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Assessing Socio-Demographic and Urban Form Changes of Sprawl Retrofitting Projects in the United States

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ASSESSING SOCIO-DEMOGRAPHIC AND URBAN FORM CHANGES OF SPRAWL RETROFITTING PROJECTS IN THE UNITED STATES

by

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ABSTRACT

ASSESSING SOCIO-DEMOGRAPHIC AND URBAN FORM CHANGES OF SPRAWL RETROFITTING PROJECTS IN THE UNITED STATES

by

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As a city grows, the population flows out of the urbanized area and forms a suburban settlement. These settlements are often auto-centric and contain big blocks with low walkability and limited accessibility to daily destinations which are geographically dominated by post-World War development. This type of development is referred to as urban sprawl (Dunham-Jones & Williamson, 2011). Urban sprawl decreases accessibility to jobs and amenities, separates different land uses, and increases car dependency, thus negatively impacting the environment, society, and the economy. Sprawl retrofitting has received a great deal of attention as a response to sprawl. It modifies the suburban environment through design approaches and aims for a mixed-land use, walkable neighborhood. Several studies have examined changes related to urban sprawl and sprawl retrofitting. However, not many studies have examined the urban form and socio-demographic changes resulting from those redevelopment projects before and after implementation. This study explores neighborhoods that have experienced urban sprawl retrofitting projects to understand their impact on urban form and socio-demographic structure.

First, this study identifies 59 sprawl retrofitting projects in the United States. Projects are mainly collected from online sources (e.g., Traditional Neighborhood Development and Congress of New Urbanism websites) and relevant literature (e.g., *Retrofitting Suburbia* by Ellen Dunham-Jones, *The Sprawl Repair Manual* by Galina Tachieva, etc.). The criteria used to define a sprawl retrofitting case are: 1) projects should have a previous use (in other words, not vacant or undeveloped), 2) the new development must have a mix of uses (e.g., public housing redevelopment projects are excluded if they remained residential-only communities), and 3) to compare socio-demographic changes before and after the project—we limited our cases to those completed between 2000 and 2016—aligned with Decennial Census 2000 and ACS 2014–2018.

After compiling and mapping a list of sprawl retrofitting projects, urban form and socio-demographic changes are analyzed before and after the projects. A case-control design methodology was used to analyze and interpret the data. Demographic and employment data are collected from the American Community Survey (ACS) 2014-2018 estimates and Longitudinal Employer-Household Dynamics (LEHD) database (2002 and 2017). The analysis is built upon an inventory of sprawl retrofitting projects that provide researchers and practitioners a foundation for future research. Some of this study's findings include increased population and job density, increase in gross rent, housing value and household income, and an increase in population with bachelor's degrees and non-Hispanic white people in the sprawl retrofitting neighborhoods. Some implications of the comparison of changes can be gentrification and displacement of specific demographics in sprawl retrofitting neighborhoods. Regarding transportation outcomes,

the percentage of walking and transit compared to commuting has decreased in projects that do not abide with the sustainable transportation goals. This implies the existing growth and development pattern that necessitates automobile use and the failure to provide accessibility in daily travels.

The other purpose of this study is to compare changes in urban form. Selected variables are average block size, intersection density, and percentage of green space. This study found that average block size has decreased, and intersection density has increased. Green space percentage did not change significantly and was inconsistent among sprawl retrofitting projects. This study attempts to reveal the changes and provide a comparison of selected variables that can inform planners and designers about the consequences of current retrofitting practices and help re-examine the methods and criteria of their projects.

(85 pages)

PUBLIC ABSTRACT

ASSESSING SOCIO-DEMOGRAPHIC AND URBAN FORM CHANGES OF SPRAWL RETROFITTING PROJECTS IN THE UNITED STATES

Hooman Hadayeghi

Growing population and urbanization have escalated the inclination in today's societies to live in the suburbs. In the United States, urban development has had a suburbanization pattern since World War II. People living in such areas must use their cars to reach their destination and commute to work. Sprawl retrofitting is a term introduced by planners and researchers to overcome urban sprawl's negative impacts on mobility, transportation, and the environment. This approach is used to densify and change the built environment to make daily trips easier, shorten daily travels, and enhance pedestrian activity in places dealing with sprawl. Sprawl retrofitting has been more frequently researched over the past few decades. It has attracted a great deal of attention among planners to utilize different tools in urban design and city planning to overcome the fast-growing sprawl. However, there are not many studies examining the aftermath.

This study attempts to analyze and compare the changes after sprawl retrofitting projects' completion. By using national demographic data and built environment changes, such as population density, block size fluctuations, and green space development, this research examines the difference in changes before and after the projects. The results are based on 59 sprawl retrofitting case studies throughout the United States chosen by the criteria, including size and completion date of the projects and other built environment factors, such as land use, that defined each project site. Results show an increase in population, job density, and the density of intersections in the project sites. By comparing the results, this study will inform future research about the implications of sprawl retrofitting and the current impacts they can have on the population and the built environment.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Growing urban sprawl is a worldwide concern for a number of environmental and economic reasons and is a significant challenge on the way to sustainable land use. After World War II, housing needs increased, and lower- and middle-class population demands for housing led to single-family residential development that expanded out of the fringes of the developed area. Americans leaving the urban areas and settling in the outskirts of these developments have shaped suburban areas with acres of cleared space for single-family housing and big-box retailers.

Some studies have shown that sprawl has amplified automobile use as these areas have large blocks and attached parking lots in common, thus increasing walking distances to and from daily destinations (Dunham-Jones & Williamson, 2011). Due to the population increase and natural growth on the city's outskirts, Meredith posits that “sprawl must be distinguished from the larger category of suburban growth” (Meredith, 2003, P. 448). Suburban growth is a type of development where population growth overflows outward to the country area and shapes settlements far from the urban core. This growth can be developed following a sprawl pattern or compact development. Ewing characterizes sprawl by its scattered commercial strip and expansive single-use development (Ewing, 1997). He mentions the negative consequences of sprawl, such as increased vehicle miles travelled, energy consumption and air pollution, infrastructure and public service costs, and social and psychological costs.

To prevent these negative impacts, sprawl retrofitting has become popular among planners and designers. It redirects developments in suburban areas to a more walkable and accessible space. These changes have impacted population structure with several physical changes in retrofitted suburban areas (Dunham-Jones, 2005). This study aims to identify socio-demographic and urban form changes of sprawl retrofitting projects before and after completion.

Research objectives

The purpose of this research is twofold. The first objective is to compile a list of recent sprawl retrofitting projects across the United States. The second objective is to examine the impact of sprawl retrofitting on the socio-demographic and urban form structures and provide a comparison of changes before and after projects. We also compare these variables inside and outside the project's boundary. Changes in physical characteristics can impact the socio-demographic structure of a place.

Definition of Terms

To better understand the context of sprawl retrofitting, some of the related concepts and definitions for the existing terms are listed below. These concepts help provide a foundation for this study before diving deep into the research.

Suburbia. The area beyond the boundaries of the existing urban environment where the built environment has a different structure than the urban core (Steil et al., 2008). These areas can be sustainable urban areas with an internal connected system to the urban center upon which they depend.

Urban Sprawl. Urban sprawl is described by its form as an unplanned, scattered development that consumes land adjacent to the city's developed area, shaping a dispersed urban environment. This type of development results in sites often segregated and poorly accessed, consuming the land without having a proper connection to the urban center (Sinha, 2018; Steil et al., 2008).

Sprawl Retrofitting. A term that engages actions to modify suburban typologies and turn them into more sustainable, livable, and walkable places (Dunham-Jones & Williamson, 2011).

Socio-demographic. Attributes that describe the structure of a population, such as age, race, ethnicity, household income, educational attainment, travel mode share, and housing value (Mack and Jim, 2019).

Urban form. Urban form refers to the physical structure and size of the urban fabric, activities, and population distribution within an area (Schwarz, 2010).

Significance of the Research

Urban sprawl is a widespread issue which can be found in developed and growing communities. Planners and researchers have put more effort into solving this issue in the past few decades. Sprawl retrofitting is a tool for planners to facilitate the changes to overcome the sprawl issue. This study contributes to sprawl retrofitting endeavors that aim to inform future research on different approaches and impacts of retrofitting projects on the built environment and demographic structure of urban sprawl places. The results will help future studies with implications of sprawl retrofitting in the U.S. by examining socio-demographic and urban form indicators mostly affected by sprawl repair projects. The results will help planners and academic researchers better understand the consequences of sprawl retrofitting on the demographic structure and the built environment.

CHAPTER II

LITERATURE REVIEW

Urban sprawl can be found in many cities in the United States. Single family development is the major factor accelerating sprawl. This type of development encouraged a physical fragmentation that necessitated cars to travel inside the city for different purposes. Single land use, shopping malls, and ample parking lots with inefficient public transportation and infrastructure accessibility are the main characteristics of sprawl. Urban sprawl is the term used by different researchers and planners to describe the existing development pattern after the Second World War in most American cities (Bruegmann, 2005; Hamidi & Ewing, 2014).

Planners have introduced several methods to overcome the issues arising from urban sprawl. One of the recent approaches in sprawl retrofitting is a term that engages actions to overcome urban sprawl and making a more sustainable, livable, and walkable place. Ellen Dunham-Jones and June Williamson argue in their book, *Retrofitting Suburbia,* that one of the biggest challenges in the future of cities is to redesign and redevelop existing suburban properties—particularly shopping malls, big box stores, and office parks—into more sustainable places and increase access to public amenities (Dunham-jones & Williamson, 2008).

