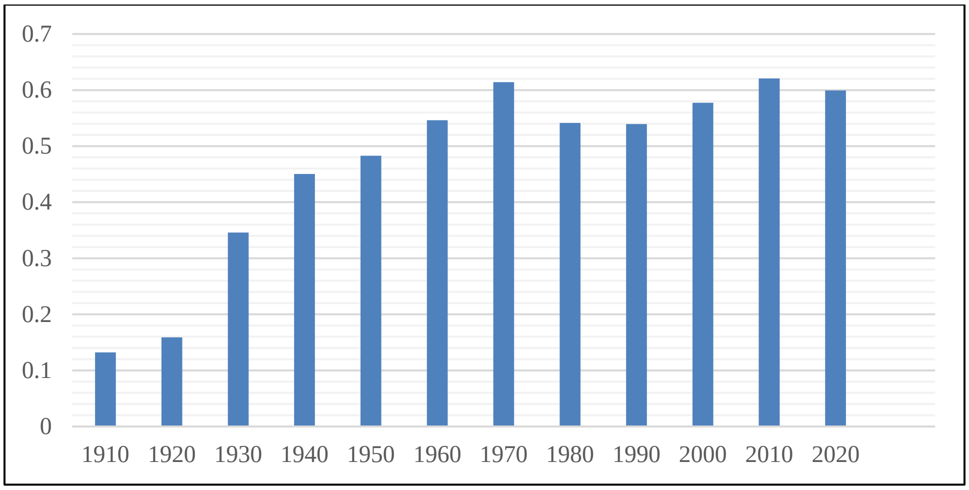


Figure 53. Moran's I values, 1910 – 2020

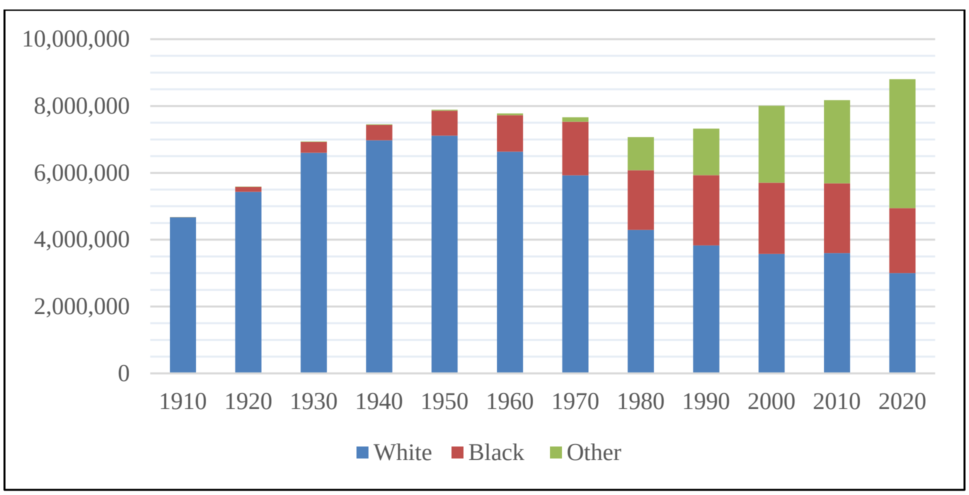


Figure 54. Population of NYC 1910 – 2020, by race

Local Moran's I measures were also run. These are particularly useful as they identify outliers from otherwise High-High and Low-Low relationships (hot and cold spots). Examining some of the High-Low outliers, shown in Figure 55, many seem to be the result of public housing on New York City Housing Authority campuses. These outlier public housing campuses were a byproduct of urban renewal policies and seem to serve as hyper-concentrated areas of Black residents in otherwise non-diverse areas. These are instructive in validating variables to consider in the regression analyses.

Figure 55. Local Moran's I, 2020, with public housing insets

4.1.2. Segregation Analyses

Global spatial segregation indices for each decade, shown in Figure 56, reaffirmed the clustering trends. While the city's population was growing, the measures of segregation increased, suggesting that new-coming Black residents settled amongst other Black residents. In the 1960s and 70s, the dissimilarity index dropped, potentially reflecting the flight of white residents, or tacit integration from urban renewal interventions, but whatever the cause, it began to rise again in the 1980s, and has largely plateaued. Observing the exposure / isolation index further, an unfortunate pattern of Black migration and settlement emerges. In the early 1900s, at the beginning of the Great Migration, many Black residents had exposure to White individuals (Black – White), and few were limited to exclusively Black communities (Black – Black). As the Black population increased over the course of the century, the Black – White and Black – Black values reversed, and isolated White and Black communities predominated.

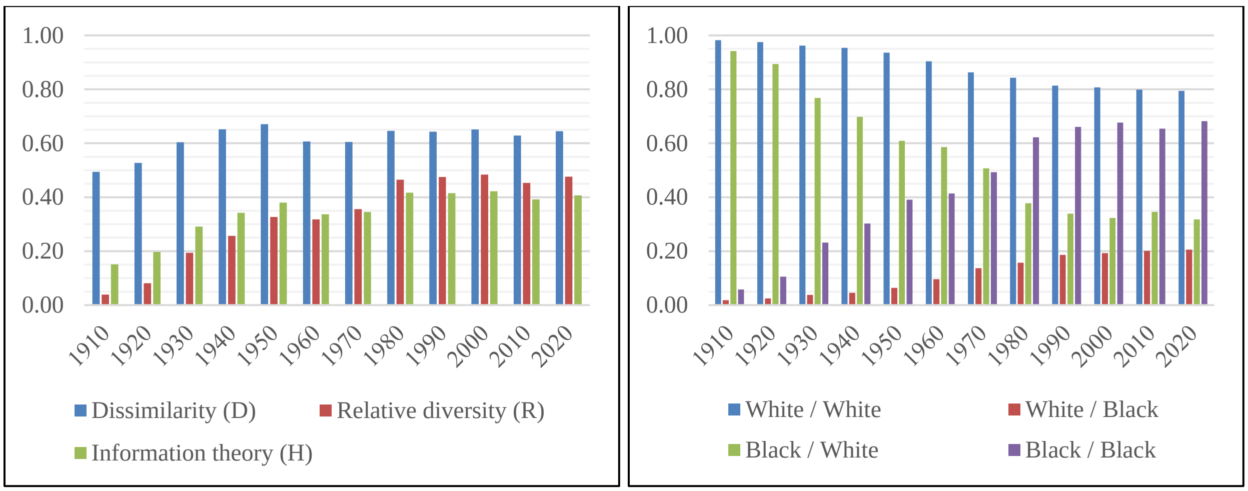
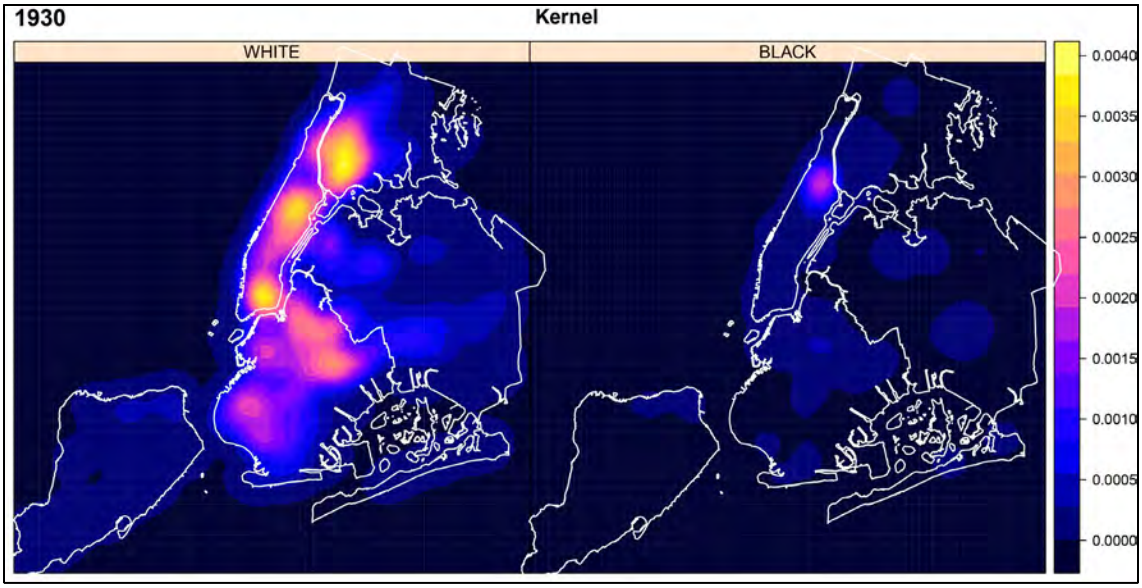


Figure 56. Dissimilarity, diversity, information theory, and exposure / isolation index results

Figure 57 compares the outputs of population density surfaces made through the spatial segregation code in R Studio by applying a kernel density estimator over the population inputs. The outputs compare the years 1930, 1960, 1990 and 2020. Assessing the sequence of images, the emergence and stubborn resilience of two separate and distinct cities – one Black, and one White – is clear. The Black community began in Harlem, split into Bedford-Stuyvesant and the South Bronx, and eventually spread outward from those areas, presumably as the core areas of Harlem and Bedford-Stuyvesant suffered gentrification in the 20th century.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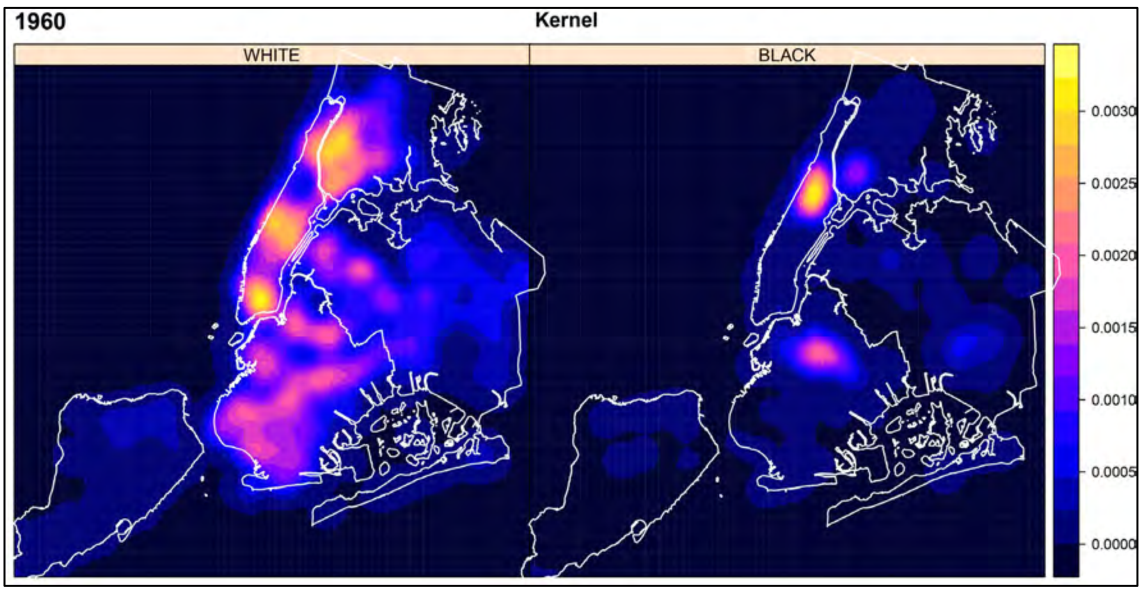
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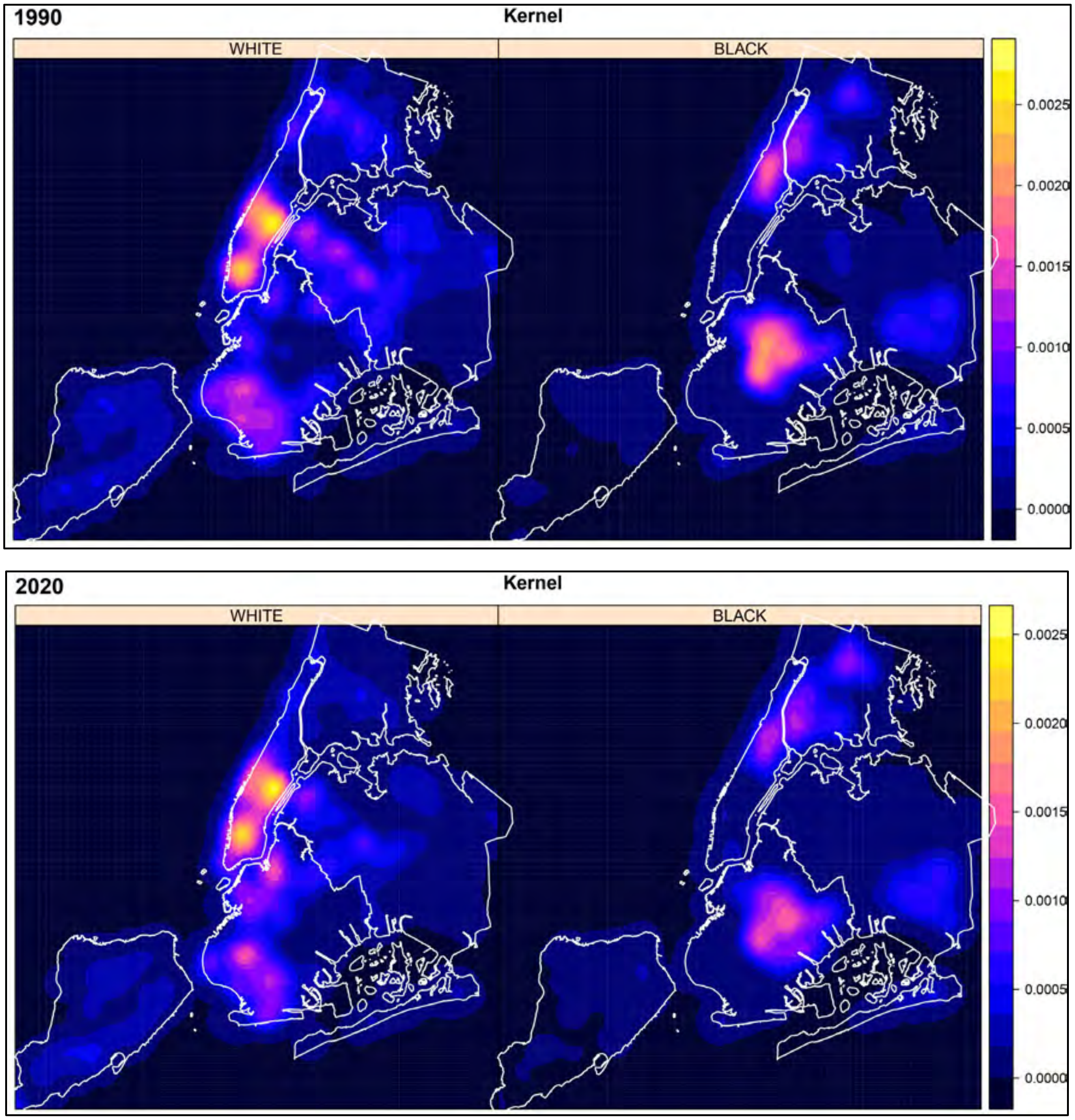


Figure 57. White and Black population density surfaces, comparing 1930, 1960, 1990, and 2020

4.2. Comparative Regression Analysis

In developing the model, first, all variables were evaluated for their skewness and kurtosis. In each case, a logarithmic transformation (or in the case of population change, a cube root transformation since it had negative values) was applied to address the distribution irregularities that can be seen in Figure 58 for a representative run of variables in the White population density model for 1960.

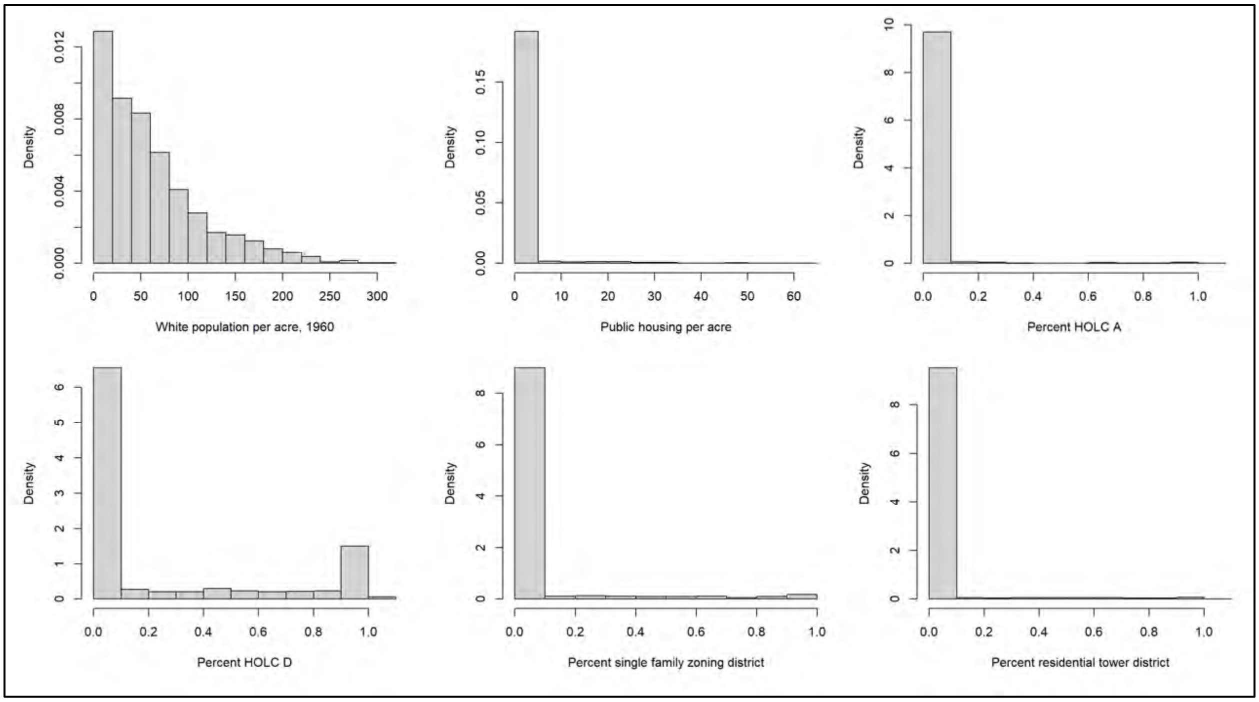


Figure 58. Histograms showing the skewness in select explanatory variables

Each set of response and explanatory variables was next passed through three OLS runs, with step functions eliminating variables that did not contribute to lowering the AIC and were not statistically significant in correlating with the response variable. However, the residuals from each model had issues; all had p-values that were auto-correlated and statistically significant, Q-Q Plots showed heteroscedasticity in the tails of the residuals, and residual scatterplots showed a clustering pattern instead of randomness (as shown in a representative run of White population density in 1960 in Figure 59), so spatial regression models were utilized in each. Of these, nearly universally, the SEM generated residuals that were not statistically significant, and also typically had the lower AIC.

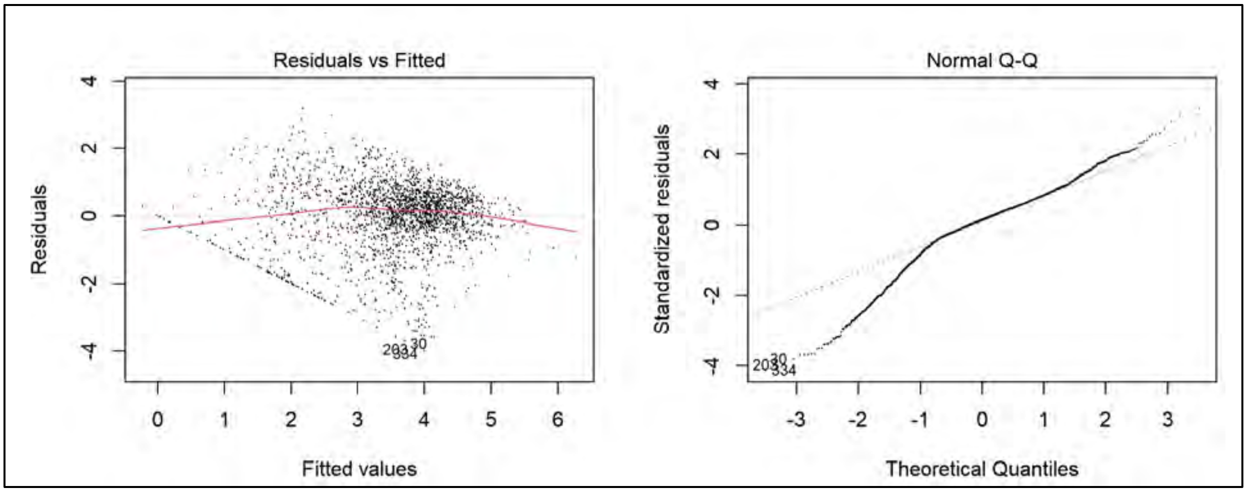


Figure 59. Fitted line and Q-Q plot of a standard OLS 3 run

The results from each OLS and spatial dependence regression run are detailed for the first two response variables: population density and population percentage. The results from the other three response variables: population density change, dissimilarity, and isolation, are set forth in Appendices A through C, and categorized by the response variable.

Additionally, the results in the following subsections detail the major findings for every different population-oriented response variable. Charts compare the resulting coefficients for explanatory variables for a Black population measure with those for a White population measure. These charts include coefficients from the last OLS run, (OLS 3 in the charts), which included only statistically significant variables, as well as those same variables applied to a SLM and SEM.

Following the linear regression models, the results of the GWR analysis are set forth. Here, select explanatory variables were compared in tabular and mapped form, for each 30-year interval, to understand spatial heterogeneity in the variable across the landscape.

4.2.1. Population Density

This section details the regression results for the population density response variable. It first details the results of the three OLS runs and then subsequent SLM and SEM runs to address autocorrelations amongst the residuals. The section then details the coefficient results and interprets their relative correlations.

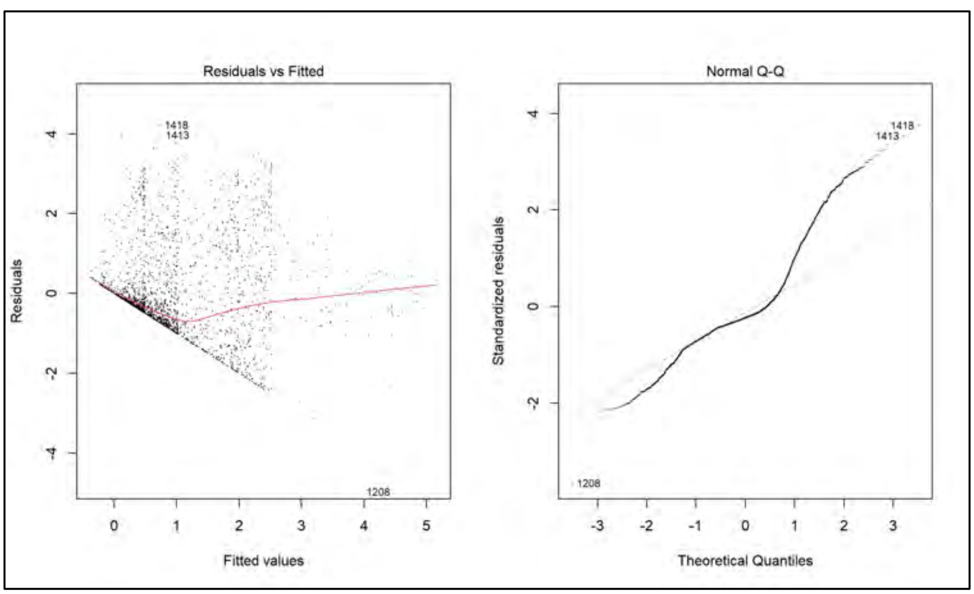
4.2.1.1. Regression runs

Table 3 shows the results of the OLS regression runs for Black and White population density in 1960. The process of winnowing down variables can be seen in the diminishing number of variables between the first and third runs. The first two OLS runs progressively removed all statistically insignificant variables (where a confidence level of less than 90% was achieved through p-values) or those whose removal would lower the models AIC. Coefficients with no asterisk next to them in the table have no statistical significance, those with a dot have 0.1 or 90% confidence level, those with a single asterisk have 0.05 or 95%, those with two have 0.01 or 99%, and those with three have 0.001 or a 99.9% confidence level in their significance. This process of running step functions reduced the initial number of 20 variables down to 7 in the Black population density model and 12 in the White density model. The R-squared value for OLS 3 in the Black population density model was 0.383, meaning the variables explained roughly 38 percent of the pattern of Black population density in the city, while in the White population density model it was 0.465, explaining over 46 percent of the pattern.

	1960 - Black population per acre						1960 - White population per acre					
	OLS run 1		OLS run 2		OLS run 3		OLS run 1		OLS run 2		OLS run 3	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	1.17779	.	0.47387	***	0.47979	***	4.80017	***	4.80869	***	5.46038	***
Distance to core	-0.03690						-0.52654	***	-0.52664	***	-0.51841	***
Percent Subway Proximate	0.79379	***	0.82033	***	0.77529	***	0.78548	***	0.78000	***	0.77331	***
Percent HOLC A areas	-0.76425						3.20260	***	3.25406	***	2.31396	***
Percent HOLC B areas	-0.42781						3.96747	***	4.00862	***	3.02286	***
Percent HOLC C areas	-0.44289						3.46773	***	3.50972	***	2.50226	***
Percent HOLC D areas	1.73510	***	2.18041	***	2.16858	***	2.84398	***	2.87550	***	1.86087	***
Percent Non-HOLC areas	-0.75672		-0.34664	***	-0.39097	***	0.96405	*	1.00680	*		
Percent Urban Renewal Areas	-0.59036						-1.65940	*	-1.64911	*		
Public housing density per acre	0.67941	***	0.68264	***	0.68765	***	0.27211	***	0.27503	***	0.27480	***
Percent highway proximate	-0.55792	**	-0.58258	**	-0.58117	**	0.22172					
Percent single-family zoning	-0.03657						2.17662	***	2.14863	***	2.16244	***
Percent two-family zoning	-0.95467	*	-0.99049	***	-0.97488	***	2.41162	***	2.36708	***	2.36235	***
Percent 'contextual' multi-family zoning	NA						N/A					
Percent 'non-contextual' multi-family zoning	0.02214						2.99250	***	2.96168	***	2.95670	***
Percent high-density 'tower' districts	-0.49192		-0.51003	*			2.78837	***	2.75922	***	2.75712	***
Percent former M-districts	NA						N/A					
Percent pure non-residential districts	-0.56896	*	-0.55113	***	-0.50697	***	1.61823	***	1.61303	***	1.66473	***
Percent Special Purpose District	NA						N/A					
Percent historic district	NA						N/A					
adjusted R-squared	0.38290		0.38390		0.38300		0.46730		0.46710		0.46510	
Rho												
Lambda												
AIC					6849.10						6179.70	
p-value of residuals (LM)					< 2.2e-16						< 2.22e-16	

Table 3. OLS Regression results, Black and White population density, 1960

Evaluating the model's residuals versus a fitted line and on a Q-Q plot, shown in Figure 60, there are indications of heteroscedasticity in each, as revealed by the clustering of points in the former and the tail in the latter.



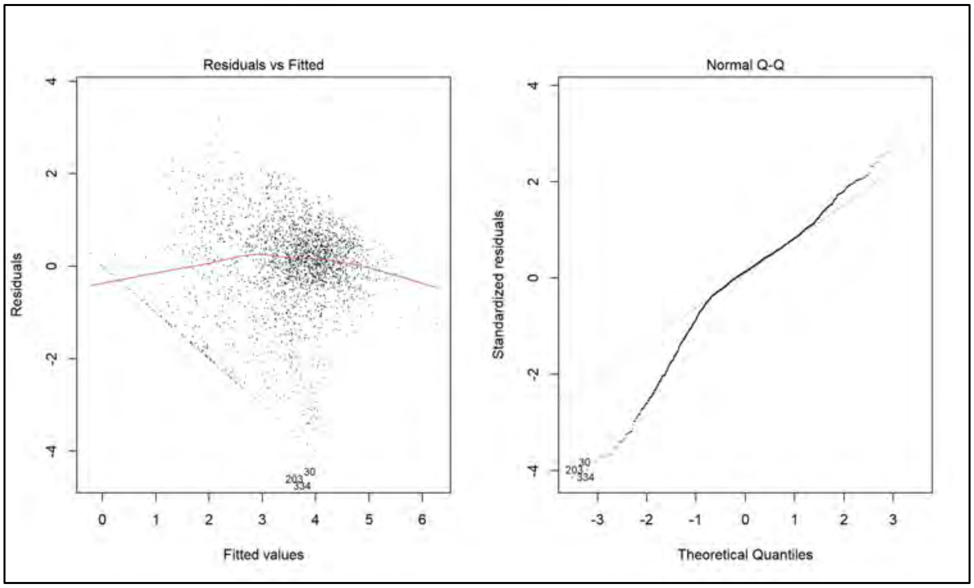


Figure 60. Residual versus Fitted Line and Q-Q Plots for Black (top) and White (bottom) population density

Considering that logarithmic transformations have already been run to all variables, spatial dependence is likely occurring amongst the residuals. To confirm this, a BP test was run as a more formal way to evaluate heteroscedasticity in the residuals, while a Jarque-Bera test was run to evaluate their distribution. In both analyses, and both models, the p-values had a value of less than 0.001. This statistically significant level of correlation, with 99.9 percent confidence, confirms that heteroscedasticity, and a non-random residual distribution, are present in the models. In the Black population density model, VIF values, which evaluate multicollinearity, did not exceed 1.36, while in the White population density model, one variable, the multi-family non-contextual zoning districts, had a value of 7.16, and all other were below 4.5. This suggests some instability in the latter model. These tests suggest spatial dependence models needed to be run.

Table 4 shows the results of SLM and SEM runs for 1960 models of Black and White population density. In the SLM, a new coefficient, Rho, accounts for spatial lag while in the SEM, Lambda accounts for unknown correlation in the error term. In each case here, the new coefficient had a statistically significant influence on the response variable. Overall model fitness is evaluated by seeking the lowest AIC score and the absence of statistically significant clustering amongst the residuals, as evaluated by an LM or Moran's I test for autocorrelation. In each of these the SEM had the lowest AIC and was the only model with random residuals.