Sprawl retrofit can be achieved by inverting the process of sprawl. In order to be practical and realistic, sprawl retrofitting should rely on available resources that empower the communities struggling with sprawl and is driven by urban forces that have created "unsustainable sprawled cities." These forces should be redirected to rebuild and redesign the current sprawl in our cities (Steil et al., 2008).

Williamson and Dunham-Jones presented several retrofitting projects from the 2010 Build a Better Burb design competition. One of the many design challenges and priorities in retrofitting projects is to connect people of various ethnocultural backgrounds and promote multicultural social interaction in the public realm. Such retrofitting strategies can also be applied to other types of suburbs. Quality public spaces can help promote social interaction among diverse groups (Dunham-Jones & Williamson, 2011).

Sprawl retrofitting is a relatively new concept that can be studied from different perspectives. It impacts various aspects of the city population, such as the environment, society, economics, urban form, and personal health. This research tries to define urban sprawl, sprawl retrofitting, and implications of each concept and evaluate demographic structure and urban form in the projects that have undergone a change after implementation.

Urban Sprawl

As a result of city growth and the increasing prevalence of mega-retail, North America is littered with dead or dying malls and big box stores. Also known as grey fields, these sites are often in prime suburban locations but have been left behind and ignored (Dunham Jones and Williamson, 2011). These sites typically take the form of single large buildings surrounded by expansive parking lots. These places do not contain the qualities of a livable and sustainable urban setting. They are formed into big blocks containing malls and parking lots with low-quality public transportation and accessibility infrastructure.

Figure 1

Urban Sprawl (Dunham-Jones & Williamson, 2011)

Torrens and Alberti describe the characteristics of sprawl as a "relatively wasteful method of urbanization, characterized by uniform low density; it is often uncoordinated and extends along the fringes of metropolitan areas with incredible speed" (Torrens & Alberti, 2001, P.3). The tendency to live in cheap housing, surrounded by natural greenery and inexpensive building lots followed by population growth, contributed to highly dispersed urban development in North America and Europe (Jaeger et al., 2010). Big cities and urban cores with congestion, pollution, and high crime rates issues have accelerated the relocation of the middle-class population and businesses in suburban areas (Power & Wilson, 2000; Weaver, 1960).

Impacts associated with urban sprawl range from the lack of scale economies (Frenkel & Ashkenazi, 2008), ecological problems such as air pollution; traffic congestion; water shortages; overburdening of amenities (Al Jarah et al., 2019); fragmentation of the eco-system; loss of agricultural land; social problems of increased segregation (Glaeser & Kahn, 2003); and increased isolation (Frumkin, 2002). Handy and her colleagues found that the physical attributes of a place that cause sprawl discourage walkability and physical activity and otherwise create auto-oriented areas with low pedestrian mobility and accessibility, leading to health issues (Handy et al., 2002). Also, this issue leads to local governments' increased public spending on health-related problems.

Characteristics of Urban Sprawl

Urban sprawl is described by its form as an unplanned, scattered development that consumes land adjacent to the city's developed area, shaping a dispersed urban environment (Sinha, 2018). A place with these attributes necessitates car ownership for the people who reside in the area. Frenkel and Ashkenazi listed characteristics of sprawl by measuring growth rates, density, spatial geometry, accessibility, and aesthetic measures. They considered that distant and segregated land uses a pattern of sprawl. Besides, accelerated urban growth and low-density development resulted from their standards (Handy et al., 2002). They characterized a higher sprawl rate by higher population and land consumption rates.

Duany et al. have identified suburban sprawl by examining the traditional neighborhood approach (Duany et al., 2000). Traditional neighborhood is a pedestrian-friendly neighborhood that provides access to daily needs and is naturally growing. On the other hand, single-use development, in which driving a car is necessary to access everyday needs, is known as suburban sprawl. Suburban sprawl initially resulted from a desire to live in the countryside, on the outskirts of urbanized areas far from the industrialized core of the city. Currently, many American cities have been built following the sprawl pattern.

Outcomes of Urban Sprawl

The negative impacts of urban sprawl encompass a variety of topics that are related to one another. As cities grow, they introduce more environmental challenges such as air pollution, traffic, and deforestation, and they modify existing equilibriums regarding human health, resource depletion, and greenhouse gas emissions. One of the consequences of sprawl is growing car dependency followed by other harmful impacts. Cars have become the primary vehicles to move from one place to another. As unmanaged urbanization scatters through a larger area, the need for cars increases, and each citizen drives more miles. One of the leading causes of air pollution is car overuse, which is intensified by sprawl. Studies on greenhouse gas emissions show that automobiles are responsible for a significant portion of ground-level ozone emission, a compound of volatile organic compounds (VOCs) and nitrogen oxides (NOx). Ground-level ozone has proven to be harmful to people with respiratory problems and can harm healthy people's lungs in the long term. There are a significant number of asthma cases in people living in areas containing high levels of ozone (Gallagher, 2001).

Sprawl Retrofitting

Sprawl retrofitting is a term that engages actions to overcome suburban typologies and turn them into a more sustainable, livable, and walkable place. Williamson and Dunham-Jones describe the advantage of a retrofit in various suburban contexts. A suburban environment can be a potential site for redevelopment as new town centers are built near existing residential neighborhoods (Dunham-Jones and Williamson, 2011). They consider redesigning existing suburban areas—particularly office parks, big box stores, and shopping malls—into more sustainable places. Increasing access to public amenities is the biggest challenge for the future.

Figure 2

Sprawl retrofit (Dunham-Jones & Williamson, 2011)

Despite lacking proper accessibility to nearby neighborhoods, they often have convenient access to automobiles. They are commercial centers along arterial roads, typically shopping and foods retail sites. A retrofit project aims at existing strengths and weaknesses to create mixed uses in a physically scattered urban environment. After a retrofit, these sites are planned to connect to nearby neighborhoods and the adjacent communities; they are also planned to connect internally, allowing pedestrian movement rather than requiring a car to move from store to store or between buildings.

Suburbia retrofit can be achieved by a strategy to invert the process of urban sprawl. In their study, Steil et al. offer that: "To be effective and realistic means that such a strategy must not rely upon utopian conditions, astronomical sums of scarce taxpayer money, or radical opportunities to reengineer or rebuild. It means, very simply, a largely incremental approach driven by typical urban forces: redirecting the same forces that created today's unsustainable sprawl" (Steil et al., 2008). He describes population growth as urban forces that require additional space in a city which can be resided towards the existing built environment as a higher density and more compact development.

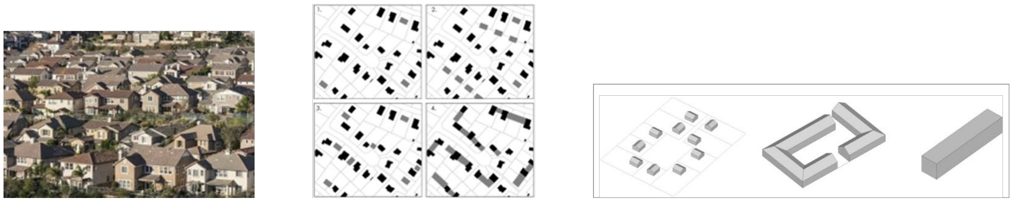
One of the motivations for promoting more compact urban development is that reducing sprawl can decrease several transportation externalities by reducing travel distances and encouraging people to use alternative modes of transportation. This becomes increasingly feasible as population density increases (Holcombe & Williams, 2010). Several studies have researched environmental determinants of physical activity. One study found that urban and suburban residents living in homes built before 1946 (a proxy for older neighborhoods) were more likely to walk long distances with some frequency than those living in newer homes (Berrigan & Troiano, 2002). This result was attributed to the greater likelihood of sidewalks, denser interconnected streets, and a mix of business and residential uses in older neighborhoods. Walking for utilitarian purposes is consistently more prevalent in dense, mixed-use areas compared to lower-density, exclusively residential neighborhoods (Saelens et al., 2003).

2.2.1. Key Characteristics of Sprawl Retrofitting

Mantey and Pokojski indicate four factors contributing to walkability and accessibility that address suburban disorder on the neighborhood scale. They consider (1) street connectivity, (2) pedestrian infrastructure, (3) centrality/nuclearity, (4) proximity to public objects and services, and (5) location of public open space to address this phenomenon in the smaller urban context. Marique and Reiter suggested three retrofitting scenarios to address the possible evolution of existing suburban neighborhoods related to urban form characteristics. One of the scenarios improves the building structure by enhancing the insulation of existing suburban stock without other manipulations of the urban form.

Figure 3

Scenarios Suggested by Marique and Reiter to Retrofit Sprawl Through Urban Form Changes

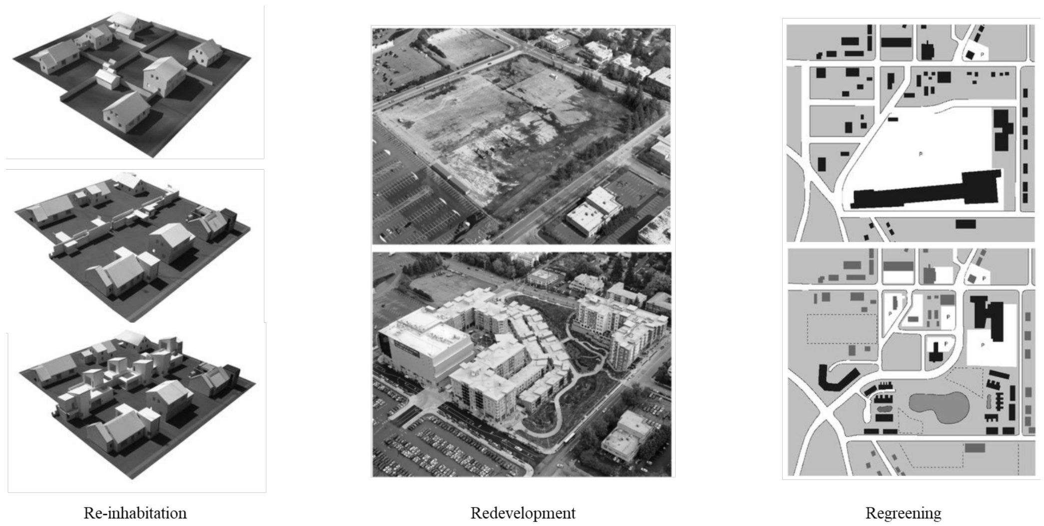


This includes using energy-efficient building materials to reduce heat leakage from the interior. The second scenario introduces additional building density to the current suburban neighborhoods with available land to construct new apartments and houses. This scenario uses the division of remaining plots to build new homes. The third scenario is based on different alternatives to building forms and seeks more dense and connected structures, rather than detached houses, to create more compact neighborhoods (Marique & Reiter, 2014).

Williamson and Dunham-Jones provide three principal strategies to overcome sprawl: re-inhabitation, redevelopment, and regreening (Dunham-Jones & Williamson, 2011). Their book defines re-inhabitation as an adaptive reuse of the place to serve the community and improve social interactions. Redevelopment replaces existing structures, specifically parking lots and abandoned buildings, with one that provides a walkable area, has a connected mix of uses, and promotes engaging social interactions in public spaces with less car dependency. Regreening, sometimes considered a redevelopment phase, is implemented by demolishing existing structures and transforming the land into green areas such as parks, community gardens, and revitalized wetlands.

Figure 4

Three Strategies to Overcome Sprawl (Dunham-Jones & Williamson, 2011)



Talen gives three stimuli for the interest in building a more sustainable urban form: (1) the need to reduce energy consumption and live local (climate change); (2) the need to build incrementally and in small-scale ways (the global recession); and (3) the need to provide smaller and more centrally located housing types (demographic change) (Talen, 2011). She asserts that the sustainable urban form has walkable and connected streets, compact building forms, well-designed public spaces, diverse uses, and mixed housing types. The sustainable urban form has qualities that often run counter to a previous generation of city buildings that promoted segregated land use, superblock 'projects', socially insular and physically disconnected housing, and car-dependent subdivisions and shopping malls (Talen, 2011). Additionally, she suggests sprawl retrofitting by considering the unsustainable urban forms and the strengths and weaknesses of the current growth patterns. She examines accessibility, density, diversity, and connectivity, including nodes such as light rail stops, to uncover sprawl (Talen, 2011).

There are many challenges facing planners for retrofitting projects. One of these challenges is related to changes made to the built environment. Some regulations should be conducted for the changes to overcome urban sprawl. However, there have been restrictions on completing retrofitting projects. One of these challenges is that residents and municipal authorities resist change (Marique & Reiter, 2014).

Sprawl Retrofitting and Background Frameworks

In the past literature, prior to sprawl retrofitting explorations, several approaches have been used to overcome the unplanned development resulting in sprawl in the cities. These approaches attempt to overcome sprawl by making changes such as increasing density, mixed-use development, and accessibility to a place where development had happened without considering the long-term consequences. Among the approaches are new urbanism and compact development, which have provided a background for sprawl retrofitting.

- **New Urbanism**

New Urbanism was proposed as a tool to overcome sprawl impacts on the urban environment. It is an urban planning movement that arose in the early 1980s in response to continuous suburban development. It was introduced to diminish patterns of low-density, auto-dependent development (Ellis, 2002). The ten principles of New Urbanism are walkability, connectivity, mixed-use and diversity, mixed housing, quality architecture and urban design, traditional neighborhood structure, increased density, green transportation, sustainability, and quality of life (CNU, 1996, 2000). These principles highly impact each other and are complementary criteria, meaning any change in one aspect can alter other factors. For instance, an increase in mixed-use in a specific place can lead to more walkable and sustainable places, encouraging mixed housing types in the area (CNU, 2019).

- **Compact City**

A compact city is a sustainable development that refers to the characteristics of an urban form with high-density, mixed-use urban development with walkable neighborhoods largely covered by the public transportation system. This approach has been one of the effective methods in redevelopment projects. Rice has applied the compact city approach to analyze the feasibility of retrofitting urban sprawl (Rice, 2010). He measured different variables, such as accessibility of public transit, city centers, and schools to support this approach in retrofitting suburban areas.

Ewing believes that compact development is not a highly dense monocentric development. He describes compact development with a high density of land-use mix, various housing options, and employment opportunities (Ewing, 1997).

Conclusion

Sprawl is one of the ongoing debates among scholars in the field, which can be found in most recent developments. This issue has impacted cities in the United States as well as globally. More emphasis has been put on it as its consequences grow and become a major problem among planners and decision-makers. Big block, auto-dependent, and detached urban forms of urban sprawl are the main characteristics that have brought economic, cultural, environmental, and transportation issues, such as air pollution and cultural fragmentation, to the neighborhoods suffering from the consequences of this phenomenon.

Sprawl retrofitting has been introduced and studied in recent decades in different regions of the United States. City planners and researchers have been using different approaches such as densifying, mixed-use development, and regreening to overcome the sprawl in their cities. Growing concerns about the consequences of urban sprawl have made sprawl retrofitting a crucial topic for environmental planners and landscape architects to reconsider human-scale development and revise design and planning codes.

The primary purpose of this research is to understand the consequences of urban sprawl and to analyze demographics and urban form changes in different sprawl retrofitting practices. There is a lack of knowledge on the impacts of sprawl retrofitting on the socio-demographic structure and urban form of the neighborhoods that underwent the process of revitalization and retrofit. Data comparison before and after the completion of each project can provide beneficial information on the changes in the corresponding districts. This study elaborates on the fact that sprawl retrofitting can have consequences for these neighborhoods, and it compares national demographic and urban form data over time by using an inventory of retrofitting projects in the United States.

CHAPTER III

METHODS

As stated previously, the core purpose of this research is to examine socio-demographic and urban form data to compare changes before and after the project completion in the retrofitted neighborhoods. To accomplish the study's goal, an inventory of the projects was built. After compiling a list of projects, socio-demographic and urban form data were collected before and after the projects. The case-control design was used to evaluate socio-demographic data in the project area compared to the control group beyond the project site. Urban form was evaluated using a single group interrupted time-series design. Data collection and analysis are discussed further in this section.

Building an Inventory of Projects

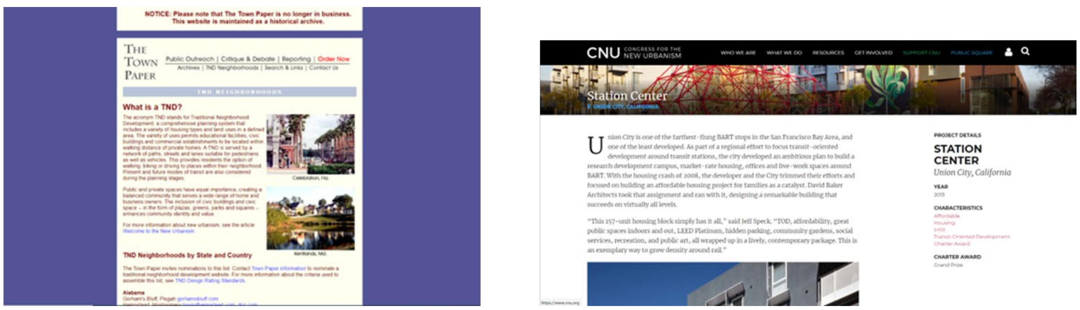
Case studies from Ellen Dunham-Jones' book, *Retrofitting Suburbia*, were studied to help understand the sprawl retrofitting concept. This book, along with *The Sprawl Repair Manual* by Galina Tachieva, gave us a frame of reference and the background knowledge to understand what sprawl retrofitting is and helped us form criteria for the case study list. Further, searching websites provided insight into the extent to which sprawl retrofitting has been practiced in different states. To build an inventory of recent sprawl retrofitting projects in the United States, we developed criteria to evaluate the projects. The following criteria were developed to select sprawl retrofitting cases for this research:

- A retrofitting project needed a previous use; while there are many examples of new developments built with sprawl retrofitting principles, they were not considered if no previous active land use was assigned.

- The new development must have a mix of uses. We came across a few projects where the previous use was public housing. The majority of the new developments had built environment changes in addition to changes in land use.
- To measure the socio-demographic and economic impacts of each case, we had to limit our list to those completed between 2000 and 2016.

Figure 5

Sources for Sprawl Retrofitting Inventory (TND and CNU websites)



We evaluated land use, urban form changes, and project completion dates. We compiled a list of over 70 sprawl retrofitting cases from two leading websites on sprawl retrofitting: The Congress of New Urbanism (CNU) and the Traditional Neighborhood Development (TND). The final inventory consists of 59 sprawl retrofitting projects using the three criteria mentioned above.

Multiple resources were used to gather the data needed for the study. Data such as overall land-use changes, retrofitting typologies, and the date before and after project completion were collected from book references (Dunham-Jones & Williamson, 2011; Tachieva, 2010), aerial imagery, and related websites and links to municipalities and other developments.

Socio-demographic Data Collection

The primary analysis in this research examines the socio-demographic attributes of the neighborhoods that experienced sprawl retrofitting. Given the changes introduced by sprawl retrofitting projects (such as density, road construction, and land-use change), this study came up with a hypothesis for a socio-demographic status shift in the retrofitted sites, which is discussed later in this study. To identify related variables, several pieces of literature have been reviewed, and relevant variables used in the articles were selected for this analysis.