	1960 - Black population per acre						**1960 - White population per acre**					
	OLS run 3		Spatial Lag		Spatial Error		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.47979	***	0.12426	***	1.01307	***	5.46038	***	0.88570	.	5.57631	***
Distance to core							-0.51841	***	-0.23873	***	-0.54724	***
Percent Subway Proximate	0.77529	***	0.06807		-0.00179		0.77331	***	0.39136	***	0.47512	***
Percent HOLC A areas							2.31396	***	1.46401	***	2.10821	***
Percent HOLC B areas							3.02286	***	1.94747	***	2.91154	***
Percent HOLC C areas							2.50226	***	1.64816	***	2.58057	***
Percent HOLC D areas	2.16858	***	0.42336	***	0.66850	***	1.86087	***	1.30775	***	2.07853	***
Percent Non-HOLC areas	-0.39097	***	-0.26507	***	-0.36160	***						
Percent Urban Renewal Areas												
Public housing density per acre	0.68765	***	0.53158	***	0.58632	***	0.27480	***	0.24635	***	0.24600	***
Percent highway proximate	-0.58117	**	-0.43547	***	-0.38718	**						
Percent single-family zoning							2.16244	***	2.62028	***	2.39922	***
Percent two-family zoning	-0.97488	***	-0.23343		-0.21715		2.36235	***	2.82639	***	2.46293	***
Percent 'contextual' multi-family zoning												
Percent 'non-contextual' multi-family zoning							2.95670	***	3.28854	***	3.38947	***
Percent high-density 'tower' districts							2.75712	***	3.17543	***	3.29752	***
Percent former M-districts												
Percent pure non-residential districts	-0.50697	***	-0.30994	***	-0.35887	***	1.66473	***	2.03508	***	1.88096	***
Percent Special Purpose District												
Percent historic district												
adjusted R-squared	0.38300						0.46510					
Rho			0.83648	***					0.56526	***		
Lambda					0.90947	***					0.73899	***
AIC	6849.10		4221.30		4134.30		6179.70		5453.50		5122.30	
p-value of residuals (LM)	< 2.2e-16		0.10737		0.99900		< 2.22e-16		< 2.22e-16		0.99600	

Table 4. SLM and SEM Regression results, Black and White population density, 1960

The OLS runs for Black and White population density in 1990 are in Table 5. Here the step functions removed fewer variables than in the 1960 model, as new zoning tools and historic districts began to emerge. However, the adjusted R-squared was slightly lower, at 0.327 and 0.350 for Black and White population density models, respectively, suggesting more variables were explaining less of the population density pattern – a potential symptom of an increasingly complex city.

BP tests confirmed heteroscedasticity in the residuals, while Jarque-Bera tests confirmed a non-random residual distribution, with statistically significant p-values of less than 0.001 in each instance. In the Black population density model, the highest VIF values hovered around 2.3 while in the White population density model, the value of the same variable with a high VIF in the 1960 model, multi-family non-contextual zoning districts, jumped to 8.0 (all others were less than 3.8). These tests again suggested spatial dependence models needed to be run.

	1990 - Black population per acre						**1990 - White population per acre**					
	OLS run 1		OLS run 2		OLS run 3		OLS run 1		OLS run 2		OLS run 3	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-1.38718	.	-1.61366	**	-1.31899	**	6.25276	***	6.62814	***	6.44806	***
Distance to core	0.21163	***	0.22602	***	0.22110	***	-0.66651	***	-0.66822	***	-0.63378	***
Percent Subway Proximate	1.05075	***	1.04453	***	1.04897	***	0.49035	***	0.49255	***	0.42496	***
Percent HOLC A areas	-1.20536	.	-1.27821	**	-1.32505	**	2.09428	***	1.59453	***	1.48902	***
Percent HOLC B areas	0.08566						1.98614	***	1.46927	***	1.43336	***
Percent HOLC C areas	-0.33568		-0.42817	**	-0.40885	**	1.53382	**	1.01179	***	1.00015	***
Percent HOLC D areas	0.60442		0.50863	***	0.52967	***	0.53367					
Percent Non-HOLC areas	-1.19312	*	-1.26701	***	-1.23129	***	0.80810	.	0.19515	.		
Percent Urban Renewal Areas	1.34092	**	1.37254	**	1.44218	**	-0.85539	*	-0.85606	*		
Public housing density per acre	0.55144	***	0.55362	***	0.55277	***	-0.00106					
Percent highway proximate	-0.02798						0.45238	*	0.45792	*		
Percent single-family zoning	0.88467	*	1.04569	***	0.72674	**	2.59823	***	2.63285	***	2.49613	***
Percent two-family zoning	-0.88715	*	-0.71019	*	-1.03812	**	4.03738	***	4.06922	***	3.89170	***
Percent 'contextual' multi-family zoning	-0.20096						6.21624	***	6.25313	***	5.98659	***
Percent 'non-contextual' multi-family zoning	1.53692	***	1.73668	***	1.37973	***	3.96996	***	4.00082	***	3.80412	***
Percent high-density 'tower' districts	1.45798	**	1.67193	***	1.27676	**	2.90272	***	2.90452	***	2.81579	***
Percent former M-districts	-0.79510						3.56969	***	3.59200	***	3.51725	***
Percent pure non-residential districts	0.35123		0.51403	.			1.33798	***	1.37584	***	1.35670	***
Percent Special Purpose District	-1.12283	***	-1.13820	***	-1.12085	***	0.58391	***	0.59258	***	0.64629	***
Percent historic district	0.13917	***	0.13697	***	0.12552	**	-0.05868	.	-0.05802	.		
adjusted R-squared	0.33350		0.32850		0.32770		0.37730		0.37750		0.34980	
Rho												
Lambda												
AIC					7410.50						6454.90	
p-value of residuals (LM)					< 2.2e-16						< 2.2e-16	

Table 5. OLS Regression results, Black and White population density, 1990

Table 6 shows the SLM and SEM runs made from the remaining variables from OLS 3. Again, the new Rho and Lambda coefficients are statistically significant. Like the 1960 results, the SEM has the lowest AIC, and the LM tests confirmed the p-value of the residuals for both White and Black density are not random (in the SLM only the p-value of the residuals in the Black population density model are random), collectively meaning it is the best fit for the data.

	1990 - Black population per acre						**1990 - Black population per acre**					
	OLS run 3		Spatial Lag		Spatial Error		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-1.31899	**	-0.90439	**	4.74090	*	6.44806	***	-0.20183		7.12654	***
Distance to core	0.22110	***	0.05221	.	-0.35724	*	-0.63378	***	-0.18637	***	-0.70846	***
Percent Subway Proximate	1.04897	***	0.27268	***	0.42485	***	0.42496	***	0.22387	***	0.39291	***
Percent HOLC A areas	-1.32505	**	-0.49933	*	-0.59229	.	1.48902	***	0.51621	*	0.74484	**
Percent HOLC B areas							1.43336	***	0.59355	***	1.22577	***
Percent HOLC C areas	-0.40885	**	-0.08103		0.05800		1.00015	***	0.31705	***	0.75884	***
Percent HOLC D areas	0.52967	***	0.04293		0.28549	*						
Percent Non-HOLC areas	-1.23129	***	-0.43503	***	-0.59353	***						
Percent Urban Renewal Areas	1.44218	**	-0.00264		0.05509							
Public housing density per acre	0.55277	***	0.35916	***	0.39584	***						
Percent highway proximate												
Percent single-family zoning	0.72674	**	0.65369	***	0.79032	***	2.49613	***	3.17315	***	3.49620	***
Percent two-family zoning	-1.03812	**	0.43595	*	0.86625	***	3.89170	***	3.85856	***	3.67542	***
Percent 'contextual' multi-family zoning							5.98659	***	4.36680	***	4.54691	***
Percent 'non-contextual' multi-family zoning	1.37973	***	1.16010	***	1.76019	***	3.80412	***	4.16138	***	4.53763	***
Percent high-density 'tower' districts	1.27676	**	1.18282	***	1.32977	***	2.81579	***	3.49074	***	3.61014	***
Percent former M-districts							3.51725	***	3.81506	***	3.81666	***
Percent pure non-residential districts							1.35670	***	2.04660	***	1.61085	***
Percent Special Purpose District	-1.12085	***	-0.15828	.	-0.00271		0.64629	***	0.11363		-0.03103	
Percent historic district	0.12552	**	0.05090	*	0.00561							
adjusted R-squared	0.32770						0.34980					
Rho			0.82416	***					0.74617	***		
Lambda					0.90389	***					0.85398	***
AIC	7410.50		5030.60		4810.30		6454.90		4908.50		4445.70	
p-value of residuals (LM)	< 2.2e-16		0.45859		0.99900		< 2.2e-16		1.16E-13		0.99900	

Table 6. SLM and SEM Regression results, Black and White population density, 1990

The results from the first three OLS runs for the Black and White population density in 2020 are shown in Table 7. The step functions removed fewer variables meaning that more variables had statistically significant influences on the population density for Black and White cohorts; in the Black density model six variables were removed and in the White population density model only three were discarded. The adjusted R-squared values were 0.304 for the OLS 3 in the Black density model, and 0.418 in the White, an uptick in the latter from the 1990 model.

After these OLS runs were conducted, BP tests and Jarque-Bera tests again confirmed heteroscedasticity and non-random distribution in the residuals, respectively, with statistically significant p-values (less than 0.001 in most instances; the Jarque-Bera test for the White density model had a value of 0.012). In the Black population density model, the highest VIF value was a safe 2.7 while in the White population density model, significant multicollinearity was present with the HOLC-related variables, with values between 18 and 33, likely causing model instability. Once again, these tests again suggested spatial dependence models needed to be run.

	2020 - Black population per acre						**2020 - White population per acre**					
	OLS run 1		OLS run 2		OLS run 3		OLS run 1		OLS run 2		OLS run 3	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-2.00104	***	-2.01078	***	-1.79682	***	5.15011	***	5.25991	***	4.77224	***
Distance to core	0.35984	***	0.36196	***	0.30680	***	-0.71430	***	-0.71747	***	-0.68549	***
Percent Subway Proximate	0.42820	***	0.43743	***	0.45700	***	0.26655	**	0.26790	***	0.32000	***
Percent HOLC A areas	-3.24182	***	-3.30148	***	-2.09209	***	4.68570	***	4.78976	***	4.93482	***
Percent HOLC B areas	-1.35695	**	-1.40963	**			4.50664	***	4.62070	***	4.79186	***
Percent HOLC C areas	-1.88627	***	-1.94243	***	-0.71306	***	3.67408	***	3.80341	***	3.96860	***
Percent HOLC D areas	-1.06340	*	-1.10617	*			3.53271	***	3.65718	***	3.80621	***
Percent Non-HOLC areas	-2.30216	***	-2.36140	***	-1.23921	***	3.33818	***	3.46257	***	3.41995	***
Percent Urban Renewal Areas	1.23087	**	1.24985	**	1.39343	**	0.00367					
Public housing density per acre	0.42259	***	0.42104	***	0.43351	***	-0.16716	***	-0.16642	***	-0.15178	***
Percent highway proximate	-0.27110						0.14336					
Percent single-family zoning	0.78644	**	0.79657	**			1.95157	***	1.75107	***	1.83976	***
Percent two-family zoning	1.12020	***	1.14285	***	0.51836	**	2.32985	***	2.12739	***	2.18306	***
Percent 'contextual' multi-family zoning	1.78817	***	1.79488	***	1.15942	***	3.68977	***	3.48343	***	3.51886	***
Percent 'non-contextual' multi-family zoning	2.36135	***	2.36700	***	1.64524	***	2.69438	***	2.48231	***	2.48144	***
Percent high-density 'tower' districts	2.61332	***	2.61952	***	1.94491	***	3.24205	***	3.04351	***	3.19256	***
Percent former M-districts	1.33880	**	1.31560	**			2.04720	***	1.88973	***	1.93760	***
Percent pure non-residential districts	0.80444	**	0.78846	**			0.31529					
Percent Special Purpose District	-0.80331	***	-0.81402	***	-0.80079	***	0.69053	***	0.69850	***	0.66544	***
Percent historic district	0.52744	*	0.55354	*			0.74456	***	0.71482	**	0.74389	***
adjusted R-squared	0.31130		0.31110		0.30420		0.42930		0.42940		0.41860	
Rho												
Lambda												
AIC					7240.70						6803.90	
p-value of residuals (LM)					< 2.2e-16						< 2.2e-16	

Table 7. OLS Regression results, Black and White population density, 2020

Like the 1960 and 1990 models, SLM and SEM runs were made for 2020 Black and White population density, and the results are shown in Table 8. The new Rho and Lambda coefficients are again statistically significant, and the SEM achieved the best model fit; the AIC was lowest in the SEM model, and the LM test indicated random p-values for residuals in both Black and White population density models in the SEM model (the Black SLM model still had correlated residuals).

	2020 - Black population per acre						**2020 - White population per acre**					
	OLS run 3		Spatial Lag		Spatial Error		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-1.79682	***	-1.26607	***	0.64368	.	4.77224	***	-0.38755		-0.13557	
Distance to core	0.30680	***	0.09753	***	0.05740	.	-0.68549	***	-0.14165	***	0.01479	
Percent Subway Proximate	0.45700	***	0.05566		0.23955	**	0.32000	***	0.05536	.	0.03682	
Percent HOLC A areas	-2.09209	***	-0.62174	***	-0.54070	*	4.93482	***	1.72806	***	1.67337	***
Percent HOLC B areas							4.79186	***	1.85647	***	2.04863	***
Percent HOLC C areas	-0.71306	***	-0.11465	*	-0.15419	.	3.96860	***	1.52602	***	1.53152	***
Percent HOLC D areas							3.80621	***	1.58929	***	1.50080	***
Percent Non-HOLC areas	-1.23921	***	-0.29289	***	-0.73918	***	3.41995	***	1.33657	***	0.62168	*
Percent Urban Renewal Areas	1.39343	**	0.32523	.	0.40399	*						
Public housing density per acre	0.43351	***	0.25547	***	0.26898	***	-0.15178	***	-0.11415	***	-0.15464	***
Percent highway proximate												
Percent single-family zoning							1.83976	***	1.52401	***	2.00515	***
Percent two-family zoning	0.51836	**	0.85565	***	1.11911	***	2.18306	***	1.85323	***	2.32256	***
Percent 'contextual' multi-family zoning	1.15942	***	0.98739	***	1.51757	***	3.51886	***	2.16495	***	2.80181	***
Percent 'non-contextual' multi-family zoning	1.64524	***	1.13643	***	1.69888	***	2.48144	***	1.86522	***	2.16841	***
Percent high-density 'tower' districts	1.94491	***	1.17865	***	1.79980	***	3.19256	***	2.02632	***	2.73624	***
Percent former M-districts							1.93760	***	2.08134	***	2.06971	***
Percent pure non-residential districts												
Percent Special Purpose District	-0.80079	***	-0.07826		-0.03486		0.66544	***	0.15026	.	-0.00736	
Percent historic district							0.74389	***	0.26060	.	0.3638	*
adjusted R-squared	0.30420						0.41860					
Rho			0.82800	***					0.79385	***		
Lambda					0.89824	***					0.90607	***
AIC	7240.70		4640.80		4443.80		6803.90		4875.90		4487.40	
p-value of residuals (LM)	< 2.2e-16		0.00287		0.99900		< 2.2e-16		0.0922		0.9990	

Table 8. SLM and SEM Regression results, Black and White population density, 2020

4.2.1.2. Coefficient results

After the models were run, and reasonable fitness achieved, the coefficients could then be interpreted.

The 1960 population density regression run shows several interesting correlations in the chart comparing explanatory variable coefficients in Figure 61. While White density is associated with all HOLC areas, even D areas, Black density is only correlated with HOLC D areas (though less so than the White population). The Black population is also negatively correlated with the areas of the city beyond the 1930s era HOLC mappings, which is likely to be emerging suburban areas that were farmland in the 1930s. Both Black and White populations correlate with public housing, supporting the notion it originally housed working-class Whites. White populations correlated positively with almost every available district type (contextual zoning, special purpose districts, and tools for transitioning manufacturing districts were only being developed after 1961), while Black populations negatively correlated with single-family zoning. Historic districts had also not yet been established in 1961.

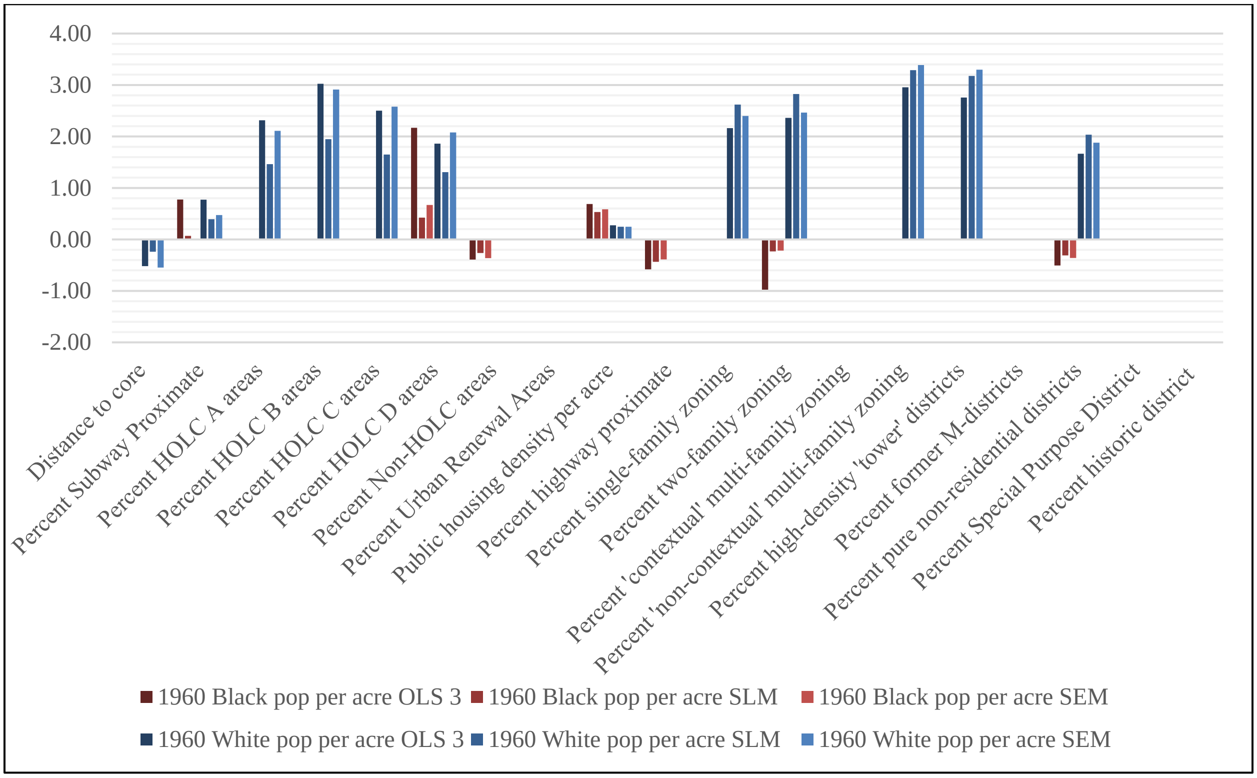


Figure 61. Regression coefficients explaining Black versus White population density, 1960

Figure 62 shows the resulting coefficients for population density measures in 1990. The Black population is correlating negatively with HOLC A areas and continuing its prior HOLC trends of a positive association with D areas and negative association with the areas beyond the original HOLC boundaries. White population is no longer correlating with D areas. Urban renewal areas are exerting an influence now on the Black population, and public housing has shifted to only influence the Black population segment. New zoning tools, like contextual zoning districts and tools for transitioning manufacturing districts are strongly correlating with White population density, while other new tools, like special purpose districts, are negatively correlating with Black density.

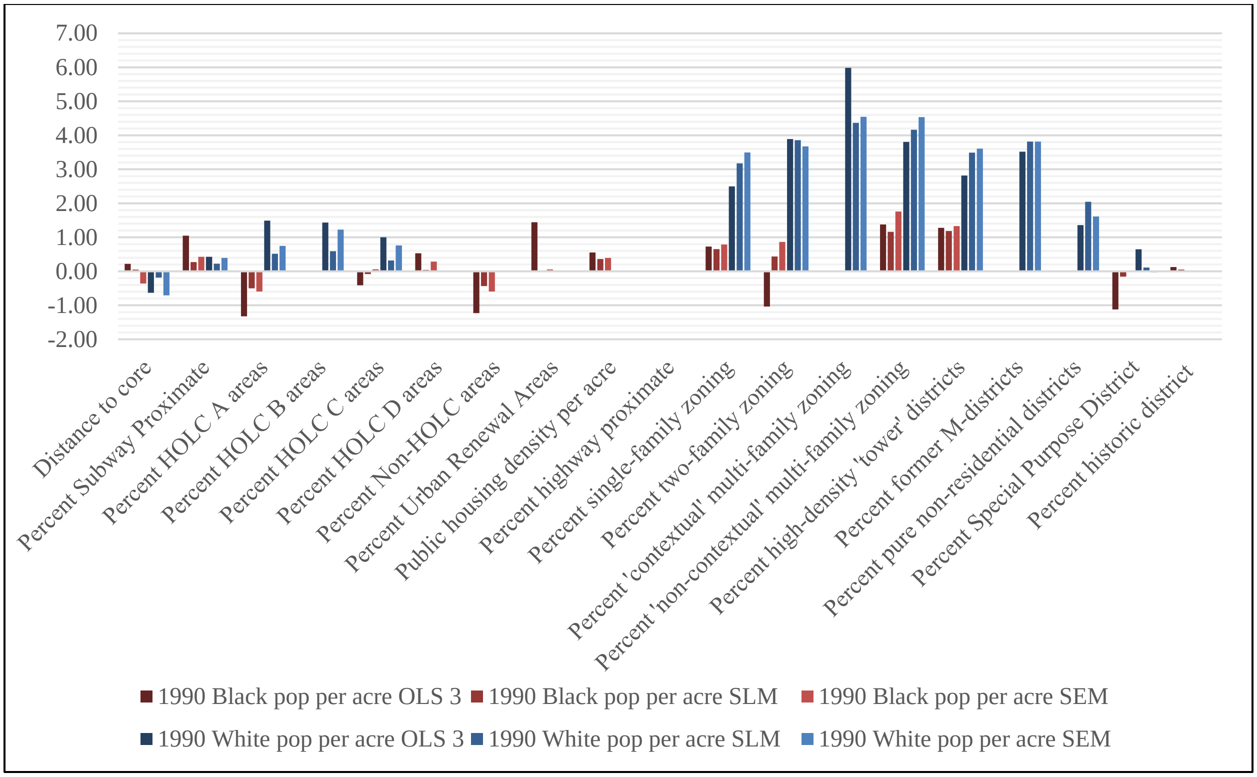


Figure 62. Regression coefficients explaining Black versus White population density, 1990

Figure 63 shows the 2020 regression coefficients for variables explaining Black and White population density. In 2020, the divergence in Black and White correlation between HOLC A areas and their respective population densities was strongest. Black populations no longer correlated with D areas, while White areas did – perhaps signifying some gentrification emerging. White populations are now negatively correlating with public housing. In terms of relationships with zoning district typologies, the Black population is now correlating with some of the newer zoning tools, but not at the same degree as White neighborhoods. Black population density still is not correlating single-family districts. Lastly, Whites are unique in correlating their density with historic district locations.

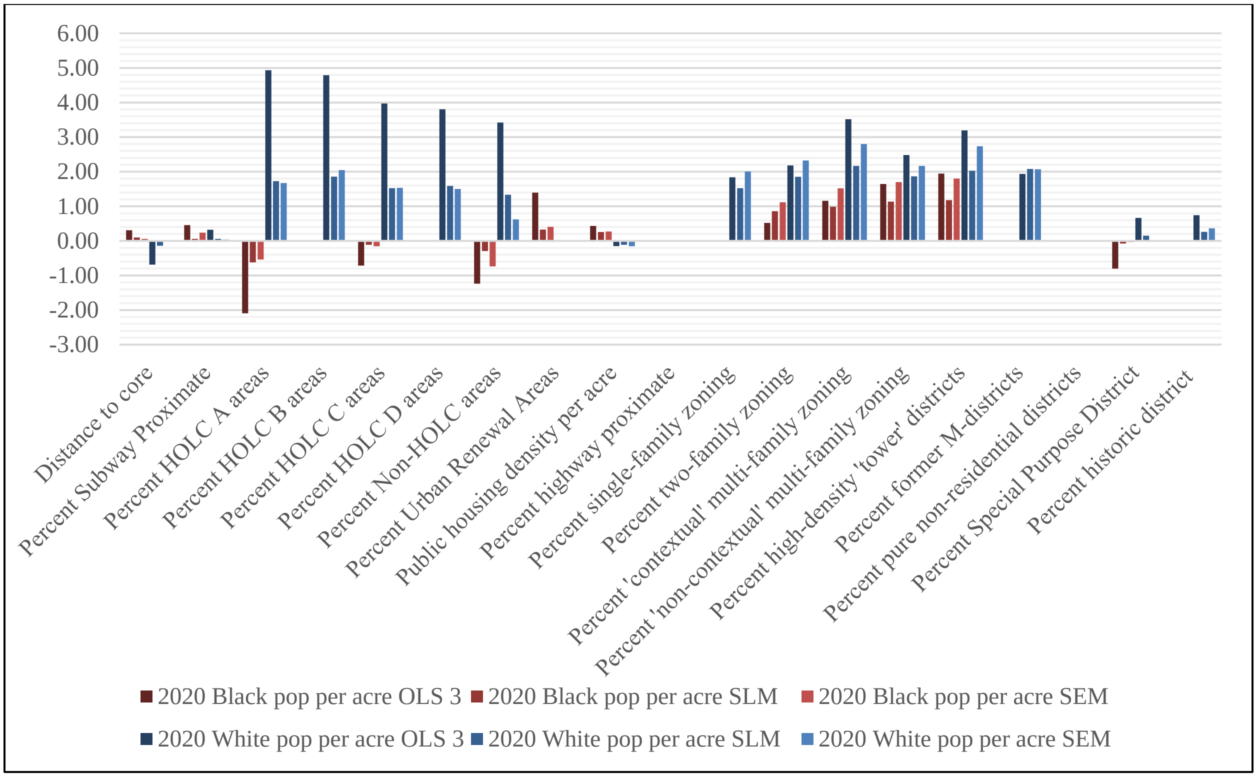


Figure 63. Regression coefficients explaining Black versus White population density, 2020

4.2.2. Population Percentage

This section details the results of the OLS, SLM and SEM regression runs for the population percentage response variable, and then delves into detailing the coefficient results for individual explanatory variables.

4.2.2.1. Regression runs

The results of the OLS runs for Black and White population percentage in 1960 are in Table 9. Like the 1960 model for population density, the step functions removed several statistically insignificant variables in OLS run 1 and 2, several more in the Black percentage model than the White. Despite evaluating the influence of the same explanatory variables, the resulting adjusted R-squared values in these models were much lower than that for population density in 1960, with values of only 0.204 and 0.185 for Black and White population percentage models, respectively.

BP tests confirmed heteroscedasticity in the residuals, while Jarque-Bera tests confirmed non-random residual distribution. Statistically significant p-values of less than 0.001were present in each instance. In the Black percentage model, the highest VIF value was safely around 1.7 while in the White population density model, many VIF values associated with HOLC areas were problematically in the 23 to 38 range, indicating high multi-collinearity; non-contextual zoning districts were also at around 7. These tests suggested spatial dependence models needed to be run.

	1960 - Black percentage of population (census tract)						**1960 - White percentage of population (census tract)**					
	OLS run 1		OLS run 2		OLS run 3		OLS run 1		OLS run 2		OLS run 3	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.00365		-0.03000		-0.01869		0.21452	*	0.21665	*	0.17856	.
Distance to core	0.02130	**	0.02304	***	0.02264	***	-0.02654	***	-0.02674	***	-0.02337	**
Percent Subway Proximate	0.02601	*	0.02447	.			-0.02375	.	-0.02368	.		
Percent HOLC A areas	-0.24289	**	-0.25977	***	-0.28995	***	0.56013	***	0.55998	***	0.57140	***
Percent HOLC B areas	-0.24289	***	-0.26858	***	-0.27337	***	0.58934	***	0.58938	***	0.59580	***
Percent HOLC C areas	-0.19666	**	-0.22046	***	-0.22416	***	0.54967	***	0.54978	***	0.55702	***
Percent HOLC D areas	0.02586						0.34668	***	0.34701	***	0.35152	***
Percent Non-HOLC areas	-0.20784	**	-0.23024	***	-0.23890	***	0.41441	***	0.41457	***	0.42886	***
Percent Urban Renewal Areas	-0.03426						0.03704					
Public housing density per acre	0.04965	***	0.05000	***	0.05055	***	-0.02513	***	-0.02511	***	-0.02441	***
Percent highway proximate	-0.08940	**	-0.08954	**	-0.08649	**	0.06051	.	0.06060	.		
Percent single-family zoning	-0.02225						0.43889	***	0.43892	***	0.43862	***
Percent two-family zoning	-0.11788	*	-0.08470	*			0.50946	***	0.50937	***	0.49716	***
Percent 'contextual' multi-family zoning	NA						NA					
Percent 'non-contextual' multi-family zoning	-0.03620						0.45674	***	0.45663	***	0.44831	***
Percent high-density 'tower' districts	-0.10084	*	-0.06456	.			0.52597	***	0.52588	***	0.50977	***
Percent former M-districts	NA						NA					
Percent pure non-residential districts	-0.04624	*					0.43439	***	0.43399	***	0.42973	***
Percent Special Purpose District	NA						NA					
Percent historic district	NA						NA					
adjusted R-squared	0.20550		0.20660		0.20390		0.18680		0.18710		0.18540	
Rho												
Lambda												
AIC					-1981.20						-1545.40	
p-value of residuals (LM)					< 2.2e-16						< 2.2e-16	

Table 9. OLS Regression results, Black and White population percentage, 1960

The results for the SLM and SEM runs for 1960 Black and White population percentage are shown in Table 10. The new Rho and Lambda coefficients are statistically significant, and larger than any other coefficient. The SEM was the best model fit as, while the residuals for both SLM and SEM were random, the AIC was the lowest in the SEM.