A sprawl retrofitting project can directly impact a neighborhood in terms of job and population density. Also, increased race diversity has been reported in sprawl retrofitting projects (Tachieva, 2010). Some other variables are derived from the transportation outcomes of sprawl retrofitting projects. Sprawl retrofitting contributes to sustainable transportation by providing different modes of transit (Torrens & Alberti, 2001). Mode share, average travel time to work, and average vehicles per housing unit are three variables related to transportation outcomes.

On the other hand, a high-density development needs additional infrastructure that could change the housing value and rental prices. This can attract or repel a specific population with higher or lower income. Median household income, gross rent, and median housing value are the other variables analyzed in this research.

The selected socio-demographic data is gathered using LEHD, Census, and ACS sources. LEHD (Longitudinal Employer Household Dynamics) data is used to collect Job information. Other socio-demographics are compiled using Census and ACS (American Community Survey) sources. To build a before and after comparison, two years were selected to encompass the completion dates of the projects. Since project completion dates vary between 2002 to 2016, we selected LEHD 2002 and ACS 2000 data for the before condition and the LEHD 2016 and ACS 2014–2018 data for the after condition to analyze socio-demographic data. The 2014–2018 ACS data was the most recent data source available for the selected socio-demographic variables at the time of this study. This data is an estimation based on the census data in prior years. In this study, 2014–2018 ACS data is referred to as 2016 ACS data for simplicity and eloquence. The 1990 census data is used as a complementary source for a comparison to identify the impact of the project after completion.

The census data was collected from NHGIS and LEHD websites. The scope of the socio-demographic data analysis was divided into two different scales. To define these two scales, boundaries for each project site were selected by analyzing each project site. Comparing historical aerial images for the project sites also helped assign an extent to each site. Second, a one-mile area outside the project boundaries was designated for each site. Since any changes to the project sites could impact the adjacent neighborhoods, this analysis could help find any correlation for the research goals. Using ArcGIS software, socio-demographic data was joined to the project sites, and the one-mile area outside the project boundaries. The data used in the one-mile radius of the projects is exclusive from the project sites and does not include the project block groups.

Socio-demographic Data Analysis

A case-control design method was used to compare the socio-demographic changes. This method determines the outcome by analyzing the changes (in this case, sprawl retrofitting modifications) in one group in relation to changes in another group

(Mann, 2003). As previously mentioned, this project incorporates two groups—project sites and the control group—to track the impacts caused by sprawl retrofitting projects on the socio-demographic structure.

Figure 6

Example of Case and Control Group (Location: Bay Meadows, California)

The control group was assigned to the one-mile area, and the cases are the block groups of sprawl retrofitting projects in this research. The case-control approach can help identify the impacts of sprawl retrofitting projects on the socio-demographic structure of the sites and the neighborhoods in the one-mile surrounding region (Figure 6).

Sprawl retrofitting conditions are not typical in each project and vary in different aspects (e.g., typology, location, existing demographic structure, land availability, etc.). The case-control method helps test the hypothesis by assessing the impact of retrofitting projects with various conditions (e.g., typology, location, and built environment changes).

Table 1

Number of Block Groups

	1990	2000	2018
Treatment Group	124	117	117
Control Group	2,161	1,879	1,872

Therefore, this study has developed a few hypotheses for socio-demographic variables by reviewing the literature. Three primary hypotheses are derived from previous literature, which build the foundation of this study's analysis.

The first hypothesis is based on the direct outcomes of sprawl retrofitting; over time, more people are being relocated in a retrofitted area with a higher building density where there is a greater number of jobs to support the newly settled population. Two approaches upon which sprawl retrofitting has had influence are compact development and smart growth. Population is the central focus that these two approaches attempt to relocate in a more compact form. This will eventually form new activity centers with mixed-land use and diverse facilities. Two indicators of this change are population density and job density, which are expected to increase due to retrofitting projects.

The second hypothesis refers to transportation outcomes of sprawl retrofitting. Sprawl retrofitting decreases car dependency by promoting sustainable transportation (Torrens & Alberti, 2001). Some of the changes could be enhancing different travel modes, providing access to transit, and increasing walkability to everyday destinations. The selected indicators of transportation outcomes are travel mode, vehicle ownership, and commute time. The presumptive changes are increased walkability, average travel time to work and transit to commute, and decreased automobile dependency in daily travel. Vehicle ownership is projected to drop by the time the projects are completed.

Third, sprawl retrofitting changes the built environment by increasing density and confirming compact development principles. These changes can bring more jobs and housing capacity to the area followed by initial needs, such as enhanced urban infrastructure and maintenance, which will increase the cost of accommodation and affect the economic value in the area. It can also cause issues such as gentrification, population displacement, and social inequity. June Williamson and Ellen Dunham-Jones have studied some of the changes resulting from sprawl retrofitting (Williamson & Dunham-Jones, 2021). Indicators related to these changes are an increase in housing value, gross rent, percentage of renters, household income, percentage of children, percentage of the population with a bachelor's degree, and non-Hispanic white population.

The hypotheses mentioned above are proposed changes in the project's sites compared to the control group. Table 2 shows each hypothesis for changes related to the socio-demographic indicator in the project sites.

Table 2

Socio-demographic Changes Hypothesis (Case-Control Comparison)

<table>
<tr><th></th><th>Outcomes</th><th colspan="2">Variables</th><th>Hypothesis</th></tr>
<tr><td rowspan="14">Socio-Demographic Data</td><td rowspan="2">Direct Population Outcomes</td><td colspan="2">Population Density</td><td>More Increase or Less Decrease</td></tr>
<tr><td colspan="2">Job Density</td><td>More Increase or Less Decrease</td></tr>
<tr><td rowspan="5">Transportation Outcomes</td><td rowspan="3">Mode Share Percentage</td><td>Transit to Commute Auto</td><td>More Increase or Less Decrease</td></tr>
<tr><td>Walking</td><td>More Increase or Less Decrease</td></tr>
<tr><td>Automobile</td><td>More Decrease or Less Increase</td></tr>
<tr><td colspan="2">Average Travel Time to Work</td><td>More Increase or Less Decrease</td></tr>
<tr><td colspan="2">Average Vehicles per Housing Unit</td><td>More Increase or Less Decrease</td></tr>
<tr><td rowspan="5">Economic and Social Outcomes</td><td colspan="2">Median Gross Rent</td><td>More Increase or Less Decrease</td></tr>
<tr><td colspan="2">Median House Value</td><td>More Increase or Less Decrease</td></tr>
<tr><td colspan="2">Median Household Income</td><td>More Increase or Less Decrease</td></tr>
<tr><td colspan="2">Percentage of People with Bachelor's Degree</td><td>More Decrease or Less Increase</td></tr>
<tr><td colspan="2">Percentage of Non-Hispanic White</td><td>Unsure</td></tr>
</table>

Given that socio-demographic analysis is implemented over time and in project sites and control groups, t-test analysis was used to identify the correlation between those changes. Using census data, a paired sample t-test analysis was chosen to identify these changes. This analysis includes two sets of socio-demographic data from three different years (1990, 2000, and 2016) and compares case and control groups simultaneously. The *p*-value is the identifying factor in understanding the results. The *p*-value determines changes for each variable and is used to identify groups with statistically significant changes. A *p*-value lower than 0.05 indicates the significance of the comparison in the t-test. A *p*-value higher than 0.05 shows no statistically significant changes between the two compared groups.

Urban Form Data Collection

Data collection for urban form analysis is mainly done manually by analyzing the aerial imagery. Urban form variables included in this study are block size, intersection density, the percentage of green space, and two density variables (population and jobs). These variables were measured by tracking the changes from a hypothetical starting date for each project until the completion date. The starting year was identified by looking at satellite images and determining when the first significant construction appeared on the project site. Major constructions include adding new street segments, demolishing existing buildings, and establishing new buildings.

Table 3

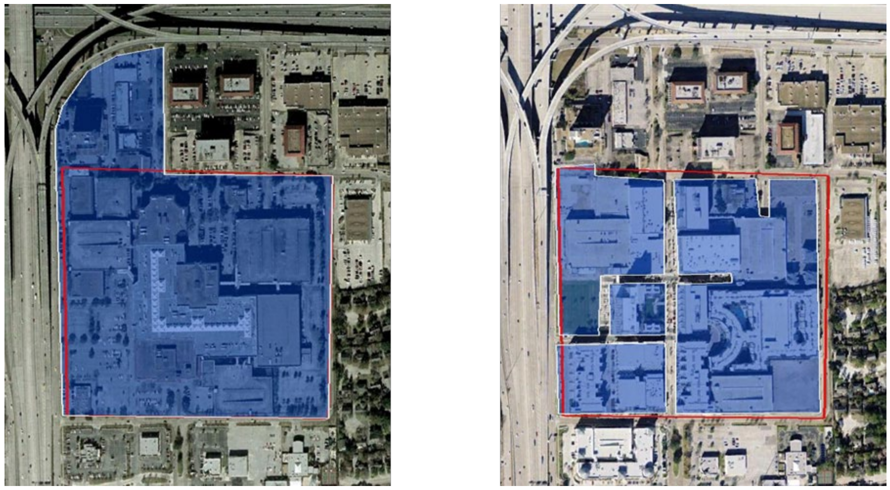
Data Sources and Hypothesis for Urban Form Changes

	Variable	Hypothesis (after the project)	Data source
Urban Form	Average Block Size	Decrease	Google Earth Pro
	Intersection Density	Increase	
	Percentage of Green Space	Increase	
	Job Density	Increase	Census 2000 and ACS 2014-2018 (population density) and LEHD (job density)
	Population Density	Increase	

To measure the block size, streets play an essential role in identifying block boundaries. Most project sites have undergone changes in the number of blocks after they are retrofitted. Number of blocks in these projects has increased, since sprawl retrofitting aims to improve walkability and access through block size modifications. As shown in Figure 7, the number of blocks in the CityCentre project in Texas increased after the retrofitting project. Consequently, the average block size decreases and improves pedestrian access in the surrounding area. This project is a dead mall retrofit and was completed in 2010.