	1960 - Black percentage of population (census tract)						1960 - White percentage of population (census tract)					
	OLS run 3		Spatial Lag		Spatial Error		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.01869		-0.03303		0.18816		0.17856	.	-0.23123	**	0.30983	.
Distance to core	0.02264	***	0.00538	*	-0.00438		-0.02337	**	-0.00645		-0.02206	
Percent Subway Proximate												
Percent HOLC A areas	-0.28995	***	-0.03107		-0.05301	.	0.57140	***	0.33131	***	0.36162	***
Percent HOLC B areas	-0.27337	***	-0.04463	***	-0.09165	***	0.59580	***	0.35056	***	0.43743	***
Percent HOLC C areas	-0.22416	***	-0.02907	***	-0.04755	***	0.55702	***	0.32032	***	0.39254	***
Percent HOLC D areas							0.35152	***	0.23981	***	0.26309	***
Percent Non-HOLC areas	-0.23890	***	-0.02796	***	-0.03996	***	0.42886	***	0.24085	***	0.20145	***
Percent Urban Renewal Areas												
Public housing density per acre	0.05055	***	0.04111	***	0.04822	***	-0.02441	***	-0.01947	***	-0.02264	***
Percent highway proximate	-0.08649	**	-0.02300	.	0.01877							
Percent single-family zoning							0.43862	***	0.37491	***	0.38280	***
Percent two-family zoning							0.49716	***	0.39477	***	0.32304	***
Percent 'contextual' multi-family zoning												
Percent 'non-contextual' multi-family zoning							0.44831	***	0.41312	***	0.41075	***
Percent high-density 'tower' districts							0.50977	***	0.44704	***	0.53506	***
Percent former M-districts												
Percent pure non-residential districts							0.42973	***	0.37623	***	0.36993	***
Percent Special Purpose District												
Percent historic district												
adjusted R-squared	0.20390						0.18540					
Rho			0.89799	***					0.68071	***		
Lambda					0.92927	***					0.76183	***
AIC	-1981.20		-5072.30		-5170.50		-1545.40		-2668.20		-2800.50	
p-value of residuals (LM)	< 2.2e-16		0.16984		0.99900		< 2.2e-16		0.7156		0.99900	

Table 10. SLM and SEM Regression results, Black and White population percentage, 1960

Moving to 1990, the OLS runs for Black and White population density are shown in Table 11. Step functions removed seven insignificant variables from the Black population density model and only three from the White. The adjusted R-squared remained comparatively lower than the population density, at 0.193 and 0.250 for Black and White population percentage models, respectively.

Both the BP and Jarque-Bera tests confirmed heteroscedasticity and non-randomness in the residuals, respectively, with statistically significant p-values of less than 0.001. The highest VIF value in the Black percentage model was a safe 1.8 and was a comfortable 2.5 in the White percentage model. The autocorrelation amongst the residuals suggested that SLM and SEM models needed to be run to address spatial dependence.

	1990 - Black percentage of population (census tract)						**1990 - White percentage of population (census tract)**					
	OLS run 1		OLS run 2		OLS run 3		OLS run 1		OLS run 2		OLS run 3	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.59461	***	-0.53565	**	-0.63921	***	0.92199	***	0.94851	***	1.11546	***
Distance to core	0.09041	***	0.08549	***	0.09203	***	-0.07812	***	-0.07771	***	-0.08653	***
Percent Subway Proximate	0.02171						-0.10898	***	-0.11008	***	-0.10595	***
Percent HOLC A areas	-0.28410	*	-0.30532	***	-0.29690	***	0.37558	***	0.33653	***	0.36204	***
Percent HOLC B areas	-0.15521	.	-0.16978	***	-0.16775	***	0.25252	**	0.21253	***	0.21048	***
Percent HOLC C areas	-0.16538	.	-0.17904	***	-0.18168	***	0.21222	**	0.17274	***	0.17499	***
Percent HOLC D areas	0.01204						0.04124					
Percent Non-HOLC areas	-0.21987	*	-0.23306	***	-0.22935	***	0.29576	**	0.25913	***	0.25578	***
Percent Urban Renewal Areas	0.21694	**	0.22573	**	0.24766	***	-0.21180	**	-0.21411	**	-0.21011	**
Public housing density per acre	0.05509	***	0.05504	***	0.05469	***	-0.05579	***	-0.05552	***	-0.05589	***
Percent highway proximate	-0.11289	**	-0.11151	**			0.02875					
Percent single-family zoning	-0.03174		-0.11151	**			0.22025	***	0.22037	***	0.13119	***
Percent two-family zoning	-0.36363	***	-0.35490	***	-0.31233	***	0.58530	***	0.58360	***	0.48682	***
Percent 'contextual' multi-family zoning	-0.50467	***	-0.48802	***	-0.44685	***	0.54930	***	0.54651	***	0.47532	***
Percent 'non-contextual' multi-family zoning	-0.05784		-0.04489				0.26706	***	0.26669	***	0.15807	***
Percent high-density 'tower' districts	0.10184		0.11298	.	0.16556	**	0.22571	**	0.22295	**		
Percent former M-districts	-0.27533	*	-0.26294	**			0.43594	***	0.43428	***	0.31746	***
Percent pure non-residential districts	0.00771						0.08724		0.09204	.		
Percent Special Purpose District	-0.18659	***	-0.18565	***	-0.19384	***	0.21202	***	0.21361	***	0.23362	***
Percent historic district	0.02684	***	0.02707	***	0.02696	***	-0.00165					
adjusted R-squared	0.19620		0.19670		0.19250		0.25200		0.25270		0.25030	
Rho												
Lambda												
AIC					-455.95						-655.54	
p-value of residuals (LM)					< 2.2e-16						< 2.2e-16	

Table 11. OLS Regression results, Black and White population percentage, 1990

Results for the 1990 Black and White population percentage SLM and SEM runs are in Table 12. Like 1960 models, the new Rho and Lambda coefficients are statistically significant, and by far the largest coefficients, suggesting large spillovers and other unexplained phenomena. The SLM model continued to have correlated residuals, as determined through an LM test, while the SEM were not statistically significant and random. The SEM had the lowest AIC and so was the best model fit again.

	1990 - Black percentage of population (census tract)						1990 - White percentage of population (census tract)					
	OLS run 3		Spatial Lag		Spatial Error		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.63921	***	-0.10431	**	0.16810		1.11546	***	0.20923	***	0.69884	*
Distance to core	0.09203	***	0.01199	**	0.00581		-0.08653	***	-0.02053	***	-0.03796	
Percent Subway Proximate							-0.10595	***	-0.01731	*	-0.01895	
Percent HOLC A areas	-0.29690	***	-0.04094		-0.09567	*	0.36204	***	0.09195	**	0.12484	*
Percent HOLC B areas	-0.16775	***	-0.01883	.	-0.06869	***	0.21048	***	0.04067	***	0.10776	***
Percent HOLC C areas	-0.18168	***	-0.00835		-0.01653		0.17499	***	0.01630	.	0.03268	*
Percent HOLC D areas												
Percent Non-HOLC areas	-0.22935	***	-0.01519		-0.01157		0.25578	***	0.03135	**	0.00483	
Percent Urban Renewal Areas	0.24766	***	-0.00668		0.00552		-0.21011	**	0.02110		0.01453	
Public housing density per acre	0.05469	***	0.03261	***	0.03908	***	-0.05589	***	-0.02664	***	-0.02945	***
Percent highway proximate												
Percent single-family zoning							0.13119	***	0.07869	***	0.14582	***
Percent two-family zoning	-0.31233	***	-0.03572	.	-0.00449		0.48682	***	0.11622	***	0.12165	***
Percent 'contextual' multi-family zoning	-0.44685	***	-0.07084	**	-0.12389	*	0.47532	***	0.10329	***	0.10284	*
Percent 'non-contextual' multi-family zoning							0.15807	***	0.07413	***	0.10827	***
Percent high-density 'tower' districts	0.16556	**	0.02359		0.02304							
Percent former M-districts							0.31746	***	0.07452	.	0.09580	.
Percent pure non-residential districts												
Percent Special Purpose District	-0.19384	***	-0.01501		-0.00773		0.23362	***	0.03221	**	0.04760	*
Percent historic district	0.02696	***	0.00138		-0.00316							
adjusted R-squared	0.19250						0.25030					
Rho			0.90815	***					0.88803	***		
Lambda					0.93163	***					0.92480	***
AIC	-455.95		-3870.00		-3923.70		-655.54		-3724.60		-3811.00	
p-value of residuals (LM)	< 2.2e-16		< 2.2e-16		0.99900		< 2.2e-16		< 2.2e-16		0.99900	

Table 12. SLM and SEM Regression results, Black and White population percentage, 1990

Finally, the OLS runs for Black and White population percentage in 2020 are in Table 13. Step functions removed a similar number of variables as the 1990 model (six from the Black percentage and four from the White). The adjusted R-squared was slightly lower in the Black percentage model, at 0.167 and higher for the White percentage model, at 0.304, when compared to 1990.

Like other models, the BP tests confirmed heteroscedasticity in the residuals, while Jarque-Bera tests confirmed the residuals were not random distributed. Each had statistically significant p-values of less than 0.001. In both Black and White percentage models, unstable VIF values emerged with some the HOLC area variables, ranging between 18 and 34 in each. Other variables did not exceed a VIF of 4 in either model. These tests again suggested spatial dependence models, in the form of SLM and SEM, needed to be run.

	2020 - Black percentage of population (census tract)						**2020 - White percentage of population (census tract)**					
	OLS run 1		OLS run 2		OLS run 3		OLS run 1		OLS run 2		OLS run 3	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.41317	***	-0.41742	***	-0.37649	***	0.60549	***	0.61597	***	0.62439	***
Distance to core	0.07605	***	0.07646	***	0.07202	***	-0.08882	***	-0.08933	***	-0.09028	***
Percent Subway Proximate	-0.04414	**	-0.04621	***	-0.03970	**	-0.05890	***	-0.05830	***	-0.06030	***
Percent HOLC A areas	-0.45547	***	-0.44759	***	-0.42229	***	0.91064	***	0.91317	***	0.87727	***
Percent HOLC B areas	-0.31118	***	-0.30500	***	-0.29142	***	0.72982	***	0.73304	***	0.69597	***
Percent HOLC C areas	-0.34756	***	-0.34191	***	-0.33276	***	0.61230	***	0.61635	***	0.57614	***
Percent HOLC D areas	-0.22647	***	-0.22158	***	-0.20607	***	0.62405	***	0.62762	***	0.59068	***
Percent Non-HOLC areas	-0.32455	***	-0.31725	***	-0.30347	***	0.68068	***	0.68306	***	0.65164	***
Percent Urban Renewal Areas	0.13355	*	0.13367	*			-0.02440					
Public housing density per acre	0.03432	***	0.03433	***	0.03494	***	-0.04061	***	-0.04092	***	-0.04186	***
Percent highway proximate	-0.13459	***	-0.13356	***	-0.14196	***	-0.05355	.	-0.05223	.		
Percent single-family zoning	0.02605						0.19388	***	0.18420	***	0.21651	***
Percent two-family zoning	0.00312						0.17340	***	0.16358	***	0.19816	***
Percent 'contextual' multi-family zoning	-0.00186						0.20899	***	0.19765	***	0.23144	***
Percent 'non-contextual' multi-family zoning	0.08401	*	0.07850	***	0.07875	***	0.08601	*	0.07391	*	0.10961	***
Percent high-density 'tower' districts	0.12863	*	0.12155	**	0.12076	**	0.12084	*	0.10601	*	0.13311	**
Percent former M-districts	0.04461						0.05199					
Percent pure non-residential districts	0.08867	*	0.08312	**	0.08280	**	-0.06515		-0.07333	.		
Percent Special Purpose District	-0.14860	***	-0.14670	***	-0.14876	***	0.23426	***	0.23707	***	0.23785	***
Percent historic district	0.08351	*	0.08396	*			0.15871	***	0.16035	***	0.16935	***
adjusted R-squared	0.16910		0.17010		0.16720		0.30420		0.30450		0.30430	
Rho												
Lambda												
AIC					-1472.40						-1600.40	
p-value of residuals (LM)					< 2.2e-16						< 2.2e-16	

Table 13. OLS Regression results, Black and White population percentage, 2020

Table 14 shows the results for SLM, and SEM runs for 2020 Black and White population percentages. As with the prior two models, the new Rho and Lambda coefficients are statistically significant, and the largest coefficients in each model. The SEM was again the best model fit; it had AIC and, unlike the SLM, the p-values for residuals were not statistically significant.

	2020 - Black percentage of population (census tract)						2020 - White percentage of population (census tract)					
	OLS run 3		Spatial Lag		Spatial Error		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.37649	***	-0.08496	**	0.01426		0.62439	***	-0.09408	*	-0.22017	***
Distance to core	0.07202	***	0.00957	***	0.01187	**	-0.09028	***	-0.00899	**	0.02091	***
Percent Subway Proximate	-0.03970	**	-0.01299	*	-0.01233		-0.06030	***	-0.01068		-0.02149	.
Percent HOLC A areas	-0.42229	***	-0.05064		-0.07847	.	0.87727	***	0.31737	***	0.34925	***
Percent HOLC B areas	-0.29142	***	-0.02818		-0.06383	.	0.69597	***	0.25270	***	0.26164	***
Percent HOLC C areas	-0.33276	***	-0.01699		-0.02043		0.57614	***	0.21724	***	0.20501	***
Percent HOLC D areas	-0.20607	***	-0.00895		-0.00045		0.59068	***	0.24317	***	0.21954	***
Percent Non-HOLC areas	-0.30347	***	-0.01128		-0.00852		0.65164	***	0.22560	***	0.17473	**
Percent Urban Renewal Areas												
Public housing density per acre	0.03494	***	0.01869	***	0.02174	***	-0.04186	***	-0.02859	***	-0.03406	***
Percent highway proximate	-0.14196	***	-0.00539		0.03691	*						
Percent single-family zoning							0.21651	***	0.12680	***	0.23449	***
Percent two-family zoning							0.19816	***	0.08935	***	0.13746	***
Percent 'contextual' multi-family zoning							0.23144	***	0.09993	***	0.15123	***
Percent 'non-contextual' multi-family zoning	0.07875	***	0.02377	***	0.04943	***	0.10961	***	0.07036	***	0.08678	***
Percent high-density 'tower' districts	0.12076	**	0.03001	.	0.03152		0.13311	**	0.06429	**	0.10734	**
Percent former M-districts												
Percent pure non-residential districts	0.08280	**	0.02354	*	0.04063	**						
Percent Special Purpose District	-0.14876	***	-0.01468	.	-0.01934		0.23785	***	0.05270	***	0.08636	***
Percent historic district							0.16935	***	0.07038	***	0.0874	***
adjusted R-squared	0.16720						0.30430					
Rho			0.92025	***					0.86649	***		
Lambda					0.93846	***					0.90226	***
AIC	-1472.40		-5364.30		-5391.40		-1600.40		-4229.10		-4421.00	
p-value of residuals (LM)	< 2.2e-16		< 2.22e-16		0.99900		< 2.2e-16		0.0012		0.9990	

Table 14. SLM and SEM Regression results, Black and White population percentage, 2020

4.2.2.2. Coefficient results

After reasonable fitness was achieved, the coefficients for explanatory variables could then be interpreted.

Switching the response variable to the percentage of Black and White population, respectively, there were a few notable modifications in each era. In 1960, shown in Figure 64, the positive and negative correlations in nearly all of the HOLC areas between Black and White are pronounced. Black populations percentages do not negatively correlate with D areas, but they do not positively correlate with them either. White population groups continued to positively correlate with each zoning district type – even areas within, or adjoining manufacturing districts. There was likely not enough Black population in 1960 to have statistically significant correlations with zoning districts yet.

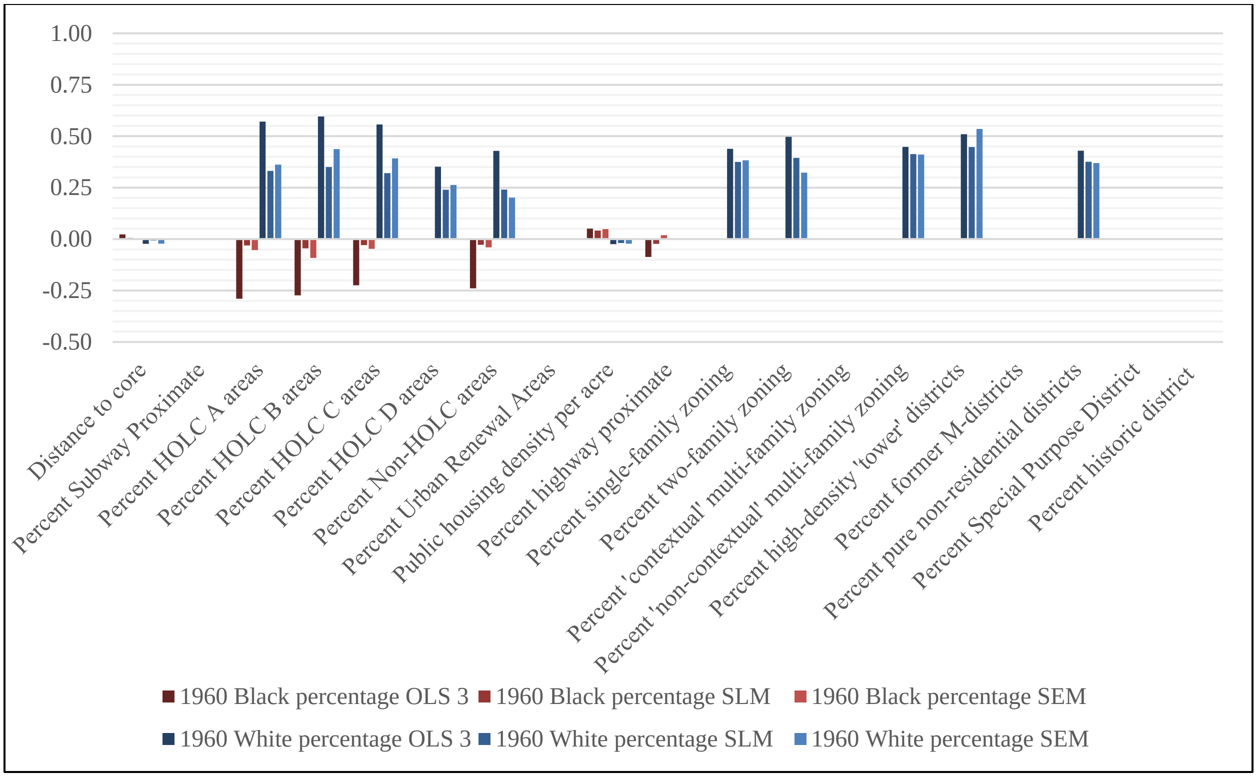


Figure 64. Regression coefficients explaining Black versus White population percentage, 1960

In 1990, as shown in Figure 65, the Black population is positively correlating with distance to the core, while White population percentage are negatively associated with it. HOLC schisms remain strong, but neither group correlates with D areas. The percentage of an area subjected to urban renewal is exerting strong influence over the percentage of a census tract that is Black and diminishing the percentage that is White. The same is true for the density of public housing, but to a lesser extent. Zoning tools also show a schism – the mapping of two-family zoning districts, contextual zoning districts and special purpose districts negatively influence Black populations while they simultaneously positively influence White population percentages.

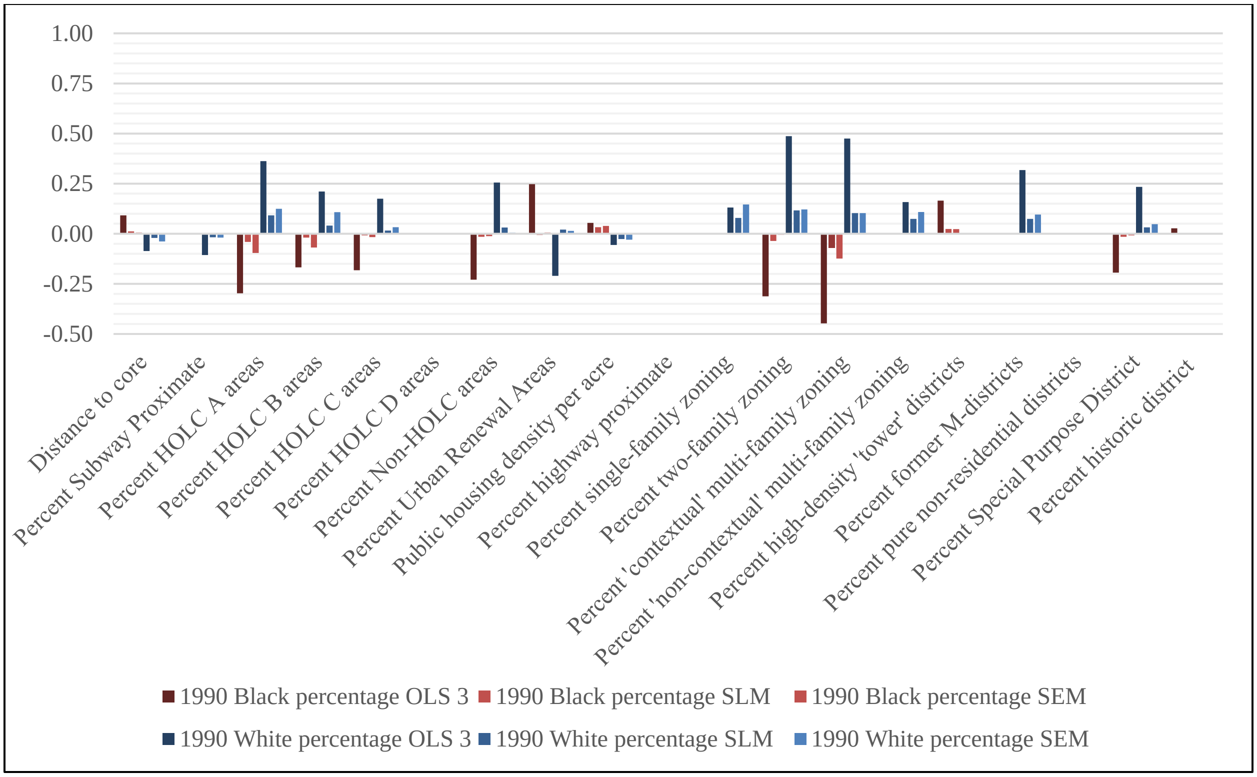


Figure 65. Regression coefficients explaining Black versus White population percentage, 1990

In 2020, shown in the chart in Figure 66, similar trends continue, however, the Black populations is negatively correlating with all HOLC areas, even D, contextual districts are now pervasive enough that they are now positively correlating with Black percentages of population, and the percentage of historic districts in a given area is now influencing the White population percentage.

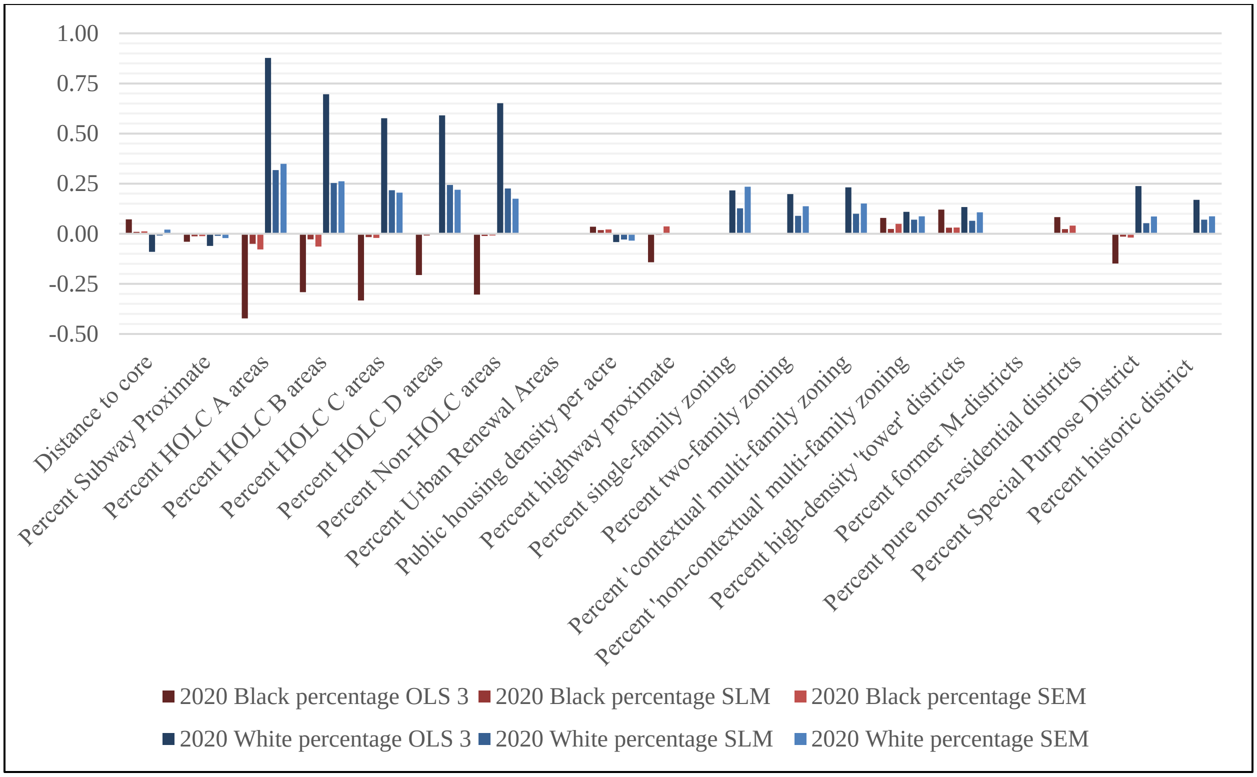


Figure 66. Regression coefficients explaining Black versus White population percentage, 2020

4.2.3. Population Density Change

The results of the regression runs for the population density change response variable are detailed in Appendix A. The explanatory coefficient results are discussed below.

In the chart in Figure 67, denoting population density change between 1930 and 1960, subway proximity has bifurcated correlations, positively with Black population change and negatively with White, perhaps suggesting suburbanization with the latter. In terms of HOLC areas, Black population change is only correlated with D areas, while White population change is associated with A, B and C, as well as the areas beyond. What is most striking in the chart is the very strong negative correlation between the percentage urban renewal areas and the change in Black population density. The percentage of a tract adjacent to a highway also manifests itself differently for Black and White population change – positively for White and negatively for Black. This potentially speaks more to suburbanization than deliberate harmful practices in highway siting. In terms of zoning correlations, the Black and White relationship to two-family districts is split, negatively and positively, respectively. All available zoning district typologies that permitted residential units, in fact, positively correlated with White population change. There was no positive correlation with a zoning district and Black population change; besides two-family zoning, there was also a negative correlation between the Black population change and manufacturing areas (which could be positive, unless being displaced for the razing of land for new industrial uses).

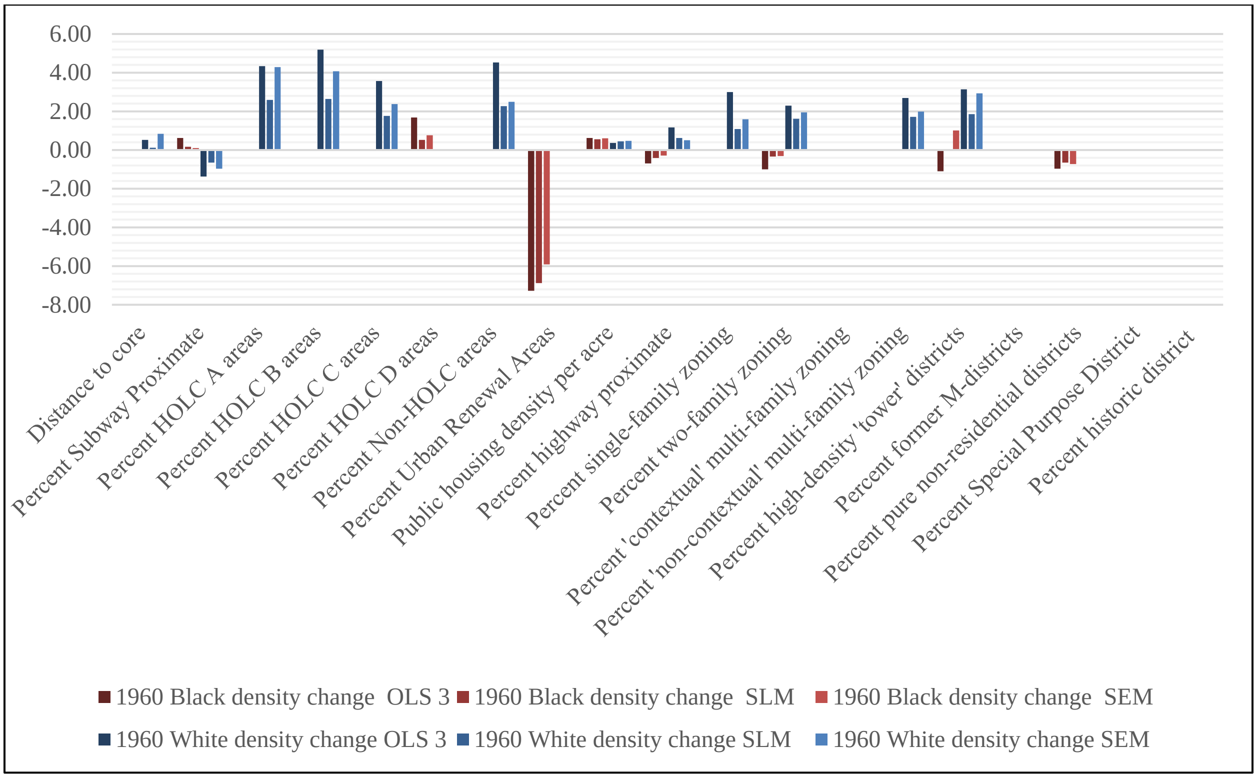


Figure 67. Regression coefficients explaining Black versus White density change, 1960

The population change between 1960 and 1990 coincided with White flight and a large growth in the Black population. In the chart in Figure 68, the prior trend in negative correlations between White populations and subway access continues. Meanwhile, Black populations have made positive correlations with HOLC B and C areas, potentially moving into neighborhoods abandoned by Whites. Both population segments have positive correlation with nearly every zoning tool, although tools like contextual zoning and two-family districts exerts far more influence on White population change.