Figure 7

The Measure of Block Size Example (City Centre, Houston, TX)



Note. The average block size decreased from 47.05 acres in 2002 to 8.56 acres in 2010.

Intersection density is calculated by the number of intersections divided by the project site area. An intersection is often referred to as a place where two, or more than two, streets converge (NamGung et al., 2020). This measure usually corresponds to the number of blocks, since blocks change by the number of roads in a place.

Figure 8

Measure of Intersection Density Example (Easter Hill, Richmond, CA)

Note. Intersection density increased from 0.18 intersection per acre in 2003 to 0.27 in 2006.

Figure 8 shows a retrofitting project in California that has undergone a residential retrofit with new construction and circulation changes. The image of the previous site condition shows the increase in the number of intersections by two, which results in a higher intersection density.

Green space is one of the factors that can contribute to human and environmental health and enhances the experience in a place. Regreening is one of the major approaches in sprawl retrofitting projects that has been discussed in the past sprawl retrofitting projects (Dunham-Jones & Williamson, 2011). The green space percentage variable is one of the urban form factors used to evaluate the changes in green space area on project sites. Since each project has a different land area, calculating the green space area does not produce a meaningful result. Therefore, the percentage of green space is measured in relation to the entire retrofitted site. Google Earth imagery is examined before and after projects, and public green spaces are traced and imported into ArcGIS pro for area measurements.

Figure 9

Measure of Percentage of Green Space Example (Potomac Yard, Alexandria, VA)

Note. Percentage of green space increased to 5 percent from 2007 to 2015.

Figure 9 shows green space improvements in a retrofitting project in Virginia. It started with no green space area before project completion and increased to five percent green space area after the completion date.

Urban Form Data Analysis

The secondary analysis of the study is to measure urban forms before and after sprawl retrofitting projects. After compiling the urban form data for the project sites, each variable was joined spatially to the projects in ArcGIS software for calculation. Anticipated changes are proposed as a hypothesis for each urban form variable. These changes are derived from compact development and sprawl retrofitting approaches aiming to increase accessibility and walkability and reduce car dependency. Therefore, average block size, intersection density, and percentage of green space were chosen for the hypothesis of changes in the project sites (Table 4).

Table 4

Urban Form Changes Hypothesis

	Variable	Hypothesis (after the project)
Urban Form	Average Block Size	Decrease
	Number of Intersections	Increase
	Percentage of Green Space	Increase
	Job Density	Increase
	Population Density	Increase

A single group interrupted time-series design method was used to analyze urban form changes. This approach measures the changes of a variable in a specific period individually for each project. In addition, a t-test was applied to the dataset in the final section to find any possible correlations in urban form changes. A t-test compares each variable's changes for all the projects given two time series before and after project completion. By running the t-test, the result was statistically analyzed to determine significant variable differences over time.

CHAPTER IV

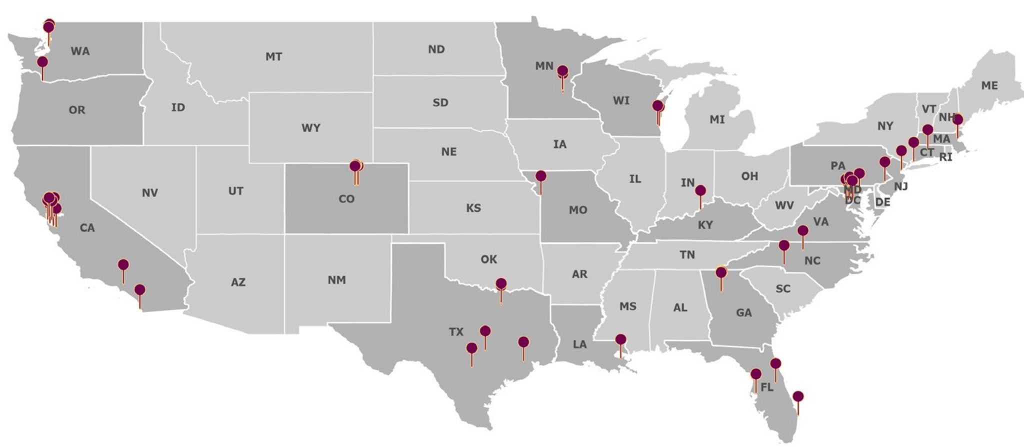
RESULTS

Inventory of Sprawl Retrofitting Projects

After reviewing multiple sources and applying the criteria, we identified 59 sprawl retrofitting cases completed between 2000 and 2016 in the United States. Figure 10 shows the distribution of the projects. Among 20 states with sprawl retrofitting projects, California has the highest number with 10 projects, followed by Texas with seven projects. The extent of each project is estimated by comparing the historical aerial imagery, and the size could vary from one project to another depending on the scale and retrofitting tools. Residential retrofits generally encompass a larger area, while other retrofits, such as dead mall projects, cover a small block.

Figure 10

Location of 59 Sprawl Retrofitting Projects



Data compilation of these sites is followed by additional information such as location, completion date, and built environment changes (Table 5). All projects were completed after 2000, and the most recent projects were completed in 2016. Most retrofits were accompanied by land-use change, demolishment, and new roads and buildings added to the site.

Table 5

Inventory of Sprawl Retrofitting Projects

Name	Location	Completion Date	Built Environment Changes			Area (acre)
			Road	Building	Use	
The Crossings	Mountain View, CA	2002	■	■	■	20.8
City Place	West Palm Beach, FL	2002	■	■	■	32.9
Santana Row	San Jose, CA	2004	■	■	■	41.4
Gateway Village	Charlotte, NC	2005	■	■	■	48.1
Brookside Park	College Park/ Atlanta, GA	2005	■	■		34.1
Lowry	Denver, CO	2005	■	■	■	42.0
Liberty Station	San Diego, CA	2005	■	■	■	89.6
Ballston Corridor	Greater DC area	2006	■	■	■	69.6
Easter Hill*	Richmond, CA	2006	■	■	■	21.9
Belmont Heights*	Tampa, FL	2006	■	■	■	102.4
Glenwood Park	Atlanta, GA	2007	■	■	■	17.1
Albemarle Square*	Baltimore, MD	2007	■	■	■	15.8
Rockville	Greater DC area	2007	■	■	■	66.1
Beerline	Milwaukee, WI	2007	■	■	■	25.1
Baldwin Park	Orlando, FL	2007	■	■	■	51.8
Martin Luther King Plaza*	Philadelphia, PA	2007	■	■	■	6.8
Legacy Town Center (1)	Plano, TX	2007	■	■	■	161
New Columbia*	Portland, OR	2007	■	■	■	93.4
Richmond Transit Village	Richmond, CA	2007	■	■	■	9.0
Valencia Gardens*	San Francisco, CA	2007	■	■		5.4
Harbour Place	Tampa, FL	2007	■	■	■	19.9
Atlanta Station	Atlanta, GA	2008	■	■	■	141.3
Highlands Garden Village	Denver, CO	2008	■	■	■	28.9

Name	Location	Completion Date	Built Environment Changes			Area (acre)
			Road	Building	Use	
Old Town	Fairfax, VA	2008	■	■	■	16.8
Reston Town Center	Greater DC area	2008	■	■	■	107.2
Southside	Greensboro, NC	2008	■	■	■	33.1
Northgate Village*	Kansas City, MO	2008	■	■	■	74.3
Belmar (1)	Lakewood, CO	2008	■	■	■	75.4
Excelsior & Grand	St. Louis Park, MN	2008	■	■	■	22.4
Blue Back Square	West Hartford, CT	2008	■	■	■	15.4
Addison Circle	Addison, TX	2009	■	■	■	65.9
Village Creek	Brooklyn Park, MN	2009	■	■	■	51.4
Northgate Mall	Seattle, WA	2009	■	■	■	75.1
City Centre	Houston, TX	2010	■	■	■	39.6
Station Landing	Medford, MA	2010	■	■	■	12.9
River Garden*	New Orleans, LA	2010	■	■	■	65.2
High Point Redevelopment Project*	Seattle, WA	2010	■	■	■	162.1
Pleasant Hill Transit Village	Walnut Creek, CA	2010	■	■	■	18.1
The Domain (1)	Austin, TX	2011	■	■	■	99.3
Tassafaronga Village*	Oakland, CA	2011	■	■	■	8.3
Legacy Town Center (2)	Plano, TX	2013	■	■	■	78.7
Norton Commons	Prospect, KY	2013	■	■	■	327.5
Harbor East	Baltimore, MD	2014	■	■	■	11.4
Gateway at Carteret	Carteret, NJ	2014	■	■	■	10.0
The Commons	Denver, CO	2014	■	■	■	67.7
Mosaic District	Fairfax, VA	2014	■	■	■	38.6
Arts District Hyattsville	Hyattsville, MD	2014	■	■	■	29.0
Westlawn Gardens*	Milwaukee, WI	2014	■	■		19.4
Harbor Point	Stamford, CT	2014	■	■	■	21.1
Capitol Quarter*	Washington D.C.	2014	■	■	■	24.8
Potomac Yard	Alexandria, VA	2015	■	■	■	63.2
Ponce City Market	Atlanta, GA	2015	■	■	■	17.4
Homes at Old Colony*	Boston, MA	2015	■	■	■	8.4
Belmar (2)	Lakewood, CO	2015	■	■	■	39.7
Westgate Pasadena	Pasadena, CA	2015	■	■	■	15.0

Name	Location	Completion Date	Built Environment Changes			Area (acre)
			Road	Building	Use	
Assembly Ro	Somerville, MA	2015	■	■	■	40.1
The Domain (2)	Austin, TX	2016	■	■	■	78.8
Pearl Brewery	San Antonio, TX	2016	■	■	■	18.8
Bay Meadows	San Mateo, CA	2016	■	■	■	78.3

* Public Housing project

Note. Built environment changes are divided into three categories. Road changes include added roads and blocks to the site. Newly added buildings are other significant built environment changes besides land-use change. Each filled built environment cell shows changes in the corresponding column.