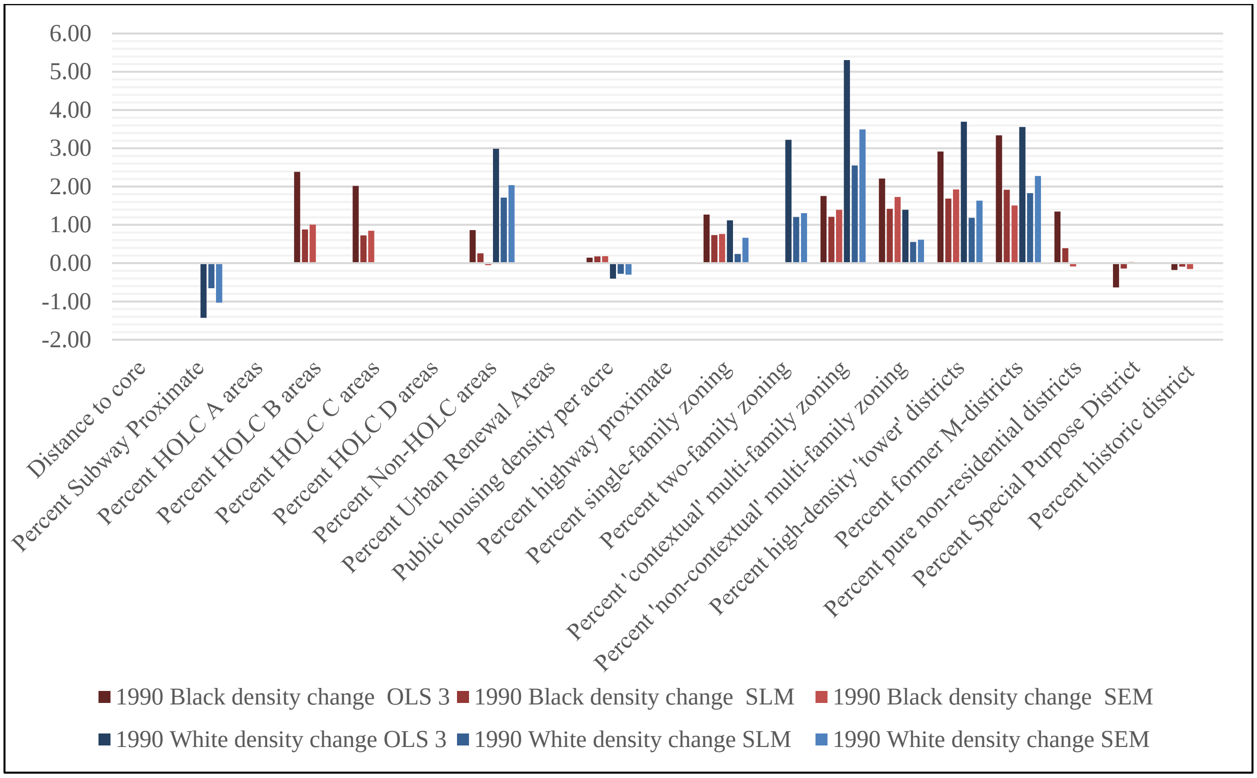


Figure 68. Regression coefficients explaining Black versus White density change, 1990

In the time period between 1990 and 2020, as the city's population stabilized, and began to outpace its previous historic high, some variables invert their statistically significant correlation from positive to negative, and vice-versa, from the prior 30-year period. This can be seen in the chart in Figure 69. White population change is negatively correlating with the percentage of HOLC A areas, while positively correlating with D areas. The percentage highway adjacent is now negatively influencing White population change. Urban renewal areas are positively correlating with White population change, while public housing density is negatively correlating with Black population change. In terms of zoning, most tools are positively associating with Black population change, while the percentage of two-family zoning districts and contextual districts are now correlating negatively with White population change.

Cumulatively, these could suggest a re-densification of more urban areas by the White population and a suburbanization of the Black population. The question on the latter would be whether this is by housing preference, or displacement as a byproduct of increased housing demand and slow-growing housing supply. Lastly, special purpose districts were positively associated with White population change, and historic districts negatively correlated with Black population change.

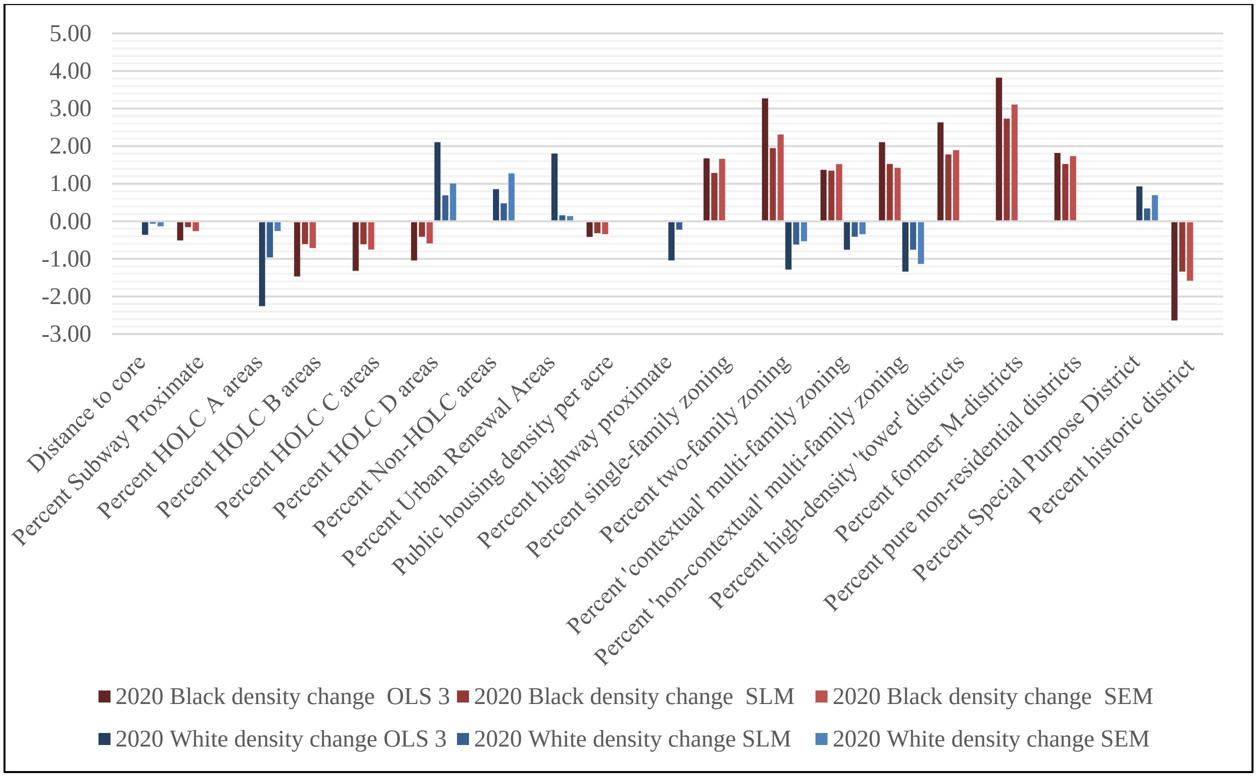


Figure 69. Regression coefficients explaining Black versus White density change, 2020

4.2.4. Dissimilarity

The results from each OLS as well as the SLM, and SEM regression runs are detailed in Appendix B for the dissimilarity response variable. The explanatory coefficient results are discussed below.

Figure 70 compares the coefficients for explanatory variables for White-other and Black-other dissimilarity in 1960, 1990, and 2020 from the SEM analyses. The dissimilarity index results in 1960 nearly mirror each other for Black and White population groups. This is likely because the absolute value measure, and lack of other population cohorts, meant that at the time it was effectively a Black-White dissimilarity index. By 1990, a significant number of Whites had left the city, the Black population had increased, as had the number of other population cohorts that identified as another race, making some divergence in Black-other and White-other dissimilarity correlations. Interestingly, White population segments in any HOLC area, and beyond, had a propensity for dissimilarity. Amongst zoning districts, the percent of a census tract that was two-family zoning districts reduced White-other dissimilarity while increasing Black-other dissimilarity. Contextual districts initially prompted large White-other dissimilarity, and transitional manufacturing district tools lessened it, but both of these correlations have dissipated over time.

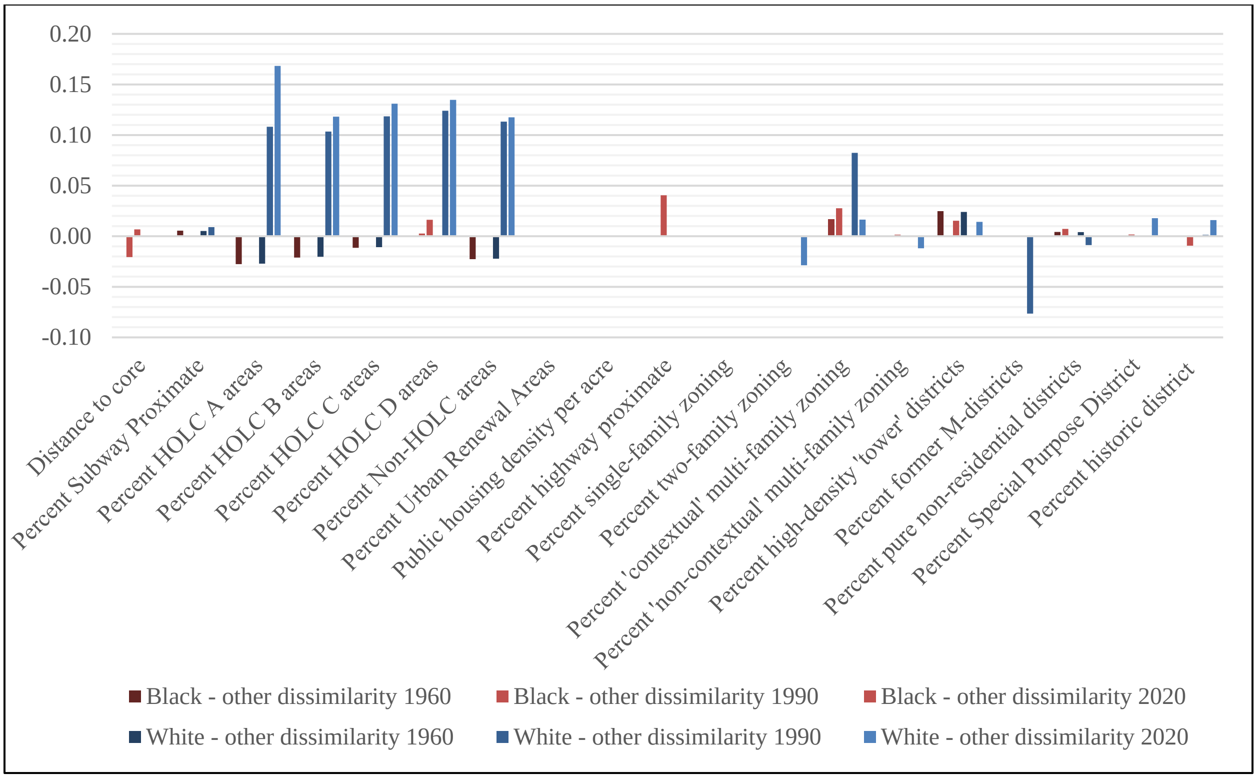


Figure 70. Comparison of SEM dissimilarity coefficients for 1960, 1990, and 2020

4.2.5. Isolation

The results from each regression run for the isolation response variable are detailed in Appendix C. The explanatory coefficient results are discussed below.

The results for the isolation index mimic some of the earlier patterns. Increases in the percentage of HOLC A, B, and C areas in 1960, shown in Figure 71, correlate negatively with Black isolation, while correlating positively with White isolation. Highway proximity and single-family zoning both were associated with White isolation, potentially as trends of suburbanization. White cohorts also were isolated by non-contextual districts and tower districts, while Black populations were negatively correlated with tower districts.

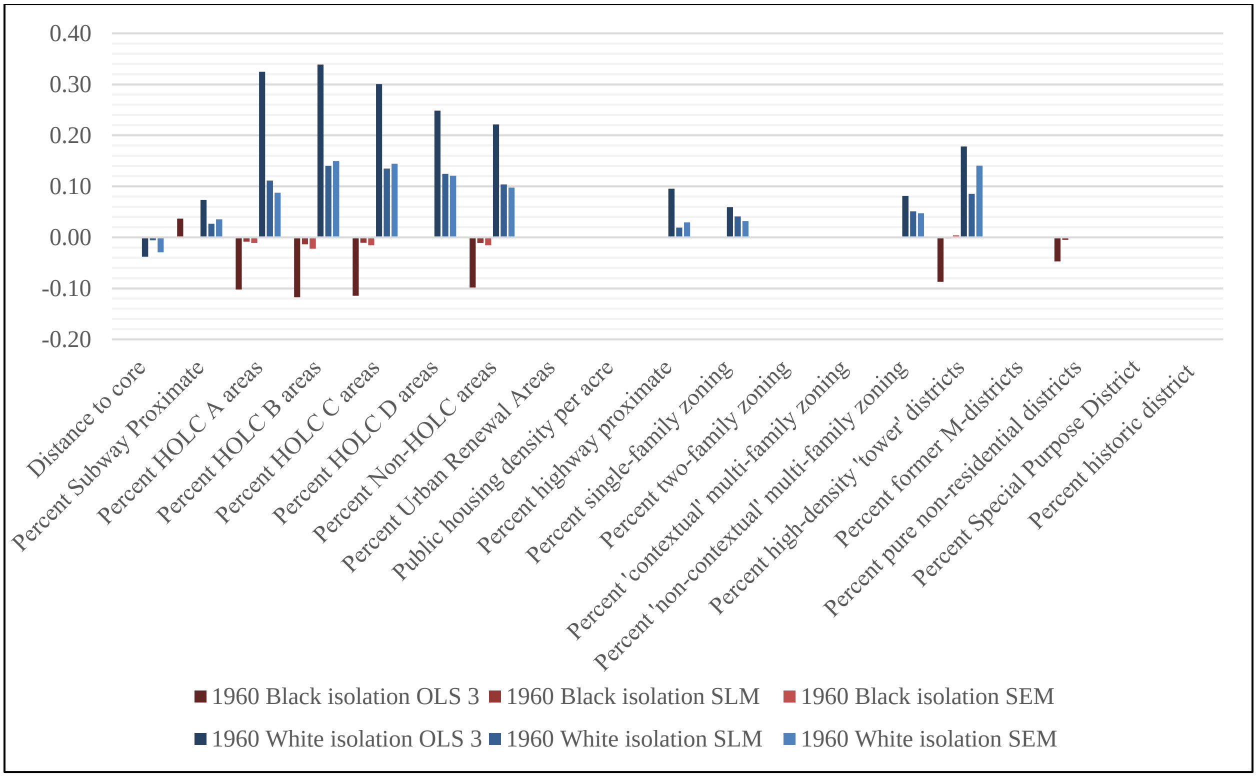


Figure 71. Regression coefficients explaining Black versus White isolation, 1960

By 1990, the degree of White isolation associated with each HOLC area had diminished, perhaps because of the contemporaneous population loss, while the negative correlation for Black population segments had been largely eliminated. This can be seen in Figure 72. Urban renewal areas were strong explanatory variables for Black isolation, while highway adjacency was not. Many zoning districts had split impacts. Two-family zoning districts, contextual districts and special purpose districts all had strong White isolation correlations, particularly contextual districts, while all had negative Black isolation correlations. This suggests that mapping these districts in an area with Black population segments would expose them to other population groups (exposure being the opposite of isolation on the exposure / isolation index), while mapping these districts in an area with a higher White population might further isolation.

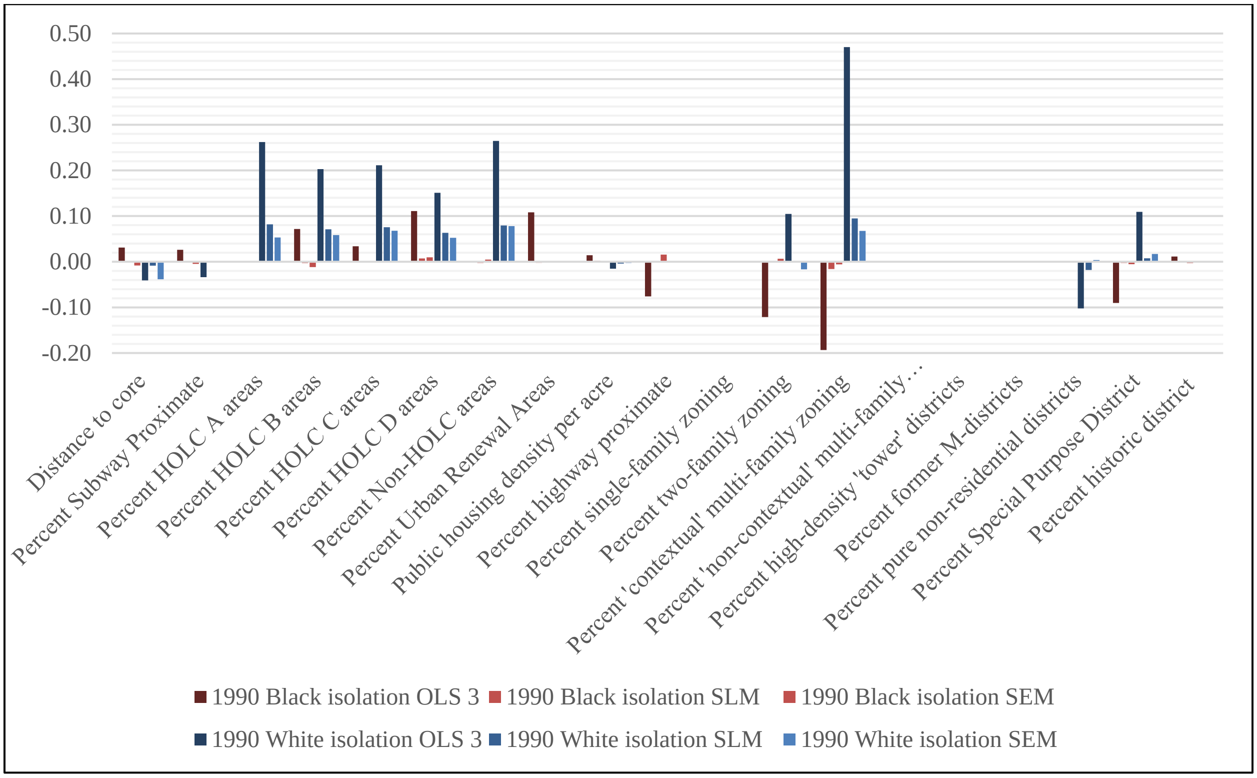


Figure 72. Regression coefficients explaining Black versus White isolation, 1990

The 2020 results in Figure 73 show a sharp increase in White isolation associated with HOLC areas again; potentially signaling the city's renaissance and a tightening housing market. Within this, the isolation associated with A areas is highest, and is higher than it has ever been. Black population groups continue to be isolated by urban renewal policies. In terms of zoning associations, White populations are again being isolated by tower provisions, and continue to be isolated by special purpose districts. These White populations have a negative correlation with manufacturing districts or other transitional formally industrial areas, so would be potentially exposed to other population segments by their increase. Black segments negatively correlate with single-, two-family, contextual districts, as well as special purpose districts. Lastly, historic districts are correlating with White isolation.

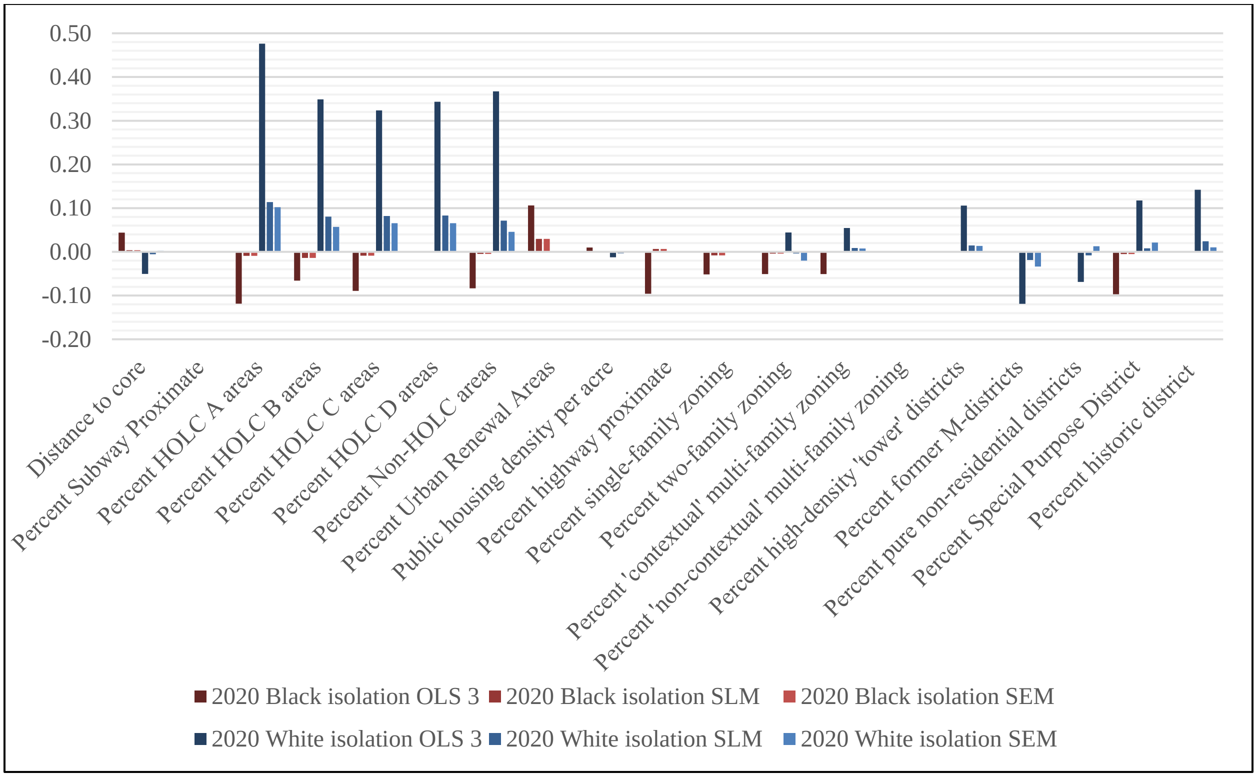


Figure 73. Regression coefficients explaining Black versus White isolation, 2020

4.2.6. Spatial Heterogeneity

GWR calculations were generated from the percentage Black and percentage White response variable to compare a subset of variables for each era. The comparisons were made on those variables where a statistically significant coefficient was present for both Black and White populations; however, the original HOLC areas were not included to focus on post-war policies. The results of these are shown in Table 15, and include the minimum, 1st quartile, median, 3rd quartile, and maximum coefficient values for these select variables. The global value is also included, as a benchmark.

Notably, several variables that have positive operators as a global value also have minimum local values that are negative, and reciprocally, several variables with negative global values have maximum local values that are positive. So, while variables like the percentage of urban renewal are positively associated with the percentage of Black residents and negatively with White residents globally, there are local instances with strong negative correlations amongst Black residents (-2481 in 1990) and strong positive amongst Whites (645 in the same year).

Variables	Minimum	1st Qu.	Median	3rd Qu.	Maximum	Global Value
1960						
Percent Non-HOLC areas, White	-36.40300	-0.01381	0.21113	0.54827	47.41100	0.42830
Percent Non-HOLC areas, Black	-9.49980	-0.23944	-0.05228	0.00115	2.72900	-0.23890
Public housing density per acre, White	-0.80544	-0.04488	-0.02004	0.00099	0.20584	-0.02430
Public housing density per acre, Black	-0.30148	0.02262	0.05055	0.08198	0.79339	0.05050
1990						
Percent Urban Renewal Areas, White	-5.42872	-0.48206	-0.14935	0.10624	645.17640	-0.21010
Percent Urban Renewal Areas, Black	-2481.20000	-0.07957	0.17939	0.62153	40.48500	0.24840
Public housing density per acre, White	-7.20200	-0.06665	-0.04425	-0.01748	30.52668	-0.05590
Public housing density per acre, Black	-49.19700	0.02946	0.05343	0.08056	13.25800	0.05470
Percent two-family zoning, White	-1.52790	0.04310	0.21440	0.41065	1.88170	0.48680
Percent two-family zoning, Black	-2.02770	-0.30330	-0.04505	0.06981	2.55680	-0.31220
Percent 'contextual' multi-family zoning, White	-33.82921	-0.08695	0.41663	2.18859	1344.62186	0.47530
Percent 'contextual' multi-family zoning, Black	-1915.90000	-2.34270	-0.31949	0.04979	51.33300	-0.44120
Percent Special Purpose District, White	-0.94534	-0.11930	0.04464	0.28747	76.99546	0.23360
Percent Special Purpose District, Black	-117.12000	-0.26473	-0.01084	0.12348	5.77360	-0.19350
2020						
Public housing density per acre, White	-0.11583	-0.06194	-0.03397	-0.01863	0.00121	-0.04190
Public housing density per acre, Black	-0.02456	0.01840	0.03881	0.05832	0.26276	0.03490
Percent 'non-contextual' multi-family zoning, White	-0.11333	0.02154	0.05709	0.17166	0.69265	0.10960
Percent 'non-contextual' multi-family zoning, Black	-0.09627	0.01160	0.05889	0.11928	0.40506	0.07870
Percent Special Purpose District, White	-0.38080	-0.06483	0.06500	0.20371	0.67459	0.23780
Percent Special Purpose District, Black	-0.97182	-0.17496	-0.02644	0.06551	0.24890	-0.14880

Table 15. Range of GWR coefficients for select variables

While several variables have extreme values at the minimums and maximum, the values within one standard deviation of the median show much lower range. Still, there are several variables with operator shifts between the 1st and 3rd quartile. While the range of coefficients for particular variables is interesting in tabular form, visualizing them in map form is often more instructive to intuit the spatial pattern.

When values were exported from R Studio, they were joined with the census shapefile and visualized with a quantile classification, relative to the specific dataset. The same standard deviation output as the chart above was not used because many variables had significant outliers, and a majority of the census tracts would be within a single standard deviation, meaning no real spatial pattern would be visible. For the same reason, the coefficients were not equalized between Black and White GWR models. GWR coefficients explaining Black population percentages are shown in a red-yellow gradient and White population percentage is shown in a green-yellow gradient. In every model, significant spatial heterogeneity was occurring, and in many instances the spatial patterns between variable coefficients were somewhat inverted.

Figure 74 shows the salient coefficient differentials for 1960, with percentage of a census tract that was not within an HOLC area on top and the public housing density on the bottom.

The coefficients for non-HOLC areas associated with a Black percentage of population were nearly always negative, except in the darkest red areas. These can be seen in core areas of Manhattan, Western Queens, downtown Brooklyn, and in the select peripheral areas of St. Albans in southeast Queens, Throgs Neck and Soundview in the Bronx, and various portions of Staten Island. White coefficients are positive in the darkest green, but this covers the majority of the city. A few portions of the city are both negatively correlated, like Washington Heights in upper Manhattan, and Flushing, Queens, and potentially showing the emergence of Dominican and Asian enclaves, respectively.

Public housing density has a strong positive association with a greater Black population percentage in a census tract (all but the yellow), while the White population is largely negative (all but the darkest green).

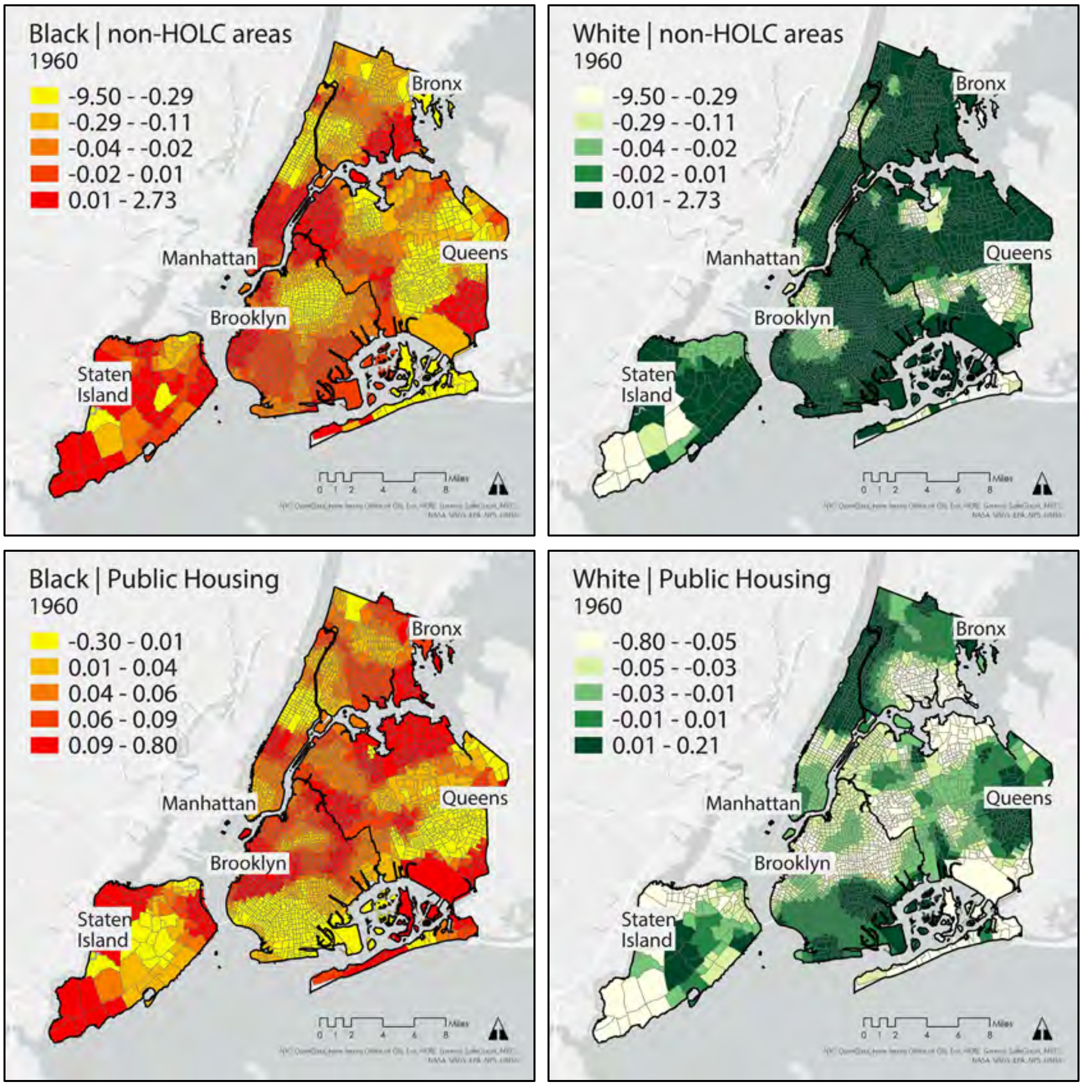


Figure 74. Select GWR coefficients influence on Black and White population percentage, 1960

Figure 75 shows the Black and White comparisons for the GWR coefficients for several explanatory variables in 1990: urban renewal, public housing density, percentage two-family zoning district, percentage contextual multi-family housing district, and percentage special district, from top to bottom respectively.