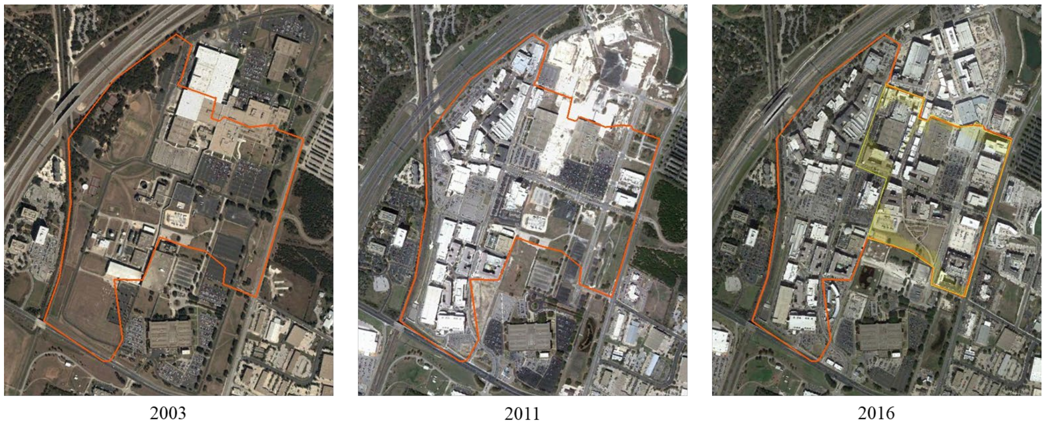
The size of the projects varies between five acres to 327 acres, and depending on the built environment changes, it can encompass a larger area. Most retrofitted sites have undergone major changes, and the urban fabric has changed significantly. The street pattern, building density, and green space development were some major changes identified by comparing the images before and after projects. Depending on the previous land use of each site, different typologies, such as dead mall, industrial, greenfield, and business park retrofits, are identified. Some sprawl retrofitting projects found in sprawl retrofitting literature, and added to the inventory for the analysis, are provided as examples in the following section to provide a context for the selected inventory of the projects.

- **Industrial retrofit: The Domain, Austin, Texas**

The Domain (Figure 11) is an industrial retrofit in Austin that attempts to disrupt auto dependency and provide more walkable areas in the sprawling industrial zone. The project site is located next to the highway, and the eastern border has a five-minute walk distance to a light rail station. This project has changed the urban form elements by adding buildings, roads, and blocks to achieve retrofitting objectives.

Figure 11

Retrofitting Changes Over Time (The Domain, TX)



This retrofit encompasses 178 acres of land and was completed in two different years. The first phase was completed in 2011 by providing shopping centers, residential buildings, and parking spaces to support the visitors in the area. The second phase was completed in 2016, providing more housing and shrinking parking lots by adding buildings to the site.

Figure 11 shows the changes over time in three different years. Existing building structures were replaced by renovated new buildings after the retrofit that contain restaurants, cafes, and other retail. The majority of the green space area on the west border of the site has turned into new urban infrastructure and new businesses, such as a museum and retail shops. According to the book *Case Studies In Retrofitting Suburbia*, 5000 residential units permits were allocated to the project to be built on 4-5 story buildings (Williamson & Dunham-Jones, 2021). New office buildings provide more jobs and proximity to a dense employment center for residents without having to drive downtown.

Figure 12

Residential Units in the Domain Are Primarily 4 to 5 Story Buildings (Source: Dunham-Jones & Williamson, 2011, Philip Jones, 2019)

This project has provided public spaces, pedestrian-oriented streets, and plazas to encourage social interactions in a vibrant space for residents and visitors. A mixed-use, high-density design has greatly changed the suburban, car-oriented characteristic of the area.

- Shopping center retrofit: The Mosaic District, Merrifield, Virginia

Built on 38.6 acres, the Mosaic District is a shopping center retrofit completed in 2014. A strip mall, big parking lots, and a dead theater demonstrated suburban traits that started to be retrofitted in the past decade. The retrofit includes providing accessibility by adding streets to the project and facilitating movement into the site. Large blocks are divided into several smaller blocks that make it easier to travel, especially by walking, inside the area.

Figure 13

Shopping Center Retrofit, The Mosaic District, Merrifield, VA

2008

2014

By demolishing some buildings and adding mixed-use and high-density compact development, the Mosaic District is more walkable and less car-dependent compared to the past. The grid street pattern has established much more connectivity, which has privileged pedestrian use in the area. The old theater maintained its activity and was transformed into a new cinema with green open spaces as a gathering area for social events (Figure 14). Also, storefront design was an essential part of the retrofits to maintain their appearance and visibility in adjacency to big-box shopping centers and cinemas. Multi-story parking lots have helped reduce land occupation and accommodate the visitors to the commercial sites with the projected needs of the population.

Figure 14

Newly Developed Theater Next to a Park as a Gathering Place (Source: Dunham-Jones & Williamson, 2011, Philip Jones, 2018)

- Residential and industrial retrofit: Assembly Row, Somerville, Massachusetts

Assembly Row is an industrial retrofitted site adjacent to the Mystic and Malden rivers confluence, a water access to the surrounding region (Figure 15). The Assembly Station provides regional access to the assembly district from the south and north. This retrofitting project contains mixed-uses and high-density buildings with walkable streets. It also encourages sustainable transportation by designating biking paths in the district.

Figure 15

Industrial Retrofit, Assembly Row, MA

2008

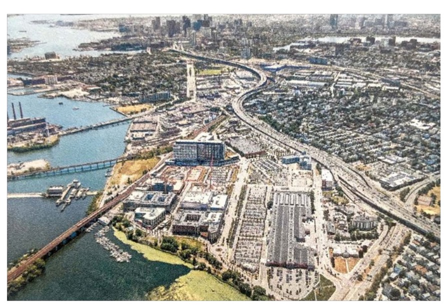
2015

Before the project started, the assembly row was an industrial district with vacant lands and a large brownfield site on the riverside. The retrofitting process has added to residential and office buildings, increased job opportunities, and enhanced pedestrian access by adding more street connections to the district, which was largely accessible only by car in the past (Figure 16).

Figure 16

Before (I) and After (II) Retrofitting (Source: Photos courtesy of Federal Realty Investment Trust, Dunham-Jones & Williamson, 2011)

I



II

This project has created many jobs in the retail and healthcare sectors. The office buildings and residential units on top of small retail shops and old shipping containers alongside the plazas and sidewalks have provided a mixed-use development that attracts social interactions in the area (Figure 17). Assembly Square has a public realm designed for walking, biking, and transit use and aims to address the job-housing imbalance in the area.

Figure 17

Reused Shipping Containers Used as Retail Shops, Providing a Public Space for Social Interactions (Source: Photos courtesy of Federal Realty Investment Trust, (Dunham-Jones & Williamson, 2011))

Socio-demographic Changes

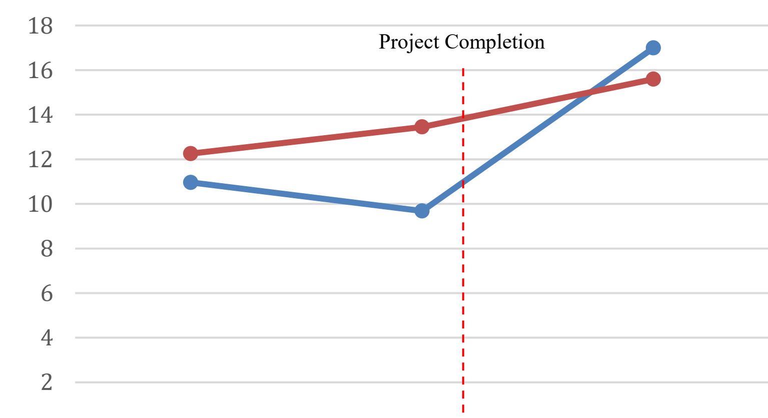
The socio-demographic analysis is based on the data collected in the previous chapter. Based on the outcomes of sprawl retrofitting, corresponding hypotheses helped choose the variables needed to evaluate the changes. The data for each variable is joined to the corresponding block group in the analysis. Socio-demographic data analysis compares the differences in changes, considering the control group, before and after projects. This analysis includes a case-control comparison to derive any relation between the project site and the one-mile area outside the project boundary. The data used for the two case and control groups are exclusive and unique to avoid double counting and inaccurate results. The following section demonstrates each variable's changes for the inventory of 59 sprawl retrofitting projects before and after projects in three different years. Since these projects were completed between 2002 and 2016, two datasets of 2000 and 2016 are selected to compare the changes. To further analyze the data, provide a more comprehensive analysis, and cover the changes before project completion dates and starting dates, 1990 data is also compared to the other two datasets.

- Population density

Population change is a direct impact of sprawl retrofitting on a site. Population density is calculated by the number of people divided by the acreage of the projects. The population density in the project site and control group has increased overall. There is a slight decrease in the project site in 2000, but population density increased more (7.31 persons per acre after project completion) in the project site. This change can be due to the buildings added to the neighborhoods that accommodate more residents and workers.

Figure 18

Population Density (person per acre), n=59



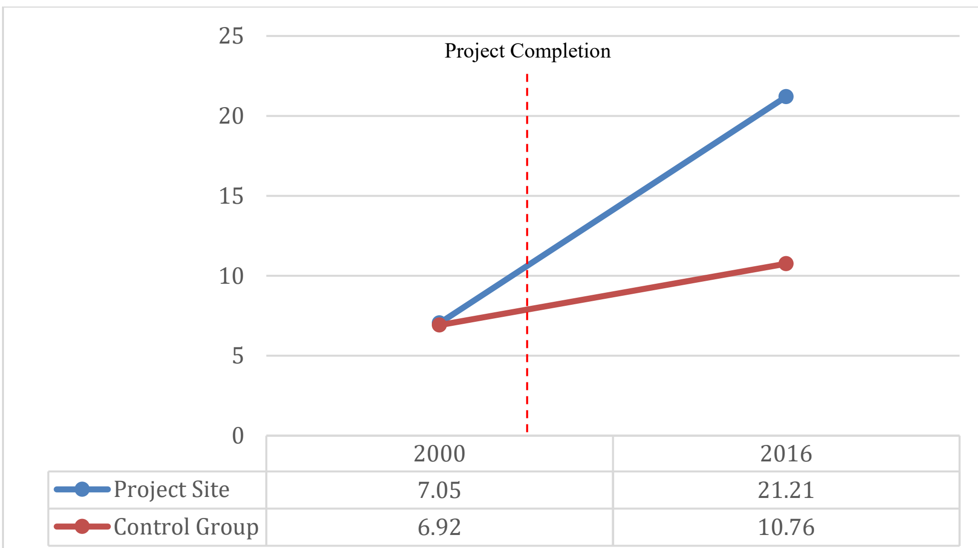
	1990	2000	2016
Project Site	10.96	9.68	16.99
Control Group	12.25	13.45	15.60

- Job density

Job density is an indicator that is directly influenced by the built environment changes. Job density is compared in two years since the 1990 database does not include job data. As demonstrated in Figure 16, job density has increased in both groups, with a greater increase in the project site. This change can be related to the number of commercial and retail shops added to the project sites over time.

Figure 19

Job Density (number of jobs per acre), n=59



	2000	2016
Project Site	7.05	21.21
Control Group	6.92	10.76

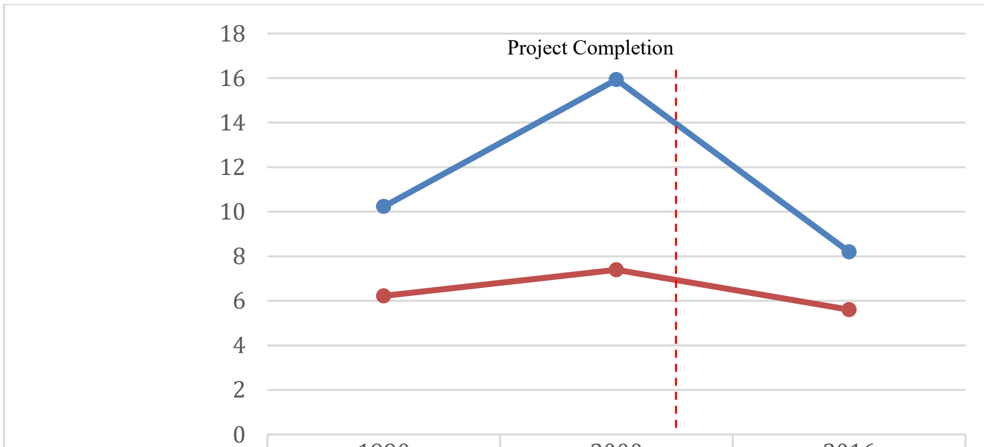
- Mode Share

    1. Percentage of walking to commuting

Walking is one of the travel modes that can be enhanced by providing a more pedestrian-friendly environment. The percentage of walking is measured by comparing it to all the travel mode options residents use. This variable has decreased over time. The project site percentage has dropped more than the control group. However, few projects have provided a more pedestrian-friendly environment and increased access by adding connections and reducing the block size. The project site has a higher percentage overall after completion compared to the control group.

Figure 20

Percentage of Walking, n=59



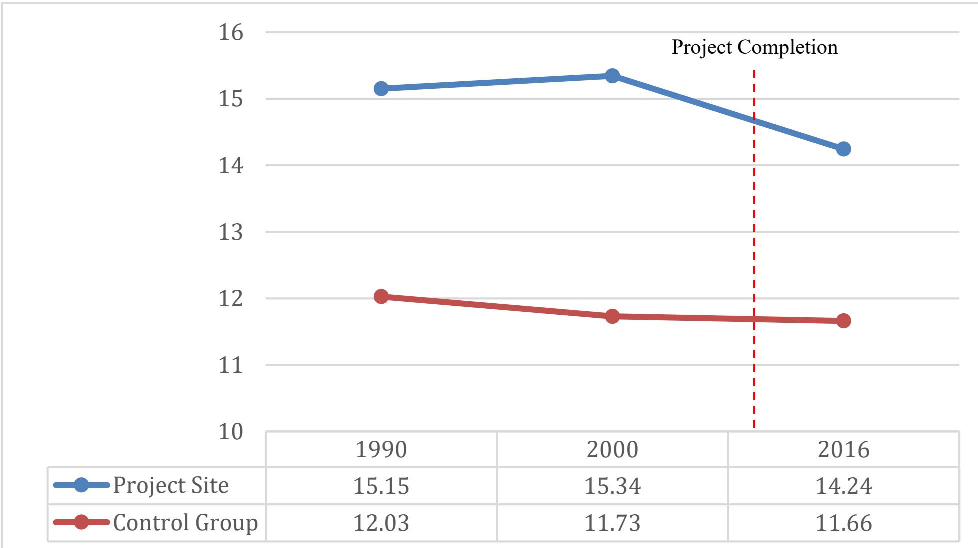
	1990	2000	2016
Project Site	10.23	15.93	8.20
Control Group	6.22	7.39	5.60

2. Percentage of transit to commuting

Transit percentage has slightly decreased in the control group and project site with greater decrease in the sprawl retrofitting neighborhoods. This can be due to the possibility that the area's new population has proportionally reduced the use of public transportation over time and therefore, lowered the percentage of transit use at the project site (Steil et al., 2008).

Figure 21

Percentage of Transit, n=59

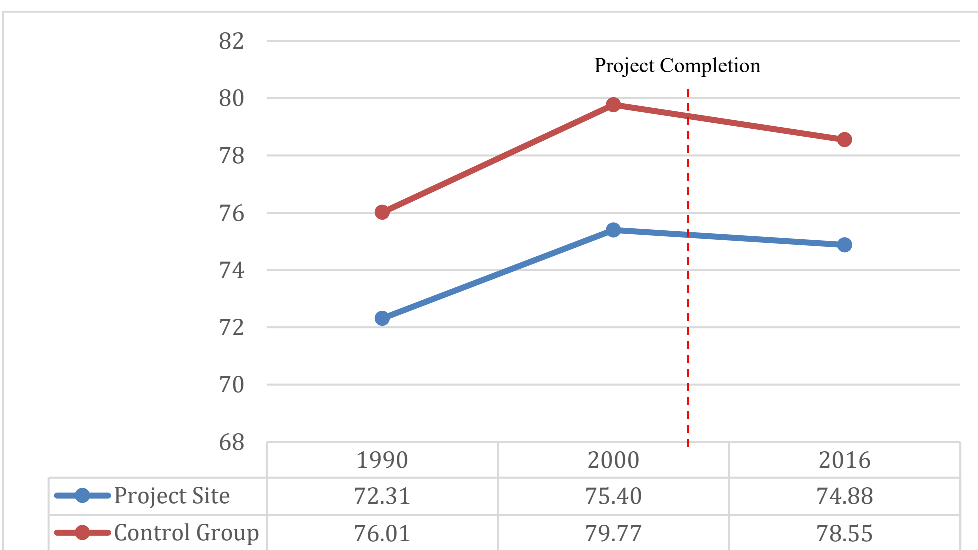


3. Percentage of automobile use

Automobile use has an increase from the 1990 to 2000 period. This number decreased less in project sites (0.52%) after the project completion than in the control group (1.22%).

Figure 22

Percentage of Automobile Use, n=59

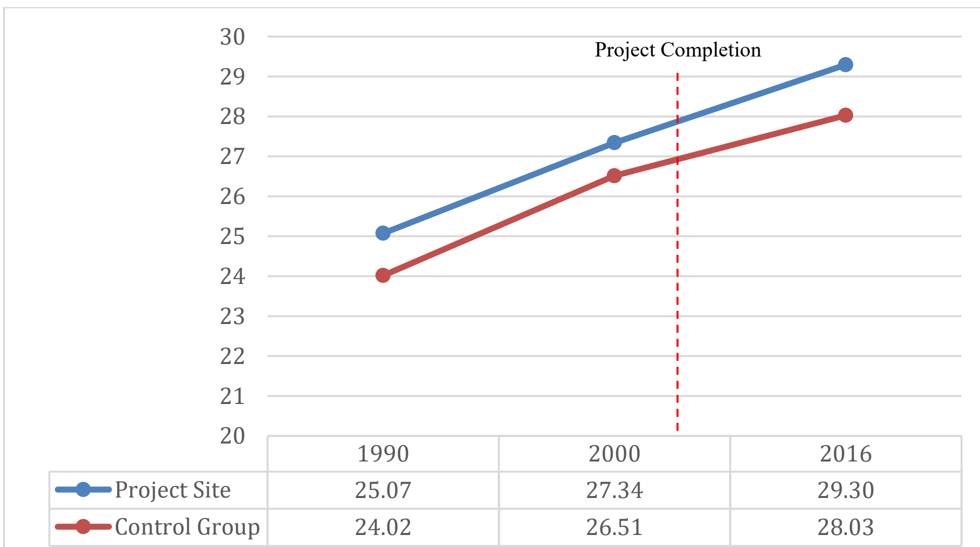


- Average travel time to work

Commute time to work has increased in both project sites and the control group. Despite this change, the increase rate has declined in the control group while remaining consistent in the project sites. The project site's average travel time increased by 4.23 minutes from 1990 to 2016.