Urban renewal areas are largely positively correlated with Black populations, and negatively with White populations. Areas where more urban renewal might have increased the White population percentage and lowered the Black percentage, the darkest green and yellow, are around Hell's Kitchen in Manhattan, Greenpoint and Sunset Park in Brooklyn, Long Island City, and northeast Queens, the northwest Bronx, and the north shore of Staten Island.

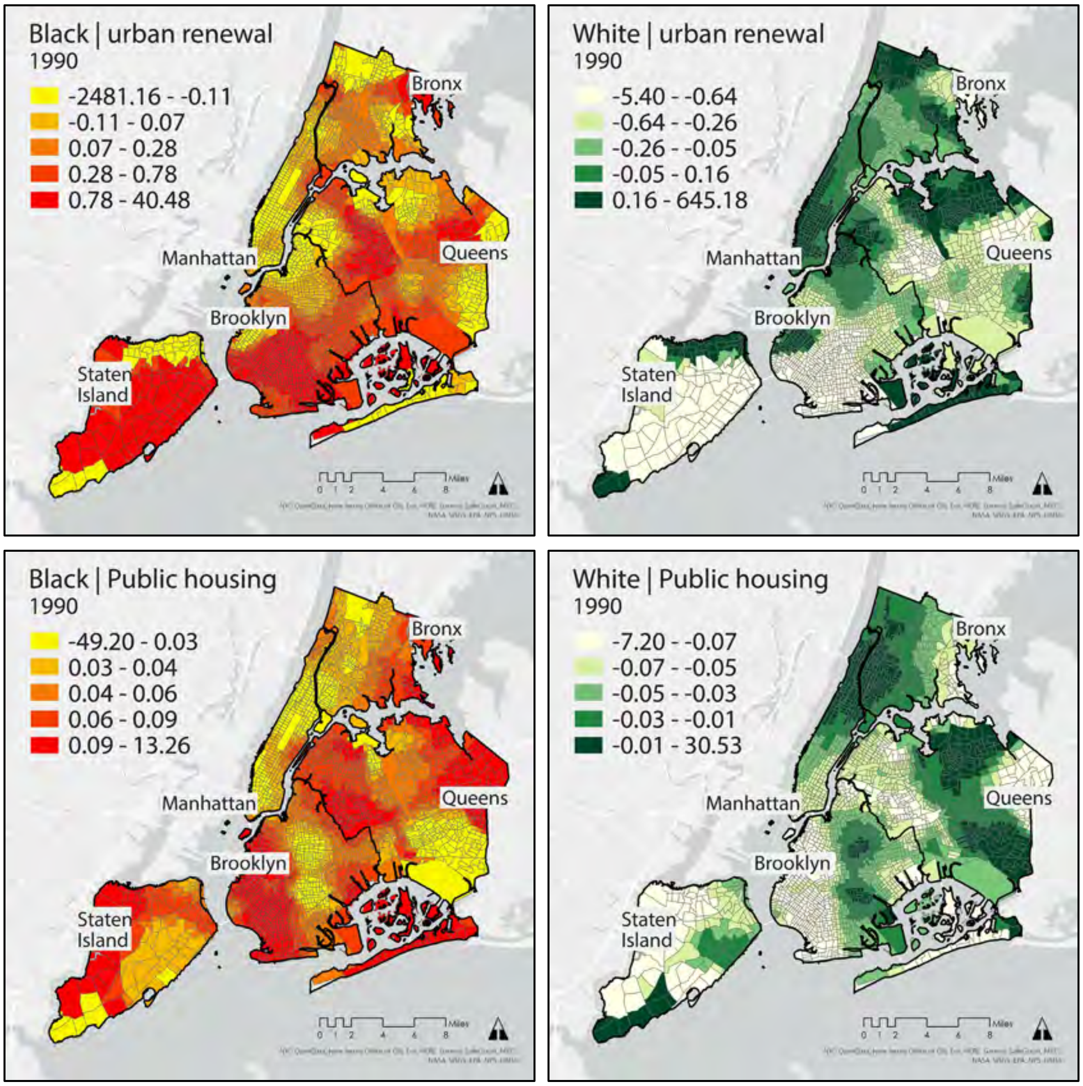
Coefficients for public housing per acre remain strongly associated with explaining greater Black population percentages and negative White population percentages. The strongest positive coefficients for Black percentages are in areas without a lot of existing public housing campuses, locations like southern Brooklyn, northeastern Queens, or southern Staten Island.

The two-family coefficients suggest increasing these districts in Jamaica, Queens and northern Bronx would be conducive to increasing the Black population. In many other locations, a two-family district increase would disproportionately benefit White population segments.

The coefficients for percentage contextual districts show strong vulnerability for the Black population in a central Brooklyn belt that includes Bedford-Stuyvesant, Crown Heights, Brownsville, and Flatlands. Percentage increases here would decrease Black populations and increase White populations. This finding is troubling as it aligns with population losses in those geographies and increases in contextual districts.

Lastly, coefficients for the increase in special purpose districts show the strongest vulnerability for the loss of Black population in a swathe from East New York, in Brooklyn, to Jamaica, Queens, as well as South Richmond in Staten Island. In these areas, based on the pre-existing correlations between population segments, new special districts would likely increase White populations and decrease Black populations. This is also an interesting finding considering subsequent public policy measures; East New York was the location for the

DeBlasio administration's first mandatory inclusionary housing area and included special purpose districts. Land speculation stemming from the upzoned residential capacity has led to claims of gentrification and displacement from the community (Hogan 2021).



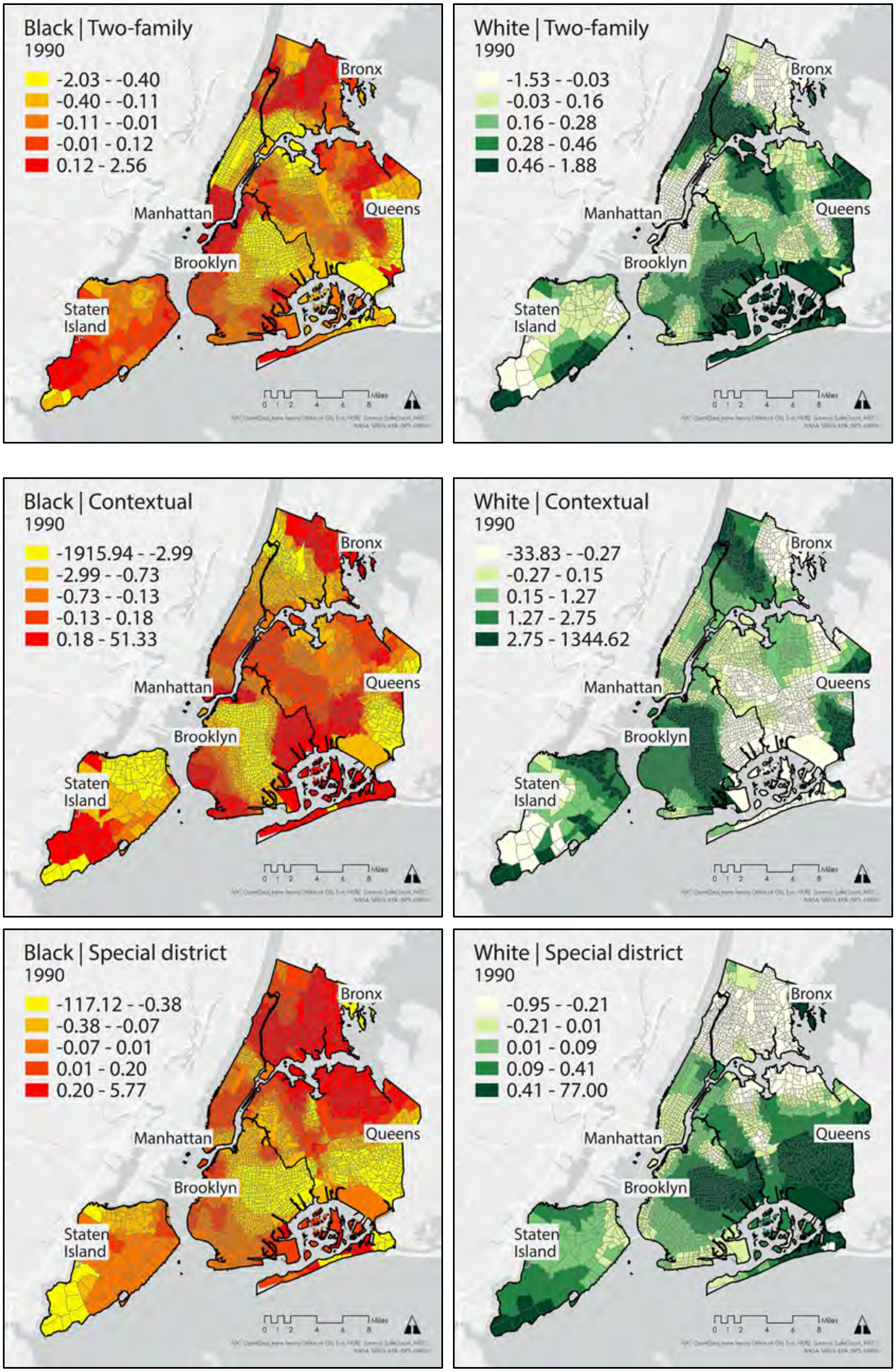
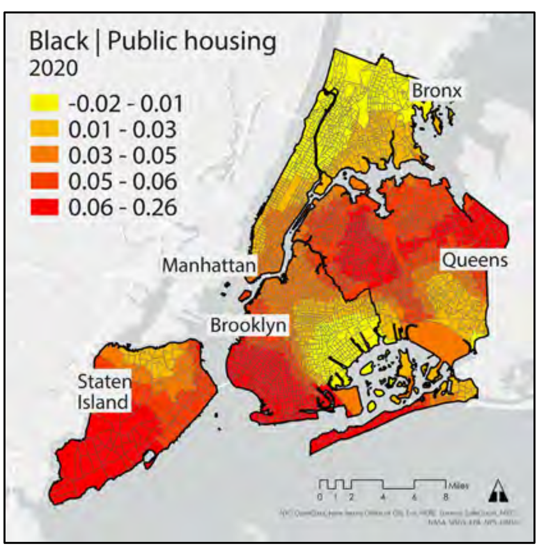
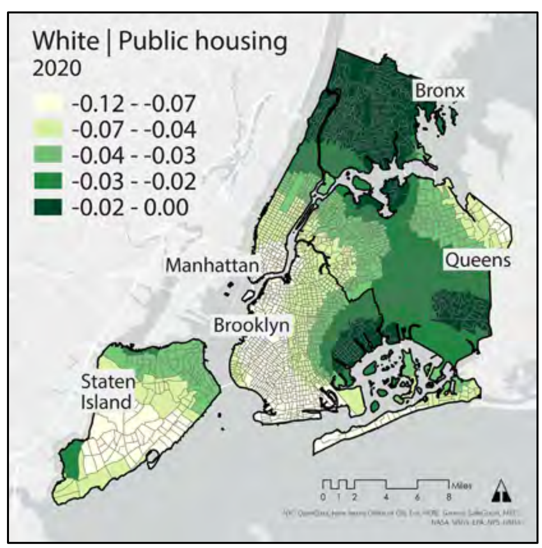


Figure 75. Select GWR coefficients influence on Black and White population percentage, 1990

Figure 76 shows the GWR coefficient comparisons for three variables in 2020 on Black and White population percentages: public housing density, percentage non-contextual multi-family housing district, and percentage special district, from top to bottom. The impact of public housing remains positively correlated with Black populations and negatively with White – even more than prior eras. Areas that would receive the largest Black population gains from more public housing density largely remain those areas without public housing campuses. The relationship between population and the percentage of non-contextual multi-family district is one of the only variables assessed where the impacts are largely positively correlated with both races. The negative correlation between these districts and Black populations along the Brooklyn and Lower East Side waterfronts should give pause, as waterfront parcels often utilize these districts and developments have spurred tremendous transformation. Finally, the relationship between increases in the number or size of special purpose districts continue to show a beneficial tilt towards White communities. Special districts in central Bronx may increase Black populations, whereas those in central Brooklyn may decrease them and lease to a tremendous uptick in White populations.





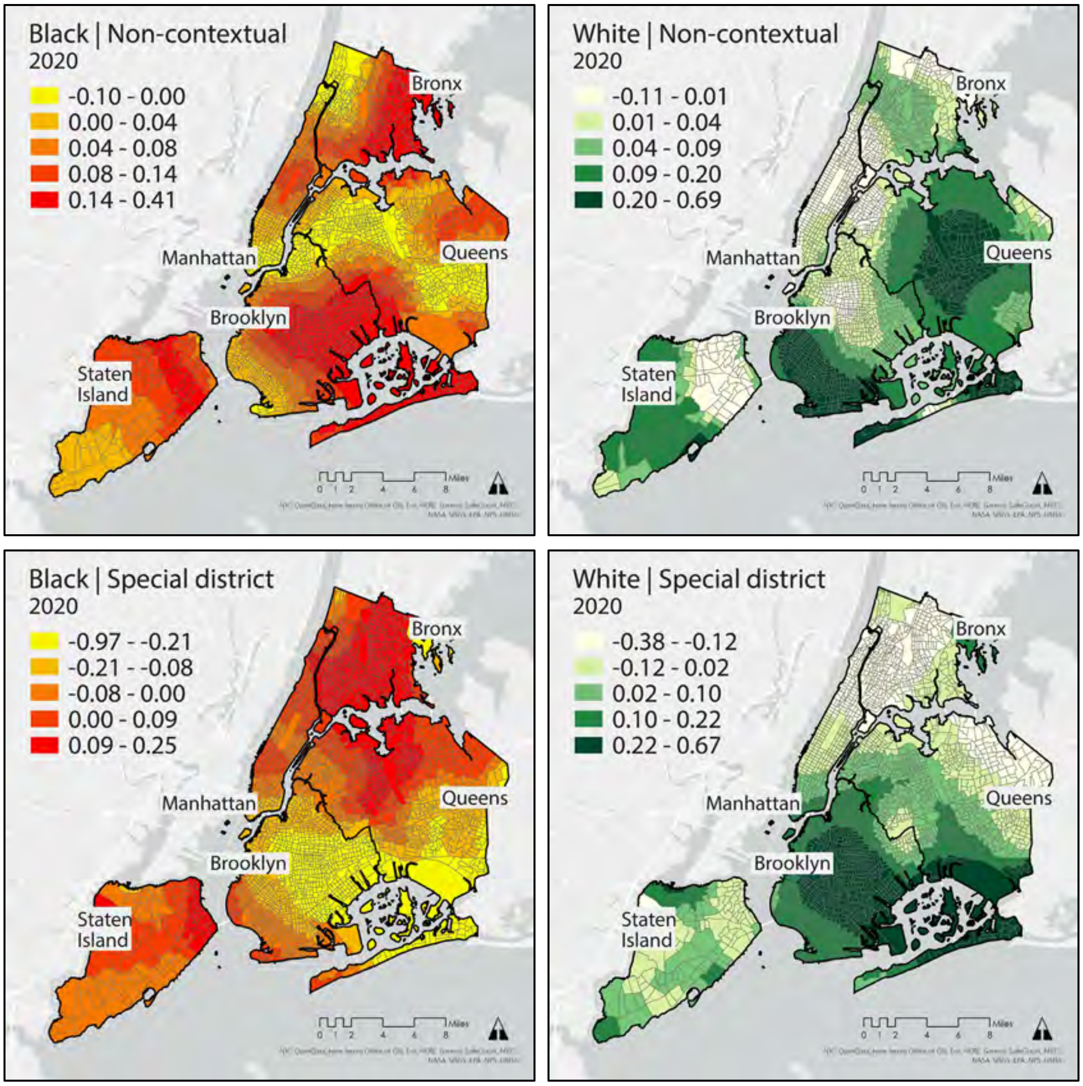


Figure 76. Select GWR coefficients influence on Black and White population percentage, 2020

Chapter 5 Discussion

This section begins with overall findings in the analysis, along with some policy discussions. The discussion then moves to data limitations and concludes with other potential research topics stimulated by these findings.

5.1. Overall Findings

The results culminated in several overall findings, including the persistence of white privilege, and a spatial path dependency between different eras of policies.

5.1.1. Persistence of White Privilege

Most broadly, there are strong correlations between the spatial pattern of numerous government policies and disparate impacts on Black and White population segments. This disparity is often so pronounced that Black and White population groups had inverse correlations for the same variable. This can be seen in Figures 77 and 78, which visualize the SEM coefficients for Black and White density and population percentage response variables, respectively, directly comparing coefficient results for 1960, 1990, and 2020. Whether it be urban renewal and public housing density positively correlating with Black population density and percent population and negatively with Whites, or inversely, HOLC A areas, contextual zoning districts, special purpose districts and historic district designations positively correlating with White segments while negatively with Black, the impacts are clear. Even in instances where both positively correlate, like recent trends in two-family zoning districts, or zoning districts that permit towers, the degree of correlation is always higher in White areas.

Figures 79 through 81 detail these two initial figures, isolating specific variables to observe the trends more granularly.

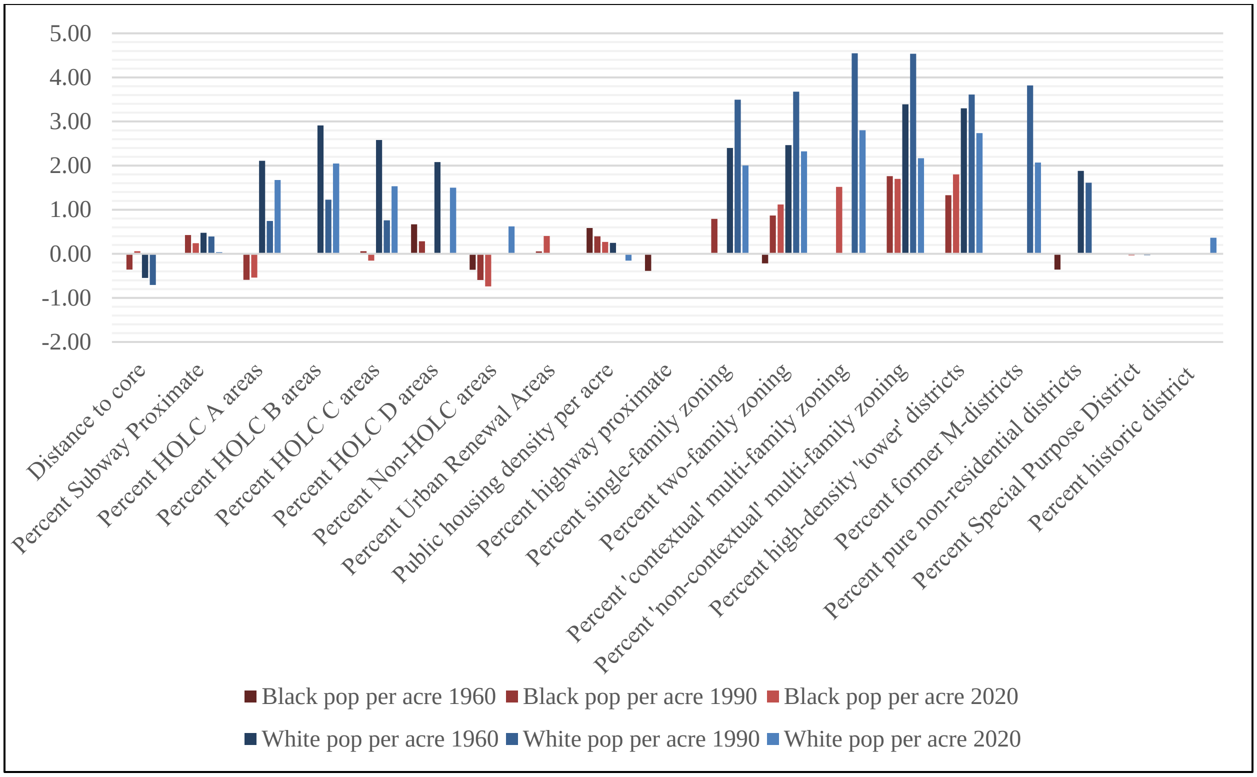


Figure 77. Comparison of SEM population density coefficients for 1960, 1990, and 2020

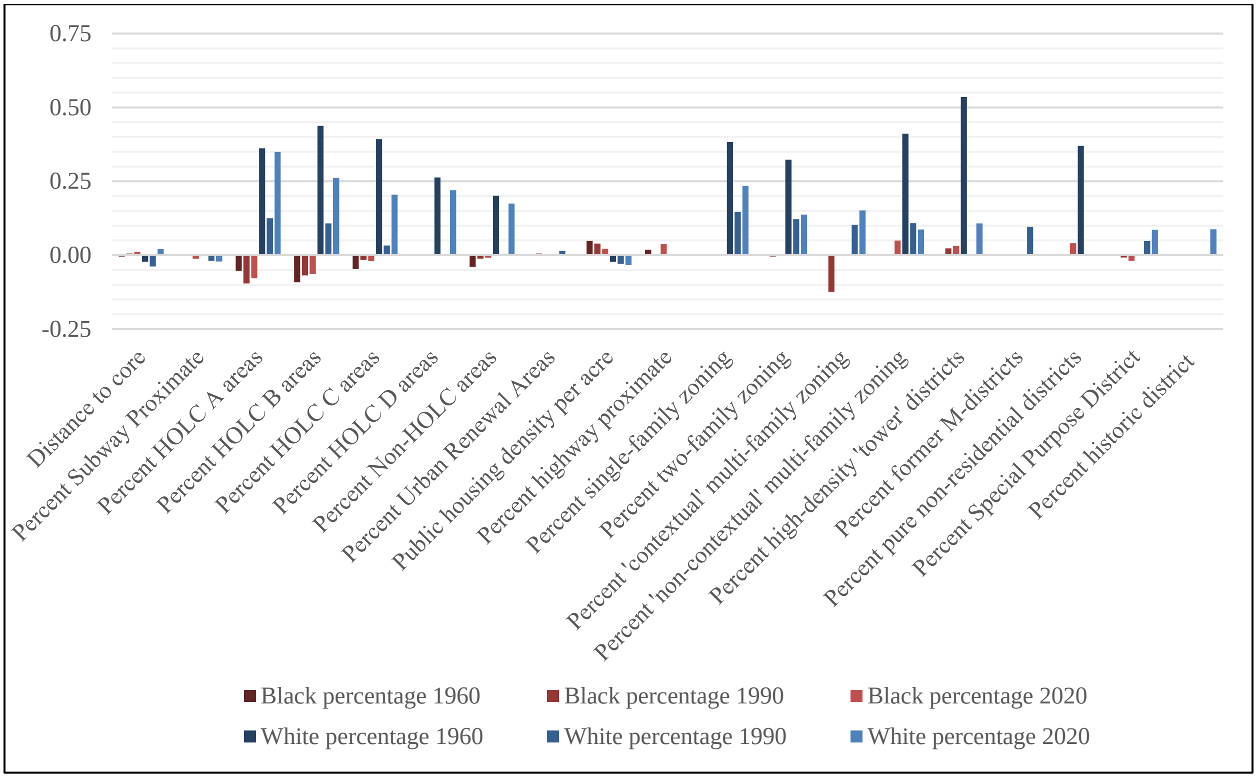


Figure 78. Comparison of SEM population percentage coefficients for 1960, 1990, and 2020

Figure 79 shows a select range of variables from the prior charts: HOLC A and D areas, non-HOLC areas, urban renewal and public housing. For certain variables the disparity between different coefficients in explaining Black and White density and population percentages not only persists, but in the worst instances, has even grown. While positively, the impact of HOLC D, urban renewal and public housing densities has slowly diminished in predicting Black population densities, there are still statistically significant correlations. Interestingly, HOLC D areas are stronger predictors of White populations today, a potential indicator of gentrification, or more complex market dynamics at play. In 1960, White population density was positively correlated with public housing density, but over time, has become negatively correlated. Tools like HOLC A areas, which represented the safest areas for investment nearly 100 years ago, still resoundingly predict White population cohort, and over time, have grown to predict the absence the absence of Black residents to a statistically significant degree. Areas that were outside of the original HOLC designations follow a similar trend.

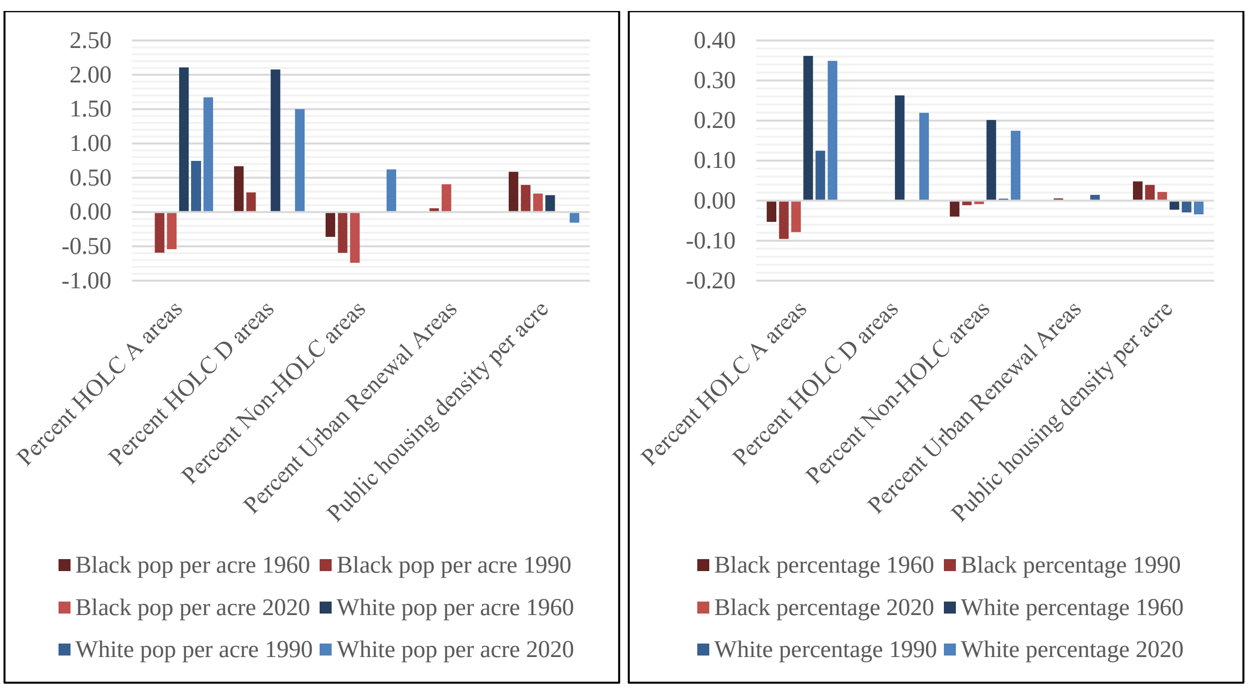


Figure 79. Select SEM population density (left) and percentage (right) coefficients

Figure 80 also shows a subset of the variables from the 1960, 1990 and 2020 SEM coefficients, detailing the influence of original zoning districts on population density and population percentage. Single-family zoning districts disproportionately benefited White populations in 1960 and have continued on that trajectory with Black populations rarely even registering enough population in those areas to register a statistically significant correlation. Non-contextual zoning districts and districts that permit towers disproportionately explained White populations in 1960, but in each, White association has diminished, and Black correlation increased. In each of these district typologies, it is important to bear in mind that the lack of fixed height controls in each has made both district typologies somewhat reviled amongst different communities for their lack of predictability and potential incompatibility with the surrounding context (Laskow 2014; Adams 2022). In 1960, White population groups were positively correlated with the percentage of a tract allocated to manufacturing districts. This could have been worker housing proximate to industrial areas, or land rendered non-conforming and aspirationally slated for redevelopment. Over time, this correlation has dissipated and disappeared, potentially as a result of global shifts in manufacturing sector, and a long-term pivot in the local economy towards other traded sectors as an economic base (Moretti 2013). In 1960, Black populations were negatively correlated with the percent of an area slated for manufacturing, but troublingly, over time, have become more positively associated with these areas, a potential indicator of rising costs, and being pushed towards increasingly fringe locations of the city. Even if these are no longer manufacturing adjacent (by virtue of larger de-industrialization trends), they may be adjacent to contaminants from former industrial byproducts or to noxious emissions from trucks accessing warehousing and wholesaling facilities, which are often relegated to these areas, raising a host of environmental justice concerns (Kilani 2019).

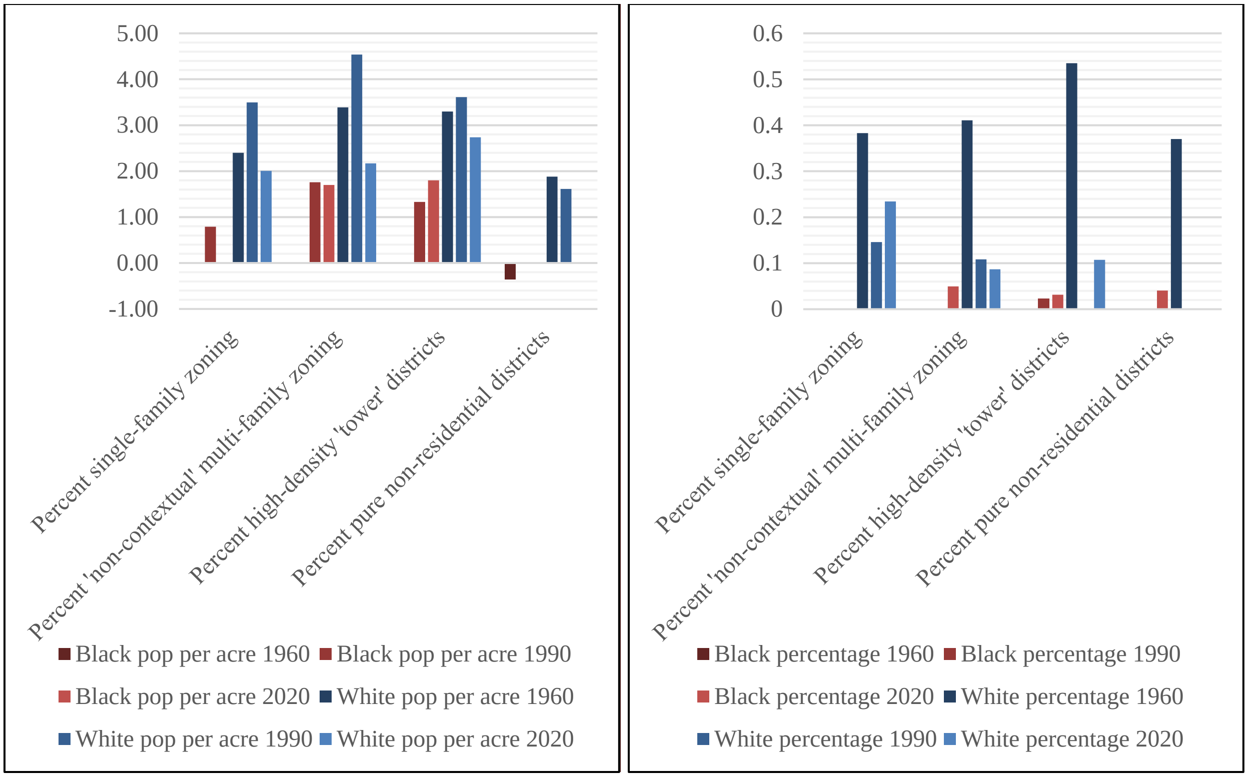


Figure 80. Select SEM population density (left) and percentage (right) coefficients

When new zoning or other planning tools were created, White population groups often seem to have been the chief beneficiaries. This can be seen in Figure 81, which continues to isolates select variables from the SEM coefficients of Figures 77 and 78. The year 1990 is particularly instructive here; new contextual districts, new two-family districts, novel transitional tools for former industrial areas, and a whole host of new special purpose districts all correlated with White communities (and, at least in some instances, negatively correlate with Black communities). To situate this finding in its historical arc, it means that in the era where Black and Latino communities in the South Bronx and central Brooklyn were at the apex of urban crisis – with nearly a full generation of disinvestment, White flight, degrading municipal services, rising crime, deteriorating schools, and a drug epidemic (Flood 2011) – tools that disproportionately benefited White neighborhoods were seemingly at the forefront of the planning agenda. While the disparity in some of these new tools has dissipated since 1990, special purpose districts and historic districts have continued to disproportionately benefit White communities into the 2020s.

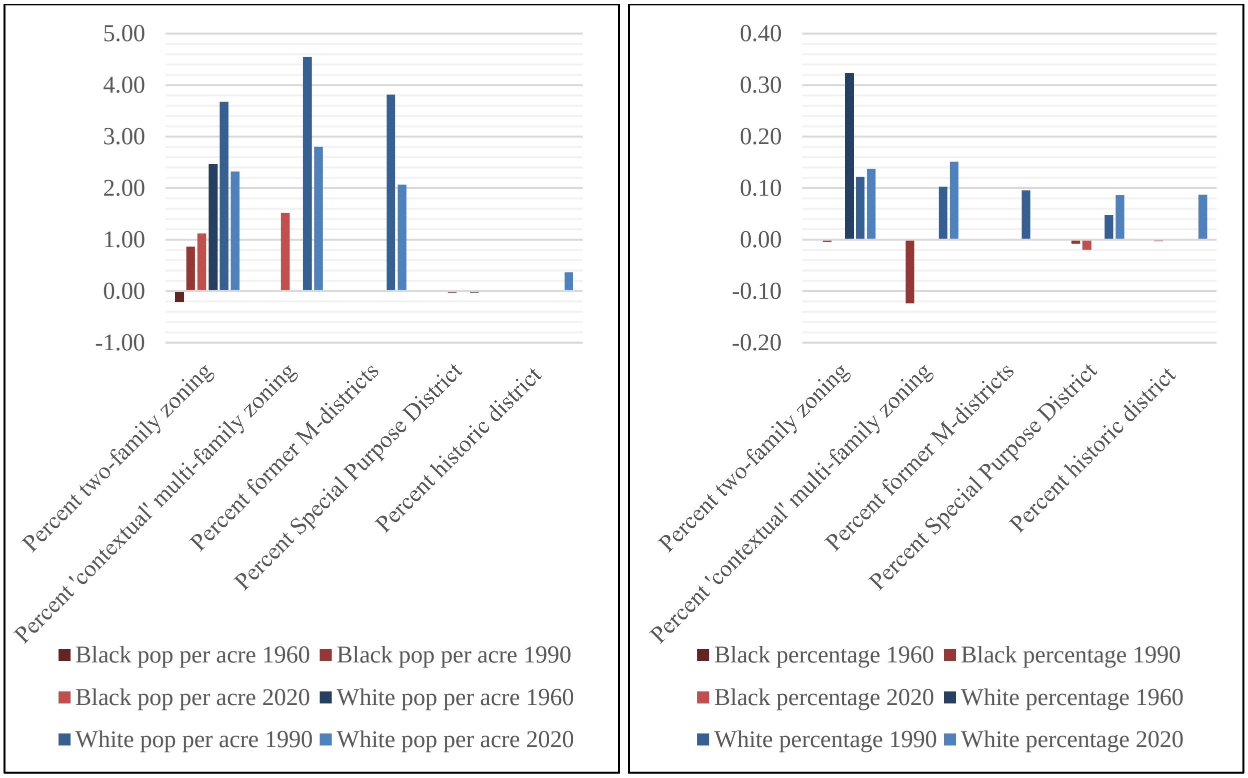


Figure 81. Select SEM population density (left) and percentage (right) coefficients

5.1.2. Path Dependency Between Policies

The spatial pattern for many policies and the manner in which their constituent variable interplay with Black and White neighborhoods often mimics that of previous policies. There appears to be a spatial path dependency (David 1985) wherein one generation's policy manifestations for an area can entrench the subsequent generations in privilege or hardship.

If an area was designated as an HOLC A area, for instance, as the Fieldston and the Riverdale-on-Hudson neighborhoods in the Bronx were, there is a stronger likelihood that it avoided public housing and urban renewal, and similarly, a greater likelihood that it would have single-family designations, not to mention other tools like special purpose districts and historic districts. In this case, all these exclusionary tools layer on each other to buttress an enclave that is nearly 70% White, in a Borough that has no majority population group, and is roughly 44% Black and White (US Census Bureau 2021). Figure 82 shows this pattern in Riverdale. At the far left are the original A and B HOLC designations, next is the percentage of the census tract that is white, in the middle are single-family zoning designations, followed by special purpose district and historic districts.

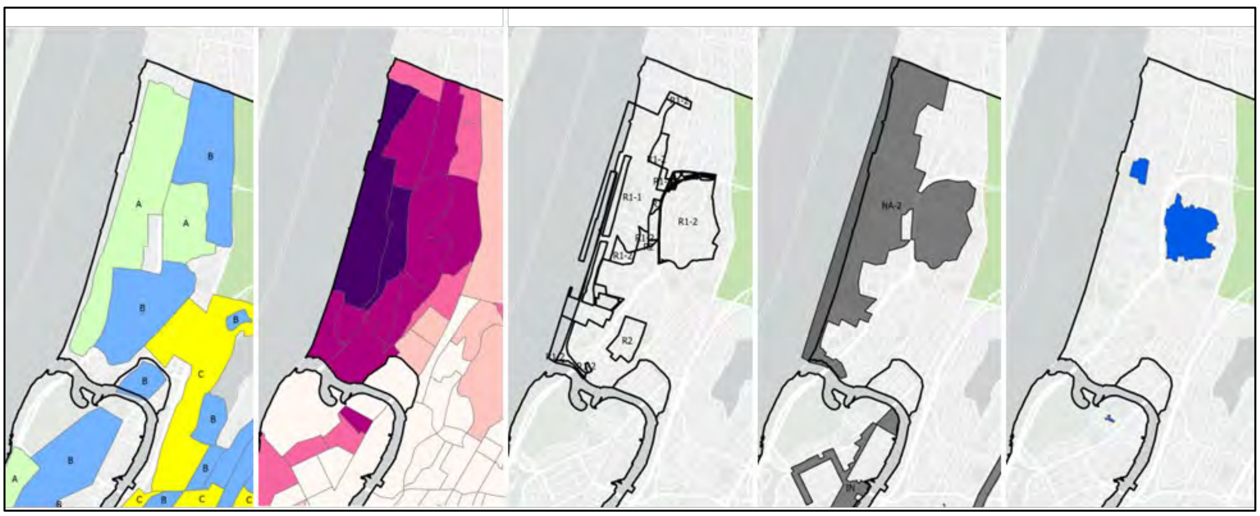


Figure 82. Patterns of layered exclusion in Riverdale, the Bronx

Inversely, HOLC D areas mapped in the 1930s not only predicted where Black populations would reside in subsequent decades, but also where urban renewal areas and public housing campuses would come to be placed. The charts in Figure 83 show the degree to which each of these were disproportionately located within HOLC D areas, and the increasingly fewer amounts located in HOLC C, B, and A areas.

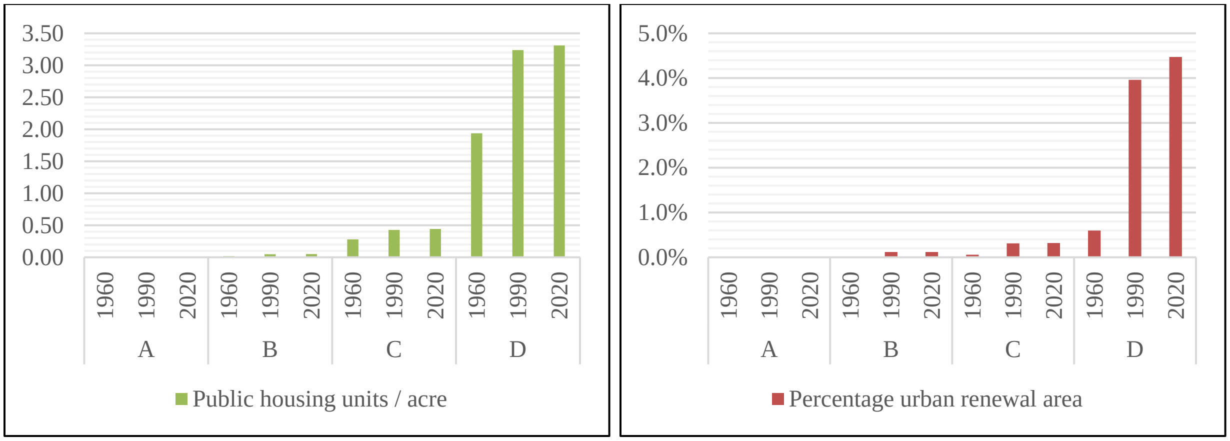


Figure 83. Public housing density and percent urban renewal area by HOLC area

As zoning districts have evolved over time, areas with those former HOLC D designations continue to have disproportionately lower percentages of the aggregate of single-, two-family and contextual zoning regulations, while they have higher percentages of non-contextual zoning districts, higher percentages of manufacturing districts and other specialized rules for transitional areas. This can be seen in the chart in Figure 84. The aggregated percentages allocated to single-, two-family, and contextual districts dramatically increase for every incrementally "better" HOLC area. They also increased dramatically within each subset between 1960 and 2020.

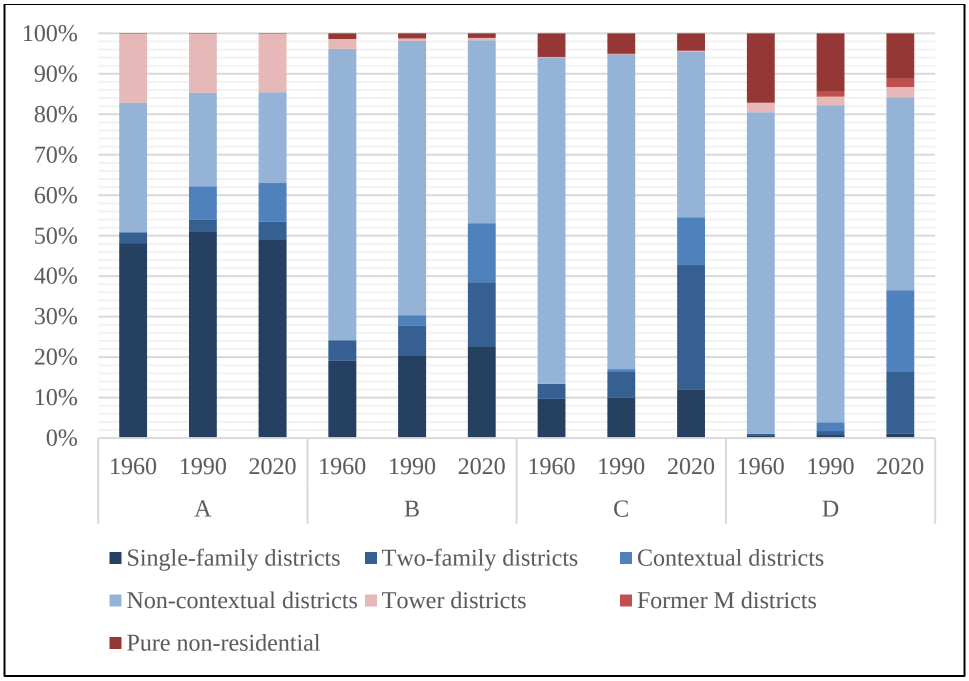


Figure 84. Percentage of zoning districts within each historic HOLC area

Similar patterns are apparent for the percentages of historic districts ascribed to each former HOLC boundary – C and D areas have proportionally fewer areas than A and B, as shown by Figure 85.

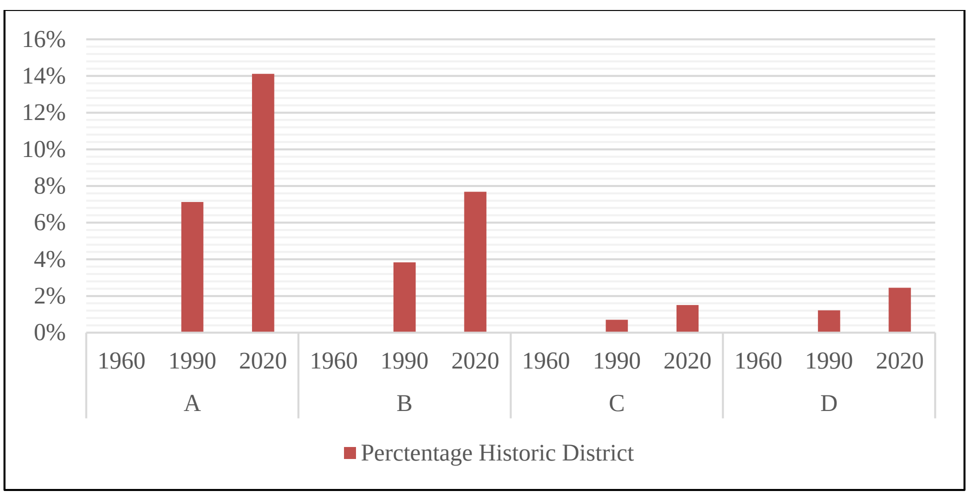


Figure 85. Percentage of historic districts within each historic HOLC area

To test the statistical significance of certain correlations, a final regression model was made to formally test the correlation between urban renewal, zoning typologies and historic districts with the old HOLC areas. The resulting coefficients are in Figure 86, and show the third OLS run, as well as SLM and SEM runs. It confirms many of these relationships. Urban renewal areas are positively correlated with D areas and negatively with B and C. Areas with single-family zoning correlate with A, B and C areas, but not D, while two-family areas, which were more working-class than their single-family counterparts, correlates more strongly with C areas. The multi-family districts that permit the majority of the city's housing correlate with C and D areas while tower districts strongly correlate with A. Special purpose districts and historic districts are positively associated with A and B areas, while negatively correlated with C and D. The results from each OLS and spatial regression run are set forth in Appendix D.

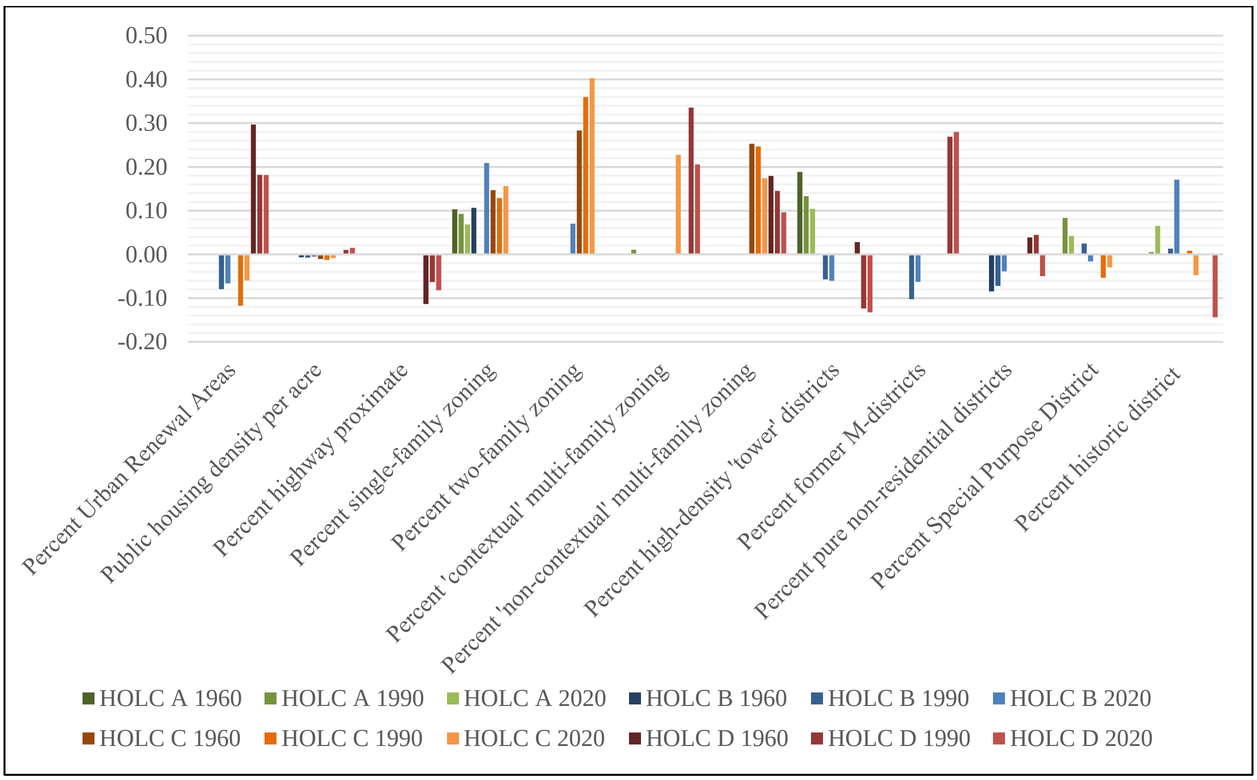


Figure 86. Correlation between post-war policies and HOLC areas

While in some instances the influence of prior generations patterns has dissipated, the original institutional racism seems to persist in the landscape and simultaneously, seems to have triggered several successive waves of segregation.

5.2. Policy Recommendations

Based on these results and overall findings, several policy recommendations were generated. Future work could incorporate these recommendations into a model and evaluate how they might be expected to work in specific locations, and reduce segregation, given some of the findings outlined above.

5.2.1. Remove Exclusionary Zoning Tools

Cities and states around the nation have been trying to eliminate exclusionary zoning tools, principally single-family zoning, in order address historic inequities. In New York, the fact that nearly every permutation of regression model showed strong correlations between single-family zoning and White populations, as well as correlations with the historic HOLC A areas, should make policymakers consider modification. Many legislative precedents have simply raised the floor on the minimum number of units permitted. Minneapolis, for example, overlaid their zoning with a mandate that no fewer than four units be permitted in any district. However, because they only explored unit numbers, and not modifications to other secondary exclusionary features of those districts, like high parking requirements, larger minimum lot sizes, not to mention onerous yard and building form rules geared towards single-family homes and not quadplexes, uptake has been limited (Fox 2022). New York should evaluate its single-family district regulations comprehensively to permit a greater range of housing typologies in workable configurations.

While it may be an impulse to associate two-family zoning districts with the same exclusion as single-family districts, the history here shows they are clearly more complex. They correlated more strongly with HOLC C areas and have had increasing correlations with Black populations over time. Changes to zoned capacity should be considered more carefully here, as drastic increases could lead to land speculation, squeezing renters. At the same, modest increases could give struggling middle-class homeowners an opportunity for rental units that provide a viable income stream, helping keep minority families in their homes, and safeguarding the ability to build generational wealth.

Since these single- and two-family areas have fewer amenities, are less transit accessible and more reliant on vehicle ownership, removing density limits altogether would be ill-advised. Many cities have explored “missing middle” models to target the creation of 3 – 8 units in a building (Opticos Design n.d.); these could be appropriate targets to explore in the areas with best access and services.

5.2.2. Reconsider Contextuality

From this analysis, it is clear that contextual districts have an origin that was closely correlated with White communities and negatively with Black. While initially under the guise of preserving the existing scale of neighborhoods, these tools, despite a relatively recent origin of the 1980s (at least in terms of planning tools), were also preserving the existing segregation in the landscape. That these districts have now been mapped in neighborhoods throughout the city does not change the fact that they were dramatically correlated with White neighborhoods, and preserved their character first and foremost. DCP should question the merits of using existing context as a planning guidepost to the zoned capacity of an area, instead of data-driven metrics like access to transit, jobs, amenities, open space, and risk from climate change.

5.2.3. Allow Infill Opportunities on Campuses

One of the most persistent racial imbalances in the city stems from the disproportionate association with Black communities and public housing campuses. The zoning on these campuses is often frozen in time, still favoring the tower-on-a-park type of developments they were often created under. Decoupling permitted zoning capacity from the amount of open space provided on these campuses could free up sizable infill development opportunities. If reasonably balanced with the preservation of key open space amenities, new infill could provide desperately needed revenue to offset deferred maintenance on the campus, while also helping to integrate those hyper-segregated areas.

5.2.4. Equitably Distribute Zoning and Planning Resources

It has been clear that the distribution of special zoning rules, like special purpose districts, or new districts, disproportionately favors White neighborhoods, as does the mapping of historic districts. While the impact is different, the commonality in all of this is that agencies seemingly spend more resources planning for White neighborhoods than Black. City resources are finite, and for every staff member working on a rezoning action in a White neighborhood, or evaluating contributing buildings to a proposed historic district, there is an opportunity cost that often means neglecting the Black neighborhood. Creative strategies that expand the attention paid to minority communities – without it only being to accommodate more affordable housing for the city – would be far more equitable.

5.3. Data and Other Research Limitations

While much of the data used in this analysis was rich and authoritative, there were a few instances where additional or more nuanced data would have been desirable.

5.3.1. Subway and Highway Datasets

Some datasets for this project had limited availability of information that would authoritatively state how the dataset changed over time, whether expanding, or contracting in its geography. For some data sources, like urban renewal designations, two datasets could be combined to show the nuance of growing adoption areas over time. For other datasets however, no authoritative source for year of completion or decommission existed, making the dataset static in all runs. Specifically, this was true for the subway access and highway proximity datasets.

The subway system began construction in earnest in the early 1900s and largely reached the system in place today by the 1940s after the city consolidated the prior Interborough Rapid Transit (IRT) Company and Brooklyn-Manhattan Transit (BMT) Corporation contracts with their Independent Subway System (IND) lines. Since then, changes have been slow and largely de minimis. The large moves include the deactivation of the 3rd Ave. El, the opening of the 2nd Ave. subway and the extension of the Flushing line to Hudson Yards. However, these may not have had tremendous impacts on the datasets.

The closure of the 3rd Ave. El had begun in the 1950s in Manhattan and by the 70s all that remained was a vestigial piece in the Bronx. Since this line necessitated a transfer to continue downtown into Manhattan, it is easy to imagine ridership diminishing as its connectedness waned.

New subway lines / extensions since 2000 have brought new connectivity to areas with historic density from prior elevated service, but are only the first phases of decades-long planned enhancements; the Second Avenue line is planned to extend into Harlem (MTA 2022) while the MTA has been exploring the extension of the Flushing line to New Jersey under the Hudson River (McGeehan 2018). While the recent enhancements are tremendous, they do not revolutionize subway access in their service boundaries; the true impacts will be yielded in future phases which will bring greater connectivity to areas with limited service.

Beyond these larger moves, several smaller changes have been made, including closing the Culver El, and extending the E train to Jamaica (nycsubway.org n.d.). While painstakingly comparing the subway maps (which graphically modify the underlying geography to better visualize the lines) to reconstruct the time applicable geography would have been interesting, it was not feasible in the time window for this project.

The parkway, expressway and highway system in NYC is one of the oldest in the nation and is largely the product of the controversial vision of Robert Moses. Many of the initial planning and construction began as early as the 1930s, using federal funding to stimulate the economy from the crippling depression. As such, the majority of highways that now crisscross the city were already constructed by 1960. Like the subway issues, there is no central repository denoting when highway components were constructed. Complicating this, many highways were constructed in phases, and several segments progressively upgraded from major roads to highway class roadways in the same geographies. So, cumulatively, while being infeasible to partition the dataset into different eras, it may not have had tremendous impacts.

One other aspect of the highway analysis that was limited involved assessing its impacts on adjacent areas. While this analysis used buffers to capture the land area impacted, it would have been more meaningful to capture the housing units abutting them. However, while the DCP has databases that denote the number of units on a zoning lot, it does not extend back past 2002. Using this to predict 1960 and 1990 housing densities seemed a very flawed assumption.

Beyond the data itself, the buffers being drawn around each in ArcGIS Pro in both the subway and highway analyses as a means for establishing proximity could also be improved. Using the Network Analyst tools in ArcGIS Pro, for example, could have incorporated the actual street network, and devised a more accurate walkshed for subway station proximity. In the highway analysis, having a more scientifically backed radius connected to the impacts of airborne particulate matter from vehicular emissions, understanding the passenger vehicle versus freight splits (and associated differentials in emissions) of different highways, and accounting for the presence of on and off-ramps would all have contributed to a more robust dataset.

5.3.2. Zoning Datasets

Initially this project was seeking to also query the influence of zoning changes in particular areas and determine if they may correlate with population clustering or segregation. For example, would a series of rezonings to reduce the residential capacity in one neighborhood have ripple effects across others by limiting future supply and potentially squeezing current and would-be residents into other areas? Would the residential racial makeup change as a result?

While much of the zoning district analysis is capturing the effects of those rezonings, as many tools like contextual zoning districts did not exist in 1961 so any occurrence represents a rezoning. What it does not indicate, however, is its relation to the previous district and whether it is increasing or decreasing capacity. Integrating this nuance would have been very compelling but was unfortunately not in the scope of this project. While DCP has shapefiles representing the boundaries of rezoned areas, they do not show every individual district change within. Historically, the Department has done large neighborhood-level rezonings which combine different moments of increased and decreased capacity, a sort of grand bargain strategy to effectuate change. Without the individual district changes it is impossible to capture the impact of those rezonings, however.

While the district designations themselves convey some very interesting narratives, there are certainly additional layers to the complexity of the zoning that are likely cloaking some additional nuance and spatial heterogeneity. For example, in 2009 the Department created a Voluntary Inclusionary Housing (VIH) program that was often, but not always mapped in conjunction with medium and high-density zoning changes, and in 2016, a Mandatory

Inclusionary Housing (MIH) program was established for the next tranche of rezonings. These boundaries change the FARs, heights and, by virtue of affordability requirements, the residents. Teasing this intersectionality out, which only really impacted the last decade, seemed daunting and better suited for a more granular study.

Another limitation is that there are many locations in the city where a textual modification in the Zoning Resolution modifies the typical district form. For example, along the waterfront, the Department enacted citywide waterfront public access requirements in 1993 and generated smaller footprint, tower-like forms for many districts to help enhance sight lines from upland areas. Many non-contextual districts have subsequently been mapped along the waterfront but because of the geographically specific modifications, the districts here do not have much similarity to the same district elsewhere, as they are height capped and have restricted footprints. Similarly, in the tower districts along the avenues of Manhattan, stricter tower controls in 'tower-on-a-base' regulations alter the permitted building form to necessitate a squat building base to match the tenement building context and restrict tower coverage to create a de-facto height limit. The portion of these districts impacted by these amendments may disproportionately correlate to White population change or existing White populations, respectively.

Another example of significantly divergent regulations not being captured by zoning maps can be seen in some of the most suburban areas of the city – Staten Island and portions of the northeastern Bronx – which are located within Lower Density Growth Management Areas. Special textual modifications increase parking requirements, minimum lot sizes, and a series of other building controls within the Zoning Resolution, to limit development in such a way that housing production and associated neighborhood socioeconomics and demographics have likely been disproportionately impacted.

5.3.3. Market-based Counterfactuals

While this thesis attempted to include a couple of market-based variables as a counterpoint to the influence of more overt government policies in codifying or perpetuating segregation in the city, those attempts had their limitations, and there were other measures that would have added nuance to the model.

Access is a core aspect to housing delivery in a market-based system, as price premiums are commonplace for shorter commutes, a greater range of services, and a larger diversity of amenities. This analysis was simplistic in using a distance from the region's core as a proxy for access in several ways. First, distance was measured in a Euclidian fashion; the evaluation could have been richer if using the ArcGIS Network Analyst tools to generate street grid-derived travel-sheds and using public transit modes to derive comparative transit times. Next, the evaluation uses the center of the two CBDs as the apex of access; a more rigorous evaluation could have combined the travel-shed work with a measure of jobs available. For instance, using data from the Bureau of Labor Statistics, a job access index could have been generated to comparatively evaluate the number of jobs available in one hour of commute time from the centroid of each census tract. Yet, even this would still be simplistic as it doesn't account for disparity in access at the origin census tract in the range of neighborhood retail and services. A census tract that is a half an hour from a half of million jobs in the South Bronx but is in a food desert should not be evaluated as having the same level of access as a tract in an affluent neighborhood of Brooklyn with a range of restaurants and specialty grocers.

Apart from the shortcomings of the variables that were evaluated, this thesis was limited by a general difficulty in teasing out the roles of the government versus the free-market in creating the racial wealth gap, and disentangling one's influence versus the other in perpetuating pre-existing divisions. The chief instrument for wealth creation for most middle-class families in the United States is derived from their home, and its increase in value over the term of their mortgage (Rothstein 2017). The federal government played a role in blocking access to this wealth creation for countless Black families by deeming investments in Black neighborhoods as risky investments, and channeling FHA-backed mortgages – the linchpin to most home purchases – to suburban areas where local government controls often filtered out the housing typologies affordable to most minority families (Rothstein 2017). Private sector real estate brokerage firms doubled down on redlining tactics by discriminating in sales in predominantly White areas (Coates 2014). Today, the combination of this public and private sector racism has generated a profound schism in wealth between Black and White families; the average Black family has just 13 cents in wealth for every dollar held by White families (The White House 2021). This racial wealth divide spawns differences in the ability to afford college tuition, start businesses, and a host of quality-of-life metrics that only perpetuate the divide generationally (Perry, Rothwell, and Harshbarger 2018). Shifts in Black populations in the city may certainly be attributable, in part, to zoning or other policy changes, and the associated influence they exert on housing supply and costs, but displacement pressures are certainly intensified by the pre-existing racial wealth gap that began generations ago.

5.4. Additional Avenues of Inquiry

This thesis spurred additional thoughts on several ways to either expand this analysis, or develop interrelated stand-alone research tracks.

5.4.1. Gentrification

Between 2010 and 2020, the Black population in NYC dropped by 4.5 percent while the city's overall population grew by 7.7 percent (NYC DCP 2021). Trends like this are incredibly troubling, and it is paramount to evaluate them, but extremely difficult to analyze through 30-year time windows, where entire generations of change have occurred.

In order to more fully evaluate trends like gentrification, more granular spatio-temporal analyses could be conducted. For example, generating a year 2000 zoning map, and coupling this with the generated 1990 and pre-existing 2010 and 2020 maps would give 10-year increments instead of 30, and dial in to see the change in influence of certain variables, like two-family districts, and contextual districts. For this type of analysis, targeting zoning map changes, instead of relying on contextual districts and other new zoning tools as proxies for them, and being able to tease out whether these changes constituted upzonings or downzonings, with added or diminished localized zoning capacity, could layer substantial nuance onto the conversation.

5.4.2. 1916 Zoning

As noted previously, the 1961 Zoning Resolution was a complete overhaul of the 1916 Zoning Resolution. The 1916 Resolution had no singular districts; instead, there were three, derived from use, height, and area maps (NYC DCP 2018). The genesis of this Resolution was, in part, discriminatory – the continued encroachment of garment factories, and their immigrant workers, into the vicinity of department stores along Fifth avenue and was an affront to the White affluent neighbors who patronized those stores (The Skyscraper Museum 1997-2020).

City officials soon called for distinct zones for residences, businesses, and industrial uses, to address the land use conflict (which may well have been a class conflict, as garment factories were not belching noxious emissions). The 1916 zoning maps were still quite liberal, with large swaths of the city zoned 'unrestricted', where any use was permitted, but it did have designated areas where only residential uses were allowed (Harrison, Ballard & Allen 1950).

Over time, the 1916 Resolution also was amended to address prevailing trends and planning best-practices. In 1944, a substantial amendment cut heights, increased mandated open space, and introduced new area district types that only permitted single-family homes (NYC DCP 2018). Extending the spatio-temporal spectrum to include some of these early designations would be fascinating. It would be particularly interesting to determine if some of these restrictions correlate closely with HOLC ratings, and therefore might be a truer original source of etching segregation into the landscape.

5.4.3. Comparative Measures Between Cities

This analysis has focused exclusively on assessing the persistence of racialized policies in New York, but the cocktail of federal and local planning policies used to divide Black and White population groups is hardly unique to New York. Comparing a series of cities would by fascinating. Cities in differing regions of the US with divergent cultural histories, development timelines and sizes would be interesting to compare to see if they might uniquely influence the degree to which these discriminatory policies explain the distribution of Black residents in each respective city. For example, adding a city like St. Louis, which has the dubious legacy of having two landmark Supreme Court cases striking down their racist housing practices (Rothstein 2014) would be compelling, as would Sun Belt cities like Phoenix or Las Vegas which experienced the majority of their growth after HOLC designations, and may therefore have experienced fewer overlapping layers of segregatory policies.

5.4.4. Other Segregation Studies

This analysis focuses exclusively on race, specifically the impact of government policies on Black and White segregation. New York, the melting pot that it is, certainly has other races and ethnicities equally worth studying to evaluate whether other minorities have historically received disparate treatment, similar to Black populations.

Besides race, socio-economic status divides the spatial landscape of many US cities, and in high-cost cities like New York, the disparity is heightened. Determining correlations between the same planning variables and historic median household incomes may be very illuminating. Historically, a prevalence of low-income households may explain HOLC D area designations more than race.

5.5. Conclusion

The perniciousness of redlining in New York for the Black community is augmented both by the cascade of other deleterious policies in a spatially duplicative boundary and by the reciprocating bulwark of overlapping White privilege. Future planning policies must be mindful of their historic impact, and should redress their role in segregating communities, and the disparate opportunities and access that emerge as byproducts of this second-class citizen status. Ideally this thesis contributes fresh insight into salient issues and elucidates pragmatic solutions borne of the analysis.

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Appendix A: Detailed Regression Results – Population density change

1960 - Black change in population per acre (1930-1960)										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.68973		0.51482	***	0.43903	***	0.13873	***	0.65320	***
Distance to core	-0.02403			.						
Percent Subway Proximate	0.54708	***	0.56205	***	0.62530	***	0.16820	*	0.10134	
Percent HOLC A areas	-0.85135		-0.68431	*						
Percent HOLC B areas	-0.28873									
Percent HOLC C areas	-0.21368									
Percent HOLC D areas	1.33500	*	1.58014	***	1.68020	***	0.52538	***	0.76532	***
Percent Non-HOLC areas	-0.52877		-0.36201	**						
Percent Urban Renewal Areas	-7.27472	***	-7.23638	***	-7.27599	***	-6.87654	***	-5.91391	***
Public housing density per acre	0.63290	***	0.63721	***	0.62282	***	0.55838	***	0.60526	***
Percent highway proximate	-0.60783	**	-0.64030	**	-0.69368	**	-0.41485	**	-0.28828	***
Percent single-family zoning	0.25477									
Percent two-family zoning	-0.68430	.	-1.02301	***	-0.99969	***	-0.33904		-0.31384	
Percent 'contextual' multi-family zoning	NA									
Percent 'non-contextual' multi-family zoning	0.37132									
Percent high-density 'tower' districts	-0.55396		-0.80437	**	-1.09870	***	-0.02379		1.01583	*
Percent former M-districts	NA									
Percent pure non-residential districts	-0.52268	.	-0.78005	***	-0.96313	***	-0.65357	***	-0.72672	***
Percent Special Purpose District	NA									
Percent historic district	NA									
adjusted R-squared	0.27340		0.27420		0.27120					
Rho							0.71690	***		
Lambda									0.76834	***
AIC					7139.20		5978.70		5984.50	
p-value of residuals (LM)					< 2.2e-16		3.13E-07		0.99900	

Table 16. Regression results, Black population density change, 1930-1960

1960 - White change in population per acre (1930-1960)										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-9.72209	***	-9.16892	***	-9.38374	***	-3.38867	***	-11.53386	***
Distance to core	0.51306	***	0.50213	***	0.52246	***	0.11649		0.83692	***
Percent Subway Proximate	-1.37229	***	-1.36417	***	-1.37031	***	-0.64861	***	-0.96184	***
Percent HOLC A areas	4.52746	***	4.29280	***	4.33818	***	2.59505	***	4.28754	***
Percent HOLC B areas	5.39658	***	5.16029	***	5.18765	***	2.64237	***	4.07054	***
Percent HOLC C areas	3.77046	***	3.54456	***	3.56592	***	1.76474	***	2.37676	***
Percent HOLC D areas	0.22557									
Percent Non-HOLC areas	4.74883	***	4.51873	***	4.53170	***	2.26994	***	2.48920	***
Percent Urban Renewal Areas	-3.87781	*	-3.92396	*						
Public housing density per acre	0.37556	***	0.37314	***	0.37080	***	0.45220	***	0.47825	***
Percent highway proximate	1.18095	**	1.18207	**	1.17127	**	0.62388	.	0.50436	
Percent single-family zoning	3.36005	***	3.03007	***	2.99461	***	1.08984	***	1.59418	**
Percent two-family zoning	2.67582	***	2.31928	***	2.29520	***	1.61943	**	1.94913	**
Percent 'contextual' multi-family zoning	NA									
Percent 'non-contextual' multi-family zoning	3.09600	***	2.71351	***	2.68843	***	1.71360	***	1.98810	***
Percent high-density 'tower' districts	3.54160	***	3.16403	***	3.13901	***	1.85364	***	2.93222	***
Percent former M-districts	NA									
Percent pure non-residential districts	0.43188									
Percent Special Purpose District	NA									
Percent historic district	NA									
adjusted R-squared	0.32770		0.32810		0.32690					
Rho							0.63951	***		
Lambda									0.68595	***
AIC					9925.90		9186.50		9204.40	
p-value of residuals (LM)					< 2.22e-16		3.90E-05		0.99600	

Table 17. Regression results, White population density change, 1930-1960

1990 - Black change in population per acre (1960-1990)										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-2.79972	**	-2.02030	***	-1.17805	***	-0.91091	***	-0.06280	
Distance to core	0.05838									
Percent Subway Proximate	0.14939									
Percent HOLC A areas	1.45346	.	1.49021	.						
Percent HOLC B areas	3.44919	***	3.49805	***	2.38824	***	0.87896	***	1.00621	***
Percent HOLC C areas	3.07646	***	3.12884	***	2.01843	***	0.72639	***	0.84762	***
Percent HOLC D areas	1.09548	.	1.13527	.						
Percent Non-HOLC areas	1.90476	*	1.89180	*	0.86307	***	0.25606	.	-0.05422	
Percent Urban Renewal Areas	0.33527									
Public housing density per acre	0.13974	**	0.14210	**	0.14528	**	0.17682	***	0.18397	
Percent highway proximate	0.72896	*	0.68071	*						
Percent single-family zoning	1.39744	**	1.20651	**	1.27025	**	0.73473	**	0.76361	*
Percent two-family zoning	0.33007									
Percent 'contextual' multi-family zoning	1.83681	**	1.66098	**	1.75624	**	1.20967	**	1.39691	*
Percent 'non-contextual' multi-family zoning	2.40994	***	2.20678	***	2.20902	***	1.42135	***	1.73020	***
Percent high-density 'tower' districts	3.13736	***	2.91547	***	2.91944	***	1.68727	***	1.92694	**
Percent former M-districts	3.58491	***	3.34546	***	3.34009	***	1.91644	***	1.50865	*
Percent pure non-residential districts	1.39672	**	1.24620	***	1.35010	***	0.39185	.	-0.08553	
Percent Special Purpose District	-0.73135	**	-0.71385	**	-0.63544	**	-0.14124		0.03142	
Percent historic district	-0.17294	**'	-0.17591	***	-0.17612	***	-0.08988	*	-0.15088	**
adjusted R-squared	0.12010		0.12090		0.11920					
Rho							0.76871	***		
Lambda									0.79692	***
AIC					8723.00		7407.70		7358.70	
p-value of residuals (LM)					< 2.2e-16		1.04E-07		0.99900	

Table 18. Regression results, Black population density change, 1960-1990

1990 - White change in population per acre (1960-1990)										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-3.63611	**	-3.11487	***	-3.12820	***	-1.25075	***	-2.51354	***
Distance to core	0.09584									
Percent Subway Proximate	-1.41780	***	-1.44782	***	-1.43010	***	-0.65590	***	-1.02922	***
Percent HOLC A areas	0.67763		1.24493	*						
Percent HOLC B areas	-0.88262		-0.34912	.						
Percent HOLC C areas	-0.64098									
Percent HOLC D areas	-0.38469									
Percent Non-HOLC areas	2.45076	**	2.95598	***	2.99110	***	1.71135	***	2.03755	***
Percent Urban Renewal Areas	0.69721									
Public housing density per acre	-0.43067	***	-0.40818	***	-0.40410	***	-0.27615	***	-0.29928	***
Percent highway proximate	0.23560									
Percent single-family zoning	0.89639	.	1.05812	**	1.11730	**	0.24135		0.66282	
Percent two-family zoning	3.08476	***	3.19061	***	3.22170	***	1.20514	**	1.30827	**
Percent 'contextual' multi-family zoning	4.85376	***	5.00832	***	5.30710	***	2.55529	***	3.49561	***
Percent 'non-contextual' multi-family zoning	1.23253	*	1.40598	***	1.39590	***	0.55255	*	0.61295	*
Percent high-density 'tower' districts	3.07360	***	3.11375	***	3.69780	***	1.18711	**	1.63365	*
Percent former M-districts	3.30282	***	3.30771	***	3.55840	***	1.83040	*	2.27839	**
Percent pure non-residential districts	-0.27119									
Percent Special Purpose District	0.38007		0.37448							
Percent historic district	0.09782	.	0.08148	.						
adjusted R-squared	0.21910		0.21940		0.21590					
Rho							0.60824	***		
Lambda									0.63461	***
AIC					9096.50		8487.20		8533.10	
p-value of residuals (LM)					< 2.2e-16		4.77E-15		0.99900	

Table 19. Regression results, White population density change, 1960-1990

2020 - Black change in population per acre (1990-2020)										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-2.14893	**	-2.17412	**	-0.64463	***	-0.71377	***	-0.74784	***
Distance to core	0.15580	*	0.15548	*						
Percent Subway Proximate	-0.49276	***	-0.50203	***	-0.50951	***	-0.15670		-0.26084	
Percent HOLC A areas	-0.18736									
Percent HOLC B areas	-1.55114	*	-1.49995	***	-1.46560	***	-0.60524	***	-0.71300	**
Percent HOLC C areas	-1.39771	*	-1.34632	***	-1.31968	***	-0.61254	***	-0.75103	***
Percent HOLC D areas	-1.07908		-1.05083	***	-1.04147	***	-0.41287	**	-0.58863	**
Percent Non-HOLC areas	-0.03101									
Percent Urban Renewal Areas	-0.37159									
Public housing density per acre	-0.40148	***	-0.40360	***	-0.41407	***	-0.31568	***	-0.34229	***
Percent highway proximate	-0.58911	.	-0.58405	.						
Percent single-family zoning	1.50621	***	1.48988	***	1.67491	***	1.28986	***	1.66435	***
Percent two-family zoning	3.08178	***	3.07739	***	3.27389	***	1.94609	***	2.30846	***
Percent 'contextual' multi-family zoning	1.37326	***	1.36959	***	1.37042	***	1.34775	***	1.52013	***
Percent 'non-contextual' multi-family zoning	2.02031	***	2.00866	***	2.10484	***	1.52524	***	1.42245	***
Percent high-density 'tower' districts	2.93886	***	2.89182	***	2.63514	***	1.77797	***	1.89396	***
Percent former M-districts	4.05261	***	4.07515	***	3.82214	***	2.73067	***	3.10566	***
Percent pure non-residential districts	1.88504	***	1.87016	***	1.82094	***	1.52461	***	1.73296	***
Percent Special Purpose District	-0.00686									
Percent historic district	-2.49059	***	-2.50145	***	-2.63954	***	-1.34023	***	-1.57972	***
adjusted R-squared	0.15550		0.15680		0.15400					
Rho							0.70160	***		
Lambda									0.72687	***
AIC					9053.20		8051.80		8067.20	
p-value of residuals (LM)					< 2.2e-16		1.40E-13		0.99900	

Table 20. Regression results, Black population density change, 1990-2020

2020 - White change in population per acre (1990-2020)										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	2.19378	**	2.39521	***	2.88188	***	0.53389		0.40695	
Distance to core	-0.29502	***	-0.29666	***	-0.35830	***	-0.05976		-0.13512	*
Percent Subway Proximate	0.07700									
Percent HOLC A areas	-2.20727	*	-2.40063	***	-2.25826	***	-0.95910	*	-0.25598	
Percent HOLC B areas	0.37632									
Percent HOLC C areas	0.25649									
Percent HOLC D areas	2.42726	**	2.09902	***	2.10609	***	0.69045	***	1.00516	***
Percent Non-HOLC areas	1.09373		0.78679	***	0.85536	***	0.47804	***	1.27606	***
Percent Urban Renewal Areas	1.80685	**	1.80395	**	1.80183	**	0.15927		0.13658	
Public housing density per acre	-0.03472									
Percent highway proximate	-0.98730	**	-1.01797	**	-1.04139	**	-0.22324		0.01288	
Percent single-family zoning	-0.59402		-0.53971							
Percent two-family zoning	-1.50494	***	-1.48083	***	-1.28492	***	-0.61967	***	-0.53106	*
Percent 'contextual' multi-family zoning	-1.10738	*	-1.01753	***	-0.75491	**	-0.41050	*	-0.34243	
Percent 'non-contextual' multi-family zoning	-1.63042	***	-1.57266	***	-1.33750	***	-0.75676	***	-1.13377	***
Percent high-density 'tower' districts	0.12007									
Percent former M-districts	-0.33462									
Percent pure non-residential districts	-0.15744									
Percent Special Purpose District	0.83967	***	0.89449	***	0.92849	***	0.34087	*	0.69657	**
Percent historic district	0.60807		0.66740	.						
adjusted R-squared	0.17780		0.17960		0.17850					
Rho							0.76708	***		
Lambda									0.79560	***
AIC					9485.30		8108.00		8099.70	
p-value of residuals (LM)					< 2.2e-16		< 2.2e-16		0.9990	

Table 21. Regression results, White population density change, 1990-2020

Appendix B: Detailed Regression Results – Dissimilarity

1960 - Black - other dissimilarity										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.14060	**	0.11293	***	0.11159	***	0.00870	***	0.01631	*
Distance to core	-0.00338									
Percent Subway Proximate	0.05199	***	0.05319	***	0.05380	***	0.00280		0.00547	
Percent HOLC A areas	-0.06997	.	-0.07452	***	-0.07942	***	-0.01514	*	-0.02757	*
Percent HOLC B areas	-0.09419	**	-0.10001	***	-0.10218	***	-0.01549	***	-0.02102	***
Percent HOLC C areas	-0.09670	**	-0.10305	***	-0.10518	***	-0.01154	***	-0.01145	**
Percent HOLC D areas	0.00454									
Percent Non-HOLC areas	-0.09962	**	-0.10485	***	-0.10743	***	-0.01920	***	-0.02264	***
Percent Urban Renewal Areas	0.01605									
Public housing density per acre	0.00118									
Percent highway proximate	-0.03028	*	-0.03011	*						
Percent single-family zoning	0.01320									
Percent two-family zoning	-0.02287		-0.02870							
Percent 'contextual' multi-family zoning	NA									
Percent 'non-contextual' multi-family zoning	0.00534									
Percent high-density 'tower' districts	-0.05877	*	-0.05700	***	-0.05550	**	0.00437		0.02479	.
Percent former M-districts	NA									
Percent pure non-residential districts	-0.05012	**	-0.05350	***	-0.05552	***	-0.00719	*	0.00428	
Percent Special Purpose District	NA									
Percent historic district	NA									
adjusted R-squared	0.18490		0.18640		0.18450					
Rho							0.95806	***		
Lambda									0.96758	***
AIC					-5260.40		-9625.10		-9588.60	
p-value of residuals (LM)					< 2.2e-16		4.33E-13		0.00100	

Table 22. Regression results, Black-other dissimilarity, 1960

1960 - White - other dissimilarity										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.12634	**	0.11286	*	0.11152	***	0.00873	***	0.01624	
Distance to core	-0.00208									
Percent Subway Proximate	0.05272	***	0.05341	***	0.05402	***	0.00279		0.00518	
Percent HOLC A areas	-0.06833	.	-0.07393	***	-0.07881	***	-0.01482	*	-0.02713	*
Percent HOLC B areas	-0.09110	**	-0.09817	***	-0.10034	***	-0.01533	***	-0.02038	***
Percent HOLC C areas	-0.09381	**	-0.10126	***	-0.10338	***	-0.01139	***	-0.01078	*
Percent HOLC D areas	0.00600		-0.10126	***						
Percent Non-HOLC areas	-0.09772	**	-0.10405	***	-0.10663	***	-0.01909	***	-0.02213	***
Percent Urban Renewal Areas	0.02213									
Public housing density per acre	0.00159									
Percent highway proximate	-0.03060	*	-0.03019	*						
Percent single-family zoning	0.01115									
Percent two-family zoning	-0.02354		-0.02834							
Percent 'contextual' multi-family zoning	NA									
Percent 'non-contextual' multi-family zoning	0.00440									
Percent high-density 'tower' districts	-0.05838	*	-0.05872	***	-0.05722	***	0.00377		0.02406	.
Percent former M-districts	NA									
Percent pure non-residential districts	-0.04986	**	-0.05335	***	-0.05539	***	-0.00733	*	0.00412	
Percent Special Purpose District	NA									
Percent historic district	NA									
adjusted R-squared	0.18150		0.18320		0.18140					
Rho							0.95673	***		
Lambda									0.96640	***
AIC					-5250.70		-9573.80		-9537.20	
p-value of residuals (LM)					< 2.2e-16		4.89E-11		0.00100	

Table 23. Regression results, White-other dissimilarity, 1960

1990 - Black - other dissimilarity										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.20801	***	0.23303	***	0.30573	***	0.04416	*	0.28262	*
Distance to core	-0.01678	***	-0.01790	***	-0.01533	**	-0.00334	.	-0.02058	
Percent Subway Proximate	0.00869									
Percent HOLC A areas	0.15543	**	0.15606	**						
Percent HOLC B areas	0.14866	**	0.15288	***						
Percent HOLC C areas	0.14061	**	0.14508	**						
Percent HOLC D areas	0.16824	***	0.17173	***	0.03532	***	0.00861	*	0.00266	
Percent Non-HOLC areas	0.12755	**	0.12643	**						
Percent Urban Renewal Areas	0.05687	.	0.05857	.						
Public housing density per acre	-0.00084									
Percent highway proximate	-0.03379	.	-0.03604	.						
Percent single-family zoning	0.01528									
Percent two-family zoning	-0.02661		-0.04486	*						
Percent 'contextual' multi-family zoning	0.14893	***	0.13415	***	0.15145	***	0.03549	*	0.01674	
Percent 'non-contextual' multi-family zoning	0.01995									
Percent high-density 'tower' districts	-0.03339		-0.04718	.						
Percent former M-districts	-0.10501	*	-0.11772	*						
Percent pure non-residential districts	-0.08987	***	-0.10326	***	-0.10770	***	-0.01931	**	0.00718	
Percent Special Purpose District	-0.02283	.	-0.02161							
Percent historic district	0.00693	*	0.00726	*						
adjusted R-squared	0.07501		0.07597		0.06127					
Rho							0.89104	***		
Lambda									0.90559	***
AIC					-3857.80		-6589.90		-6563.90	
p-value of residuals (LM)					< 2.2e-16		2.58E-08		0.99900	

Table 24. Regression results, Black-other dissimilarity, 1990

1990 - White - other dissimilarity										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.03243		-0.03093		-0.02791		-0.06256	***	0.01912	
Distance to core	-0.00534									
Percent Subway Proximate	0.02398	**	0.02887	***	0.03262	***	0.00988	*	0.00895	
Percent HOLC A areas	0.28085	***	0.26790	***	0.28931	***	0.10412	***	0.10825	**
Percent HOLC B areas	0.26886	***	0.25910	***	0.25854	***	0.10383	***	0.10338	***
Percent HOLC C areas	0.25189	***	0.24208	***	0.23890	***	0.10841	***	0.11848	***
Percent HOLC D areas	0.29470	***	0.28942	***	0.29687	***	0.12056	***	0.12395	***
Percent Non-HOLC areas	0.25520	***	0.24820	***	0.25327	***	0.10118	***	0.11327	***
Percent Urban Renewal Areas	0.06887	*	0.07271	*						
Public housing density per acre	0.00628	*	0.00640	*						
Percent highway proximate	-0.02451									
Percent single-family zoning	-0.02700	.								
Percent two-family zoning	-0.01214									
Percent 'contextual' multi-family zoning	0.23466	***	0.25041	***	0.23812	***	0.06716	***	0.08241	**
Percent 'non-contextual' multi-family zoning	-0.01336									
Percent high-density 'tower' districts	-0.01307									
Percent former M-districts	-0.20846	***	-0.18848	***	-0.19754	***	-0.06556	*	-0.07642	*
Percent pure non-residential districts	-0.12525	***	-0.11374	***	-0.11701	***	-0.02995	***	-0.00871	
Percent Special Purpose District	0.03598	**	0.03654	**						
Percent historic district	0.01398	***	0.01534	***	0.01520	***	0.00416	*	0.00141	
adjusted R-squared	0.14170		0.14230		0.13690					
Rho							0.84444	***		
Lambda									0.87253	***
AIC					-3872.20		-5966.10		-5910.80	
p-value of residuals (LM)					< 2.2e-16		0.00015		0.99000	

Table 25. Regression results, White-other dissimilarity, 1990

2020 - Black - other dissimilarity										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.00360		0.00155		-0.02931		-0.04718	*	0.01570	
Distance to core	0.00980	*	0.00983	*	0.01515	***	0.00454	*	0.00684	*
Percent Subway Proximate	-0.01988	*	-0.01964	*						
Percent HOLC A areas	0.02855									
Percent HOLC B areas	-0.00355									
Percent HOLC C areas	0.00245									
Percent HOLC D areas	0.06396		0.06342	***	0.05762	***	0.01413	***	0.01628	*
Percent Non-HOLC areas	0.01956		0.01767							
Percent Urban Renewal Areas	0.05016		0.04916							
Public housing density per acre	-0.00724	*	-0.00722	*						
Percent highway proximate	-0.04679	*	-0.04573	*			0.00895		0.04044	***
Percent single-family zoning	0.04749	.	0.04228	*						
Percent two-family zoning	0.05312	*	0.04768	**						
Percent 'contextual' multi-family zoning	0.10112	***	0.09448	***	0.05086	***	0.02781	***	0.02757	**
Percent 'non-contextual' multi-family zoning	0.10954	***	0.10250	***	0.05523	***	0.01210	*	0.00153	
Percent high-density 'tower' districts	0.14562	***	0.14428	***	0.11650	***	0.03191	**	0.01524	
Percent former M-districts	0.02060									
Percent pure non-residential districts	0.00663									
Percent Special Purpose District	-0.06055	***	-0.05911	***	-0.06387	***	-0.00546		0.00165	
Percent historic district	0.06759	**	0.06940	**	0.07022	**	0.00932		-0.00933	
adjusted R-squared	0.06291		0.06443		0.05533					
Rho							0.88891	***		
Lambda									0.89819	***
AIC					-3820.10		-6645.70		-6692.40	
p-value of residuals (LM)					< 2.2e-16		1.32E-09		0.99900	

Table 26. Regression results, White-other dissimilarity, 1990

2020 - White - other dissimilarity										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.03473		0.03535		-0.03210		-0.08022	***	0.00088	
Distance to core	-0.00631	.	-0.00497							
Percent Subway Proximate	-0.00478									
Percent HOLC A areas	0.25886	***	0.22221	***	0.23421	***	0.14476	***	0.16835	***
Percent HOLC B areas	0.17472	***	0.14973	***	0.15208	***	0.10957	***	0.11817	***
Percent HOLC C areas	0.19015	***	0.16229	***	0.16552	***	0.11753	***	0.13098	***
Percent HOLC D areas	0.22462	***	0.19047	***	0.20153	***	0.11881	***	0.13481	***
Percent Non-HOLC areas	0.17767	***	0.14643	***	0.15798	***	0.10276	***	0.11755	***
Percent Urban Renewal Areas	0.06073	.	0.05673	.						
Public housing density per acre	-0.00483	.	-0.00486	.						
Percent highway proximate	0.00029									
Percent single-family zoning	-0.02236									
Percent two-family zoning	0.02233		0.04151	**	0.04017	**	-0.00134		-0.02871	**
Percent 'contextual' multi-family zoning	0.06541	**	0.08279	***	0.08879	***	0.02515	***	0.01639	
Percent 'non-contextual' multi-family zoning	0.05695	**	0.07617	*	0.07729	***	0.00870		-0.01190	
Percent high-density 'tower' districts	0.16826	***	0.18393	***	0.20487	***	0.03046	**	0.01426	
Percent former M-districts	-0.06690	.	-0.05356							
Percent pure non-residential districts	-0.02741									
Percent Special Purpose District	0.07389	***	0.07304	***	0.06950	***	0.01122	.	0.01777	.
Percent historic district	0.14575	***	0.14550	***	0.15147	***	0.02753	**	0.01588	
adjusted R-squared	0.15430		0.15500		0.15260					
Rho							0.88325	***		
Lambda									0.90295	***
AIC					-4331.70		-6897.40		-6862.40	
p-value of residuals (LM)					< 2.2e-16		0.0441		0.9460	

Table 27. Regression results, White-other dissimilarity, 2020

Appendix C: Detailed Regression Results – Isolation

1960 - Black isolation										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.05007		0.01936		0.08167	***	0.00708	***	0.01222	
Distance to core	0.00605	.	0.00594	.						
Percent Subway Proximate	0.03931	***	0.03885	***	0.03666	***	-0.00108		0.00058	
Percent HOLC A areas	-0.12369	***	-0.10214	***	-0.10238	***	-0.00850		-0.01108	
Percent HOLC B areas	-0.13749	***	-0.11636	***	-0.11728	***	-0.01349	***	-0.02215	***
Percent HOLC C areas	-0.13532	***	-0.11437	***	-0.11450	***	-0.01067	***	-0.01555	***
Percent HOLC D areas	-0.02274									
Percent Non-HOLC areas	-0.12111	***	-0.09664	***	-0.09816	***	-0.01105	***	-0.01554	***
Percent Urban Renewal Areas	0.07373									
Public housing density per acre	0.00403		0.00392							
Percent highway proximate	-0.03593	**	-0.03382	*						
Percent single-family zoning	-0.01363									
Percent two-family zoning	-0.04140	.								
Percent 'contextual' multi-family zoning	NA									
Percent 'non-contextual' multi-family zoning	-0.02349									
Percent high-density 'tower' districts	-0.09341	***	-0.07308	***	-0.08730	***	-0.00189		0.00419	
Percent former M-districts	NA									
Percent pure non-residential districts	-0.05598	**	-0.03929	***	-0.04715	***	-0.00500	*	0.00031	
Percent Special Purpose District	NA									
Percent historic district	NA									
adjusted R-squared	0.18240		0.18230		0.17910					
Rho							0.97805	***		
Lambda									0.98389	***
AIC					-5342.30		-10855.00		-10829.00	
p-value of residuals (LM)					< 2.2e-16		< 2.2e-16		0.00100	

Table 28. Regression results, Black isolation, 1960

1960 - White isolation										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.25989	***	0.25781	***	-0.26470	***	-0.05032		0.28746	*
Distance to core	-0.03751	***	-0.03733	***	-0.03815	***	-0.00556	*	-0.02925	*
Percent Subway Proximate	0.07290	***	0.07284	***	0.07331	***	0.02665	***	0.03537	***
Percent HOLC A areas	0.31523	*	0.31550	**	0.32476	**	0.11150	***	0.08744	*
Percent HOLC B areas	0.32864	***	0.32883	***	0.33892	***	0.14006	***	0.14951	***
Percent HOLC C areas	0.28838	**	0.28849	***	0.30065	***	0.13478	***	0.14438	***
Percent HOLC D areas	0.23782	**	0.23751	***	0.24848	***	0.12461	***	0.12077	***
Percent Non-HOLC areas	0.21748		0.21734	***	0.22151	***	0.10397	***	0.09759	***
Percent Urban Renewal Areas	-0.02850									
Public housing density per acre	-0.00051									
Percent highway proximate	0.10008	***	0.09982	***	0.09539	***	0.01920	.	0.02933	*
Percent single-family zoning	0.11765	***	0.11761	***	0.05943	**	0.04105	***	0.03202	*
Percent two-family zoning	0.09692	**	0.09691	**						
Percent 'contextual' multi-family zoning	NA									
Percent 'non-contextual' multi-family zoning	0.14868		0.14865	***	0.08133	***	0.05113	***	0.04722	***
Percent high-density 'tower' districts	0.23959	***	0.23985	***	0.17830	***	0.08527	***	0.14045	***
Percent former M-districts	NA									
Percent pure non-residential districts	0.06415	**	0.06459	**						
Percent Special Purpose District	NA									
Percent historic district	NA									
adjusted R-squared	0.20830		0.20900		0.20610					
Rho							0.84585	***		
Lambda									0.87712	***
AIC					-3901.10		-6028.00		-5948.00	
p-value of residuals (LM)							2.92E-05		0.99900	

Table 29. Regression results, White isolation, 1960

1990 - Black isolation										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.21272	**	-0.25630	**	-0.28949	***	0.00528		0.10169	
Distance to core	0.02869	***	0.02859	***	0.03118	***	-0.00045		-0.00813	
Percent Subway Proximate	0.02637	**	0.02790	**	0.02598	**	-0.00200		-0.00476	
Percent HOLC A areas	0.01276									
Percent HOLC B areas	0.05791		0.06336	**	0.07170	**	-0.00287		-0.01173	.
Percent HOLC C areas	0.02135		0.02690	*	0.03391	**				
Percent HOLC D areas	0.09935	*	0.10734	***	0.11095	***	0.00713	*	0.00950	.
Percent Non-HOLC areas	-0.01604						-0.00273		0.00466	
Percent Urban Renewal Areas	0.10599	**	0.10602	**	0.10832	**	-0.00223		-0.00010	
Public housing density per acre	0.01337	***	0.01302	***	0.01411	***	0.00214	*	-0.00006	
Percent highway proximate	-0.07468	***	-0.07024	***	-0.07601	***	0.00126		0.01569	.
Percent single-family zoning	-0.06172	*								
Percent two-family zoning	-0.17244	***	-0.12262	***	-0.12117	***	0.00013		0.00637	
Percent 'contextual' multi-family zoning	-0.25381	***	-0.20370	***	-0.19352	***	-0.01579	.	-0.00580	
Percent 'non-contextual' multi-family zoning	-0.05615	.		.						
Percent high-density 'tower' districts	-0.05551									
Percent former M-districts	-0.15939	**	-0.11636	*						
Percent pure non-residential districts	-0.05988	*	-0.02783	.						
Percent Special Purpose District	-0.09059	***	-0.09205	***	-0.09035	***	-0.00273		-0.00531	
Percent historic district	0.01139	***	0.01123	***	0.01138	**	-0.00077		-0.00310	*
adjusted R-squared	0.14000		0.14020		0.13780					
Rho							0.94918	***		
Lambda									0.95331	***
AIC					-3463.00		-8230.40		-8228.30	
p-value of residuals (LM)					< 2.2e-16		1.35E-06		0.99700	

Table 30. Regression results, Black isolation, 1990

1990 - White isolation										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.34292	***	0.33791	***	0.38540	***	0.04740	*	0.39531	***
Distance to core	-0.03881	***	-0.03854	***	-0.04069	***	-0.00865	***	-0.03838	***
Percent Subway Proximate	-0.03317	***	-0.03330	***	-0.03394	***	-0.00099		0.00107	
Percent HOLC A areas	0.23920	***	0.23916	***	0.26218	***	0.08192	***	0.05303	.
Percent HOLC B areas	0.18644	***	0.18621	***	0.20294	***	0.07105	***	0.05850	**
Percent HOLC C areas	0.19553	***	0.19513	***	0.21137	***	0.07575	***	0.06778	**
Percent HOLC D areas	0.14158	***	0.14110	***	0.15107	***	0.06320	**	0.05236	*
Percent Non-HOLC areas	0.25533	***	0.25518	***	0.26483	***	0.07962	***	0.07790	***
Percent Urban Renewal Areas	-0.06221	*	-0.06161	*						
Public housing density per acre	-0.01513	***	-0.01508	***	-0.01507	***	-0.00413	***	-0.00260	*
Percent highway proximate	0.03653	*	0.03665	*						
Percent single-family zoning	0.04041		0.04321	.						
Percent two-family zoning	0.14667	***	0.14974	***	0.10467	***	0.00024		-0.01660	
Percent 'contextual' multi-family zoning	0.49312	***	0.49648	***	0.47033	***	0.09502	***	0.06754	**
Percent 'non-contextual' multi-family zoning	0.04402		0.04755	*						
Percent high-density 'tower' districts	0.04662		0.05053	.						
Percent former M-districts	-0.01486									
Percent pure non-residential districts	-0.06725	**	-0.06435	**	-0.10224	***	-0.01809	**	0.00372	
Percent Special Purpose District	0.10729	***	0.10697	***	0.10924	***	0.00758		0.01702	
Percent historic district	0.00579	*	0.00574	*						
adjusted R-squared	0.32430		0.32450		0.32120					
Rho							0.85465	***		
Lambda									0.89463	***
AIC					-4415.60		-7174.30		-7105.00	
p-value of residuals (LM)					< 2.2e-16		< 2.2e-16		0.99900	

Table 31. Regression results, White isolation, 1990

2020 - Black isolation										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.29407	***	-0.31085	***	-0.31058	***	-0.03033	*	-0.03033	
Distance to core	0.04538	***	0.04467	***	0.04409	***	0.00356	**	0.00356	**
Percent Subway Proximate	-0.02144	*	-0.02110	*						
Percent HOLC A areas	-0.18886	***	-0.12818	***	-0.11870	***	-0.00908		-0.00908	
Percent HOLC B areas	-0.12905	**	-0.06753	***	-0.06573	***	-0.01403	***	-0.01403	***
Percent HOLC C areas	-0.15100	**	-0.08826	***	-0.08911	***	-0.00890	*	-0.00890	*
Percent HOLC D areas	-0.06288									
Percent Non-HOLC areas	-0.14154	**	-0.08814	***	-0.08348	***	-0.00481		-0.00481	
Percent Urban Renewal Areas	0.11317	**	0.11404	**	0.10625	**	0.02953	*	0.02953	*
Public housing density per acre	0.00998	**	0.01029	**	0.01006	**	-0.00036		-0.00036	
Percent highway proximate	-0.09206	***	-0.09578	***	-0.09574	***	0.00659		0.00659	
Percent single-family zoning	-0.03525		-0.06062	***	-0.05153	**	-0.00818		-0.00818	
Percent two-family zoning	-0.03219		-0.05731	***	-0.05075	***	-0.00417		-0.00417	
Percent 'contextual' multi-family zoning	-0.02133		-0.04959	***	-0.05076	***	0.00082		0.00082	
Percent 'non-contextual' multi-family zoning	0.03130									
Percent high-density 'tower' districts	0.03255									
Percent former M-districts	0.00649									
Percent pure non-residential districts	0.01531	.								
Percent Special Purpose District	-0.09259	***	-0.09240	***	-0.09680	***	-0.00503		-0.00503	
Percent historic district	0.04837	*	0.04596	*						
adjusted R-squared	0.14510		0.14560		0.14360					
Rho							0.93075	***		
Lambda									0.93075	***
AIC					-3472.80		-8302.60		-8305.20	
p-value of residuals (LM)					< 2.2e-16		4.59E-14		0.99900	

Table 32. Regression results, Black isolation, 2020

2020 - White isolation										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.35541	***	0.35216	***	0.33930	***	-0.03712	*	-0.05374	*
Distance to core	-0.05230	***	-0.05131	***	-0.05032	***	-0.00548	***	0.00237	
Percent Subway Proximate	-0.01823	*	-0.02001	**						
Percent HOLC A areas	0.46957	***	0.47550	***	0.47615	***	0.11400	***	0.10214	***
Percent HOLC B areas	0.34888	***	0.35355	***	0.34902	***	0.08043	***	0.05726	**
Percent HOLC C areas	0.32420	***	0.32857	***	0.32358	***	0.08198	***	0.06542	***
Percent HOLC D areas	0.34416	***	0.34726	***	0.34334	***	0.08298	***	0.06561	***
Percent Non-HOLC areas	0.36472	***	0.36650	***	0.36728	***	0.07125	***	0.04580	***
Percent Urban Renewal Areas	-0.01161									
Public housing density per acre	-0.01170	***	-0.01191	***	-0.01222	***	-0.00331	***	-0.00132	**
Percent highway proximate	-0.01154									
Percent single-family zoning	0.03122									
Percent two-family zoning	0.05072	*	0.03835	***	0.04449	***	-0.00376		-0.02007	***
Percent 'contextual' multi-family zoning	0.07174	***	0.05932	***	0.05440	***	0.00882	*	0.00788	
Percent 'non-contextual' multi-family zoning	0.01306									
Percent high-density 'tower' districts	0.12443	***	0.11381	***	0.10586	***	0.01466	.	0.01344	
Percent former M-districts	-0.10148	**	-0.11139	**	-0.11884	***	-0.01849		-0.03346	*
Percent pure non-residential districts	-0.05413	**	-0.06736	***	-0.06861	***	-0.00815	.	0.01296	.
Percent Special Purpose District	0.12028	***	0.12006	***	0.11744	***	0.00792	.	0.02123	**
Percent historic district	0.14469	***	0.14692	***	0.14199	***	0.02410	**	0.0103	**
adjusted R-squared	0.33340		0.33370		0.33200					
Rho							0.93150	***		
Lambda									0.95358	***
AIC					-4465.20		-8363.20		-8315.30	
p-value of residuals (LM)					< 2.2e-16		< 2.2e-16		0.8260	

Table 33. Regression results, White isolation, 2020

Appendix D: Detailed Regression Results – HOLC boundaries

1960 - HOLC - A										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.01419		0.00237		0.00304	.	-0.00130		0.00574	
Percent Urban Renewal Areas	-0.06979									
Public housing density per acre	-0.00143									
Percent highway proximate	0.02302	.	0.02425	.						
Percent single-family zoning	0.08453	***	0.09962	***	0.10295	***	0.05274	***	0.10320	***
Percent two-family zoning	0.03066		0.04635	*						
Percent 'contextual' multi-family zoning	N/A									
Percent 'non-contextual' multi-family zoning	-0.01667									
Percent high-density 'tower' districts	0.21153	***	0.22566	***	0.22563	***	0.06459	***	0.18859	***
Percent former M-districts	N/A									
Percent pure non-residential districts	-0.03056		-0.01625	.						
Percent Special Purpose District	N/A									
Percent historic district	N/A									
adjusted R-squared	0.11760		0.11770		0.11370					
Rho							0.85522	***		
Lambda									0.86970	***
AIC					-5346.10		-6942.60		-6998.10	
p-value of residuals (LM)					< 2.2e-16		1.53E-08		0.02000	

Table 34. Regression results, HOLC A boundaries, 1960

1960 - HOLC - B										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.08140	*	0.12252	***	0.12384	***	0.02186	***	0.09742	***
Percent Urban Renewal Areas	-0.25677		-0.25796							
Public housing density per acre	-0.03242	***	-0.03205	***	-0.03293	***	-0.00857	*	-0.00660	
Percent highway proximate	0.03848									
Percent single-family zoning	0.13889	**	0.09100	**	0.09090	**	0.03664	*	0.10649	
Percent two-family zoning	0.15528	*	0.10185	.						
Percent 'contextual' multi-family zoning	N/A									
Percent 'non-contextual' multi-family zoning	0.05703									
Percent high-density 'tower' districts	0.04979									
Percent former M-districts	N/A									
Percent pure non-residential districts	-0.16514	***	-0.20972	***	-0.21288	***	-0.07277	***	-0.08473	
Percent Special Purpose District	N/A									
Percent historic district	N/A									
adjusted R-squared	0.04902		0.04944		0.04767					
Rho							0.87939	***		
Lambda									0.88549	***
AIC					-576.80		-2666.60		-2653.40	
p-value of residuals (LM)					< 2.2e-16		0.1139		0.2170	

Table 35. Regression results, HOLC B boundaries, 1960

1960 - HOLC - C										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.03649		0.00480		-0.00259		-0.06602	***	0.09516	***
Percent Urban Renewal Areas	-0.41154	.	-0.41383	.						
Public housing density per acre	-0.06703	***	-0.06721	***	-0.06636	***	-0.01527	**	-0.01052	.
Percent highway proximate	0.10791	*	0.10606	*						
Percent single-family zoning	0.42244	***	0.36919	***	0.39137	***	0.11035	***	0.14673	**
Percent two-family zoning	0.68755	***	0.63279	***	0.64623	***	0.21215	***	0.28322	***
Percent 'contextual' multi-family zoning	N/A									
Percent 'non-contextual' multi-family zoning	0.52731	***	0.46956	***	0.48875	***	0.19678	***	0.25286	***
Percent high-density 'tower' districts	-0.09112		-0.14431	*						
Percent former M-districts	N/A									
Percent pure non-residential districts	0.06535									
Percent Special Purpose District	N/A									
Percent historic district	N/A									
adjusted R-squared	0.13260		0.13260		0.12800					
Rho							0.85280	***		
Lambda									0.87451	***
AIC					605.15		-1327.40		-1301.60	
p-value of residuals (LM)					< 2.2e-16		0.3994		0.9460	

Table 36. Regression results, HOLC C boundaries, 1960

1960 - HOLC - D										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.00214		-0.03966	.	-0.03966	.	-0.04709	***	0.03570	
Percent Urban Renewal Areas	0.79978	***	0.80410	***	0.80410	***	0.38440	***	0.29692	**
Public housing density per acre	0.07697	***	0.07741	***	0.07741	***	0.00992	*	-0.00202	
Percent highway proximate	-0.24698	***	-0.24274	***	-0.24274	***	-0.07778	**	-0.11367	***
Percent single-family zoning	-0.08142									
Percent two-family zoning	-0.04664									
Percent 'contextual' multi-family zoning	N/A									
Percent 'non-contextual' multi-family zoning	0.28128	***	0.33980	***	0.33980	***	0.12412	***	0.17939	***
Percent high-density 'tower' districts	0.30470	***	0.35961	***	0.35961	***	0.07282	*	0.02812	
Percent former M-districts	N/A									
Percent pure non-residential districts	0.36483	***	0.41764	***	0.41764	***	0.07118	***	0.03876	
Percent Special Purpose District	N/A									
Percent historic district	N/A									
adjusted R-squared	0.10880		0.10900		0.10900					
Rho							0.87789	***		
Lambda									0.89845	***
AIC					263.54		-1947.20		-1953.40	
p-value of residuals (LM)					< 2.2e-16		0.7538		0.8610	

Table 37. Regression results, HOLC D boundaries, 1960

1990 - HOLC - A										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.01423		0.01602	.	-0.00463	**	-0.00434	***	-0.00179	
Percent Urban Renewal Areas	-0.03270		-0.03318							
Public housing density per acre	0.00029									
Percent highway proximate	0.01075									
Percent single-family zoning	0.04869	**	0.04748	**	0.07501	***	0.04674	***	0.09243	***
Percent two-family zoning	0.00237									
Percent 'contextual' multi-family zoning	0.15030	***	0.14866	***	0.17614	***	0.02621	.	0.01065	
Percent 'non-contextual' multi-family zoning	-0.02732		-0.02886	*						
Percent high-density 'tower' districts	0.12427	***	0.12276	***	0.14650	***	0.03332	**	0.13326	***
Percent former M-districts	-0.07102	*	-0.07230	*						
Percent pure non-residential districts	-0.02969	.	-0.02972	*						
Percent Special Purpose District	0.10087	***	0.10104	***	0.10197	***	0.04211	***	0.08344	***
Percent historic district	0.00835	***	0.00825	***	0.00762	***	0.00530	***	0.00514	.
adjusted R-squared	0.19890		0.19970		0.19700					
Rho							0.83123	***		
Lambda									0.85466	***
AIC					-5553.70		-6876.50		-6923.60	
p-value of residuals (LM)					< 2.2e-16		3.84E-13		0.00300	

Table 38. Regression results, HOLC A boundaries, 1990

1990 - HOLC - B										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.07265	.	0.12217	***	0.12922	***	0.02343	***	0.11822	***
Percent Urban Renewal Areas	-0.22221	**	-0.22255	**	-0.23607	***	-0.08465	*	-0.07950	.
Public housing density per acre	-0.03079	***	-0.03103	***	-0.03288	***	-0.00927	**	-0.00745	*
Percent highway proximate	-0.02268									
Percent single-family zoning	0.15465	**	0.09163	**						
Percent two-family zoning	0.11885	.								
Percent 'contextual' multi-family zoning	0.15473	*	0.09443							
Percent 'non-contextual' multi-family zoning	0.07203									
Percent high-density 'tower' districts	-0.18574	**	-0.25431	***	-0.24938	***	-0.05085	.	-0.05719	
Percent former M-districts	-0.24774	*	-0.31058	**	-0.32663	***	-0.08922	.	-0.10260	
Percent pure non-residential districts	-0.13147	*	-0.19742	***	-0.21073	***	-0.07128	***	-0.07201	***
Percent Special Purpose District	0.12848	***	0.13169	***	0.13190	***	0.02075		0.02490	
Percent historic district	0.02862	***	0.02864	***	0.03027	***	0.01148	***	0.01324	**
adjusted R-squared	0.07727		0.07700		0.07372					
Rho							0.88667	***		
Lambda									0.89483	***
AIC					-533.48		-2636.10		-2605.10	
p-value of residuals (LM)					< 2.2e-16		0.1264		0.1660	

Table 39. Regression results, HOLC B boundaries, 1990

1990 - HOLC - C										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.00089		0.05129	*	0.07239	***	-0.04815	***	0.12613	***
Percent Urban Renewal Areas	-0.59281	***	-0.58393	***	-0.60111	***	-0.15627	**	-0.11743	.
Public housing density per acre	-0.06540	***	-0.06529	***	-0.06514	***	-0.01409	**	-0.01246	*
Percent highway proximate	0.07933		0.07883							
Percent single-family zoning	0.38535	***	0.32085	***	0.30220	***	0.07669	**	0.12898	**
Percent two-family zoning	0.60149	***	0.53574	***	0.51079	***	0.22567	***	0.35965	***
Percent 'contextual' multi-family zoning	0.17558	.	0.12300							
Percent 'non-contextual' multi-family zoning	0.51532	***	0.44403	***	0.42021	***	0.17430	***	0.24658	***
Percent high-density 'tower' districts	0.09045									
Percent former M-districts	0.01550									
Percent pure non-residential districts	0.07792									
Percent Special Purpose District	-0.17853	***	-0.17329	***	-0.17486	***	-0.02910		-0.05339	
Percent historic district	-0.02876	***	-0.02886	***	-0.02747	***	0.00396		0.00825	
adjusted R-squared	0.16070		0.16130		0.16050					
Rho							0.85501	***		
Lambda									0.88008	***
AIC					535.13		-1309.80		-1299.80	
p-value of residuals (LM)					< 2.2e-16		0.0237		0.3810	

Table 40. Regression results, HOLC C boundaries, 1990

1990 - HOLC - D										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.00667		-0.03040		-0.03613	.	-0.04288	***	0.08299	
Percent Urban Renewal Areas	0.78252	***	0.78095	***	0.79066	***	0.22495	***	0.18192	***
Public housing density per acre	0.08816	***	0.08831	***	0.08942	***	0.01884	***	0.01015	*
Percent highway proximate	-0.17691	***	-0.17444	***	-0.17760	***	-0.04951	.	-0.06325	.
Percent single-family zoning	-0.05114									
Percent two-family zoning	-0.00848									
Percent 'contextual' multi-family zoning	0.49807	***	0.51258	***	0.52601	***	0.18540	***	0.33549	***
Percent 'non-contextual' multi-family zoning	0.26010	***	0.29199	***	0.29468	***	0.10354	***	0.14541	***
Percent high-density 'tower' districts	0.25847	**	0.28189	***	0.24086	***	0.02217		-0.12386	.
Percent former M-districts	0.69990	***	0.71512	***	0.70787	***	0.24477	***	0.26911	***
Percent pure non-residential districts	0.31385	***	0.34371	***	0.34783	***	0.06768	**	0.04456	
Percent Special Purpose District	-0.07738	*	-0.07727	*						
Percent historic district	-0.00586									
adjusted R-squared	0.19020		0.19080		0.18910					
Rho							0.87549	***		
Lambda									0.90550	***
AIC					122.10		-2015.10		-1986.30	
p-value of residuals (LM)					< 2.2e-16		0.7662		0.7890	

Table 41. Regression results, HOLC D boundaries, 1990

2020 - HOLC - A										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.01151		0.00000		-0.00254		-0.00370	**	-0.00056	
Percent Urban Renewal Areas	-0.05182	*	-0.05514	**						
Public housing density per acre	-0.00125									
Percent highway proximate	0.00941									
Percent single-family zoning	0.03619	*	0.05128	***	0.05649	***	0.03558	***	0.06832	***
Percent two-family zoning	-0.01764									
Percent 'contextual' multi-family zoning	-0.01336									
Percent 'non-contextual' multi-family zoning	-0.01721									
Percent high-density 'tower' districts	0.16758	***	0.18340	***	0.18361	***	0.04629	***	0.10444	***
Percent former M-districts	-0.07171	**	-0.05576	*						
Percent pure non-residential districts	-0.03044	*	-0.01527							
Percent Special Purpose District	0.04079	***	0.04147	***	0.03902	***	0.01893	***	0.04226	***
Percent historic district	0.09105	***	0.09251	***	0.09154	***	0.05082	***	0.06518	***
adjusted R-squared	0.14080		0.14140							
Rho							0.80788	***		
Lambda									0.82425	***
AIC					-5932.70		-7276.70		-7303.60	
p-value of residuals (LM)					< 2.2e-16		8.23E-03		0.28100	

Table 42. Regression results, HOLC A boundaries, 2020

2020 - HOLC - B										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.08642	**	0.10518	***	0.13135	***	0.01444	***	0.11050	***
Percent Urban Renewal Areas	-0.25919	***	-0.25794	***	-0.25333	***	-0.07201	.	-0.06629	
Public housing density per acre	-0.03328	***	-0.03320	***	-0.03151	***	-0.00637	*	-0.00512	
Percent highway proximate	-0.00434									
Percent single-family zoning	0.15012	**	0.12561	***	0.09501	**	0.07967	***	0.20882	***
Percent two-family zoning	-0.05667		-0.07968	**	-0.11439	***	-0.00009		0.07027	***
Percent 'contextual' multi-family zoning	0.03111									
Percent 'non-contextual' multi-family zoning	0.07856	.	0.05206	*						
Percent high-density 'tower' districts	-0.17315	**	-0.19682	***	-0.23723	***	-0.04310	.	-0.06041	
Percent former M-districts	-0.31099	***	-0.33371	***	-0.37147	***	-0.07352	.	-0.06289	
Percent pure non-residential districts	-0.15923	***	-0.18236	***	-0.21124	***	-0.05238	**	-0.03892	.
Percent Special Purpose District	0.08855	***	0.08833	***	0.08783	***	0.00505		-0.01609	
Percent historic district	0.23715	***	0.24012	***	0.22188	***	0.13263	***	0.17092	***
adjusted R-squared	0.08360		0.08416		0.08223					
Rho							0.89181	***		
Lambda									0.90313	***
AIC					-691.05		-2876.40		-2894.80	
p-value of residuals (LM)					< 2.2e-16		0.0207		0.2170	

Table 43. Regression results, HOLC B boundaries, 2020

2020 - HOLC - C										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	-0.02521		-0.00327		0.04498	*	-0.05831	***	0.12776	***
Percent Urban Renewal Areas	-0.51029	***	-0.50575	***	-0.50658	***	-0.07932		-0.05961	
Public housing density per acre	-0.05121	***	-0.05101	***	-0.05092	***	-0.00975	*	-0.00859	.
Percent highway proximate	0.08572	.	0.08510	.						
Percent single-family zoning	0.41066	***	0.38150	***	0.32997	***	0.09336	***	0.15614	***
Percent two-family zoning	0.68998	***	0.66118	***	0.60706	***	0.25822	***	0.40306	***
Percent 'contextual' multi-family zoning	0.41323	***	0.38503	***	0.32882	***	0.16741	***	0.22755	***
Percent 'non-contextual' multi-family zoning	0.48301	***	0.45150	***	0.39757	***	0.15226	***	0.17436	***
Percent high-density 'tower' districts	0.06155									
Percent former M-districts	0.06040									
Percent pure non-residential districts	0.12949	*	0.10399	*						
Percent Special Purpose District	-0.14858	***	-0.14053	***	-0.14691	***	-0.01792		-0.02958	
Percent historic district	-0.14775	**	-0.14364	**	-0.16338	**	-0.02754		-0.04765	
adjusted R-squared	0.19270		0.19310		0.19100					
Rho							0.85089	***		
Lambda									0.88457	***
AIC					450.78		-1457.00		-1476.40	
p-value of residuals (LM)					< 2.2e-16		0.0127		0.4220	

Table 44. Regression results, HOLC C boundaries, 2020

2020 - HOLC - D										
	OLS run 1		OLS run 2		OLS run 3		Spatial Lag		Spatial Error	
Variables	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
y-intercept	0.02491		0.05185	***	0.02524	*	-0.01069		0.13217	***
Percent Urban Renewal Areas	0.76661	***	0.76426	***	0.76884	***	0.23469	***	0.18159	***
Public housing density per acre	0.08450	***	0.08437	***	0.08530	***	0.02087	***	0.01507	***
Percent highway proximate	-0.19318	***	-0.19655	***	-0.20820	***	-0.07347	**	-0.08204	*
Percent single-family zoning	-0.06879		-0.10093	*						
Percent two-family zoning	0.04327									
Percent 'contextual' multi-family zoning	0.43648	***	0.40264	***	0.43565	***	0.13087	***	0.20559	***
Percent 'non-contextual' multi-family zoning	0.18174	***	0.14513	***	0.17762	***	0.05604	***	0.09610	***
Percent high-density 'tower' districts	0.29748	***	0.26248	***	0.24696	***	0.00297		-0.13269	*
Percent former M-districts	0.72183	***	0.68877	***	0.68145	***	0.25953	***	0.28005	***
Percent pure non-residential districts	0.14704	**	0.11566	**	0.14497	***	-0.03284		-0.04988	.
Percent Special Purpose District	-0.07062	*	-0.07016	*						
Percent historic district	-0.16538	***	-0.16889	***	-0.17520	***	-0.13730	***	-0.14388	***
adjusted R-squared	0.23760		0.23770		0.23420					
Rho							0.86716	***		
Lambda									0.90166	***
AIC					-59.67		-2168.20		-2139.20	
p-value of residuals (LM)					< 2.2e-16		0.8811		0.8460	

Table 45. Regression results, HOLC D boundaries, 2020