Figure 23

Average Travel Time to Work, n=59



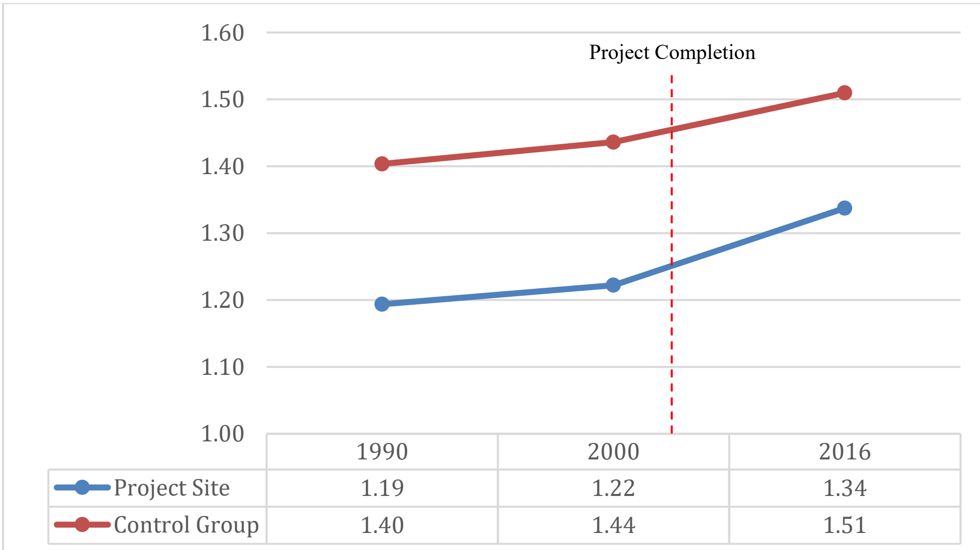
	1990	2000	2016
Project Site	25.07	27.34	29.30
Control Group	24.02	26.51	28.03

- Number of vehicles per housing unit

Number of vehicles owned by people living in a house increased after the project's completion. Although vehicle ownership is lower in the project sites, it has a growing rate after project completion.

Figure 24

Number of Vehicles Per Housing Unit, n=59

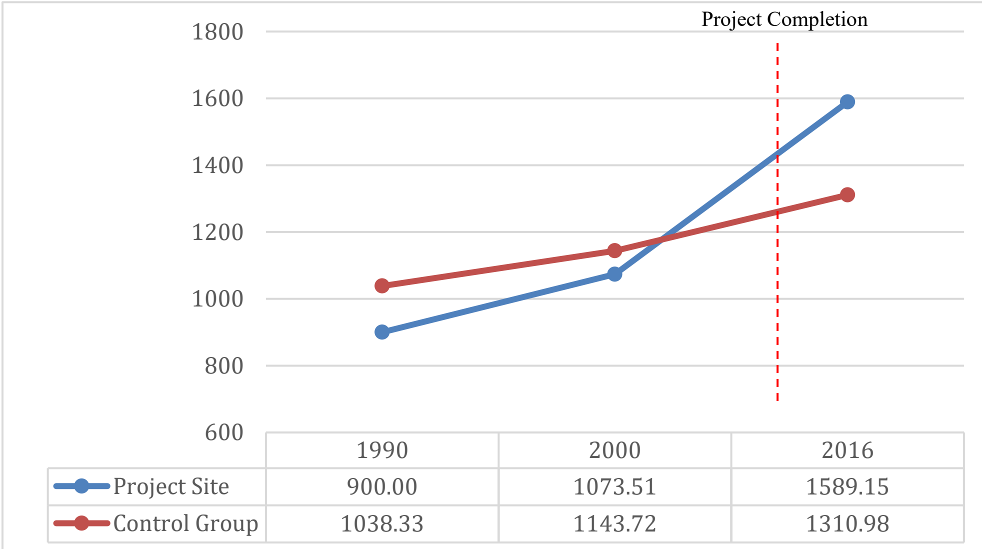


- Gross rent

There is an increase in gross rent in both groups. As shown in Figure 24, there is a larger change in the rental price in the project sites after the completion date. Injecting more urban infrastructure and providing more housing units alongside other commercial amenities could have influenced the rental price.

Figure 25

Median Gross Rent, n=59

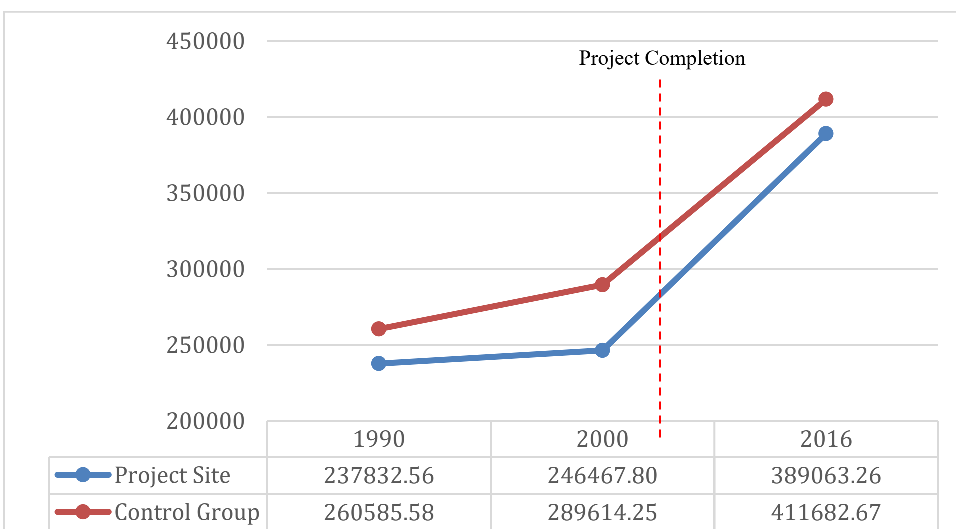


- Median housing value

Median house value is an indicator of the average housing cost in the area. Housing costs have increased, especially after project completion in both groups. Higher quality housing with more access to jobs and services can impact housing costs after retrofits.

Figure 26

Median housing value, n=59



- Median household income

The average household income in the study area has increased overall. The project sites have had greater increase compared to the control group. Also, project completion can have an impact on the residents' economy. Since 2000, median household income has increased by $22,452 in the project sites, while the control group had a $6,682 increase.

Figure 27

Median household income, n=59

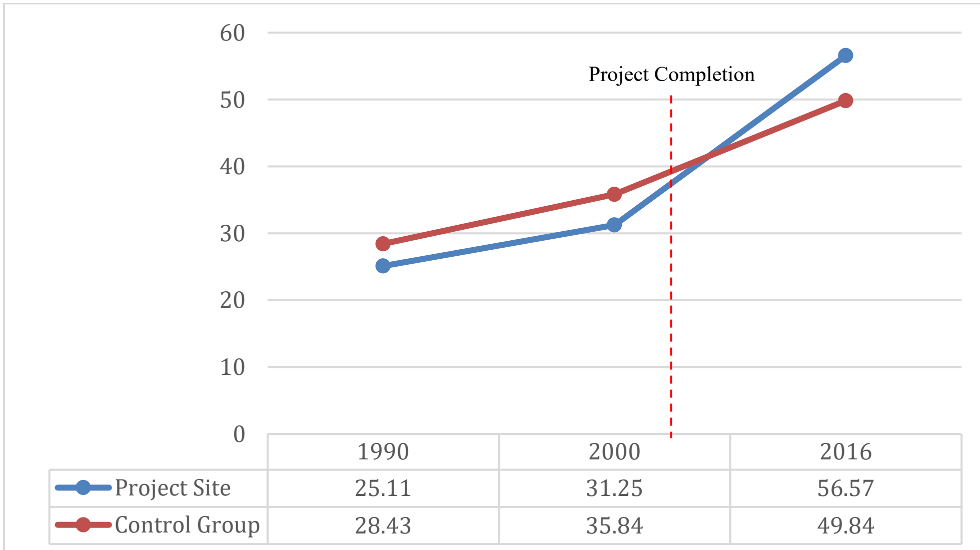
	1990	2000	2016
Project Site	58606.34	61450.02	83902.80
Control Group	66387.03	74976.12	81658.67

- Percentage of population with bachelor's degree

Percentage of the population with a bachelor's degrees had a 31.46 percent increase in the project sites, with 56.57 percent in 2016. It also increases in the control group, though with a lower change of 21.41 percent.

Figure 28

Percentage of Population with Bachelor's Degree, n=59



- Percentage of non-Hispanic white

The non-Hispanic white population increased after the project completion date at the project site (1.46 percent), while it decreased in the control group by 4.56 percent in the control group. This can be interpreted as the white population migration from the surrounding region to the project site.

Figure 29

Percentage of the Non-Hispanic White Population, n=59

	1990	2000	2016
Project	56.17	49.26	50.72
Control	64.21	56.54	51.98

Table 6 shows all socio-demographic variables' changes in three different years. The results show each variable before and after retrofitting projects.

Table 6

Socio-demographic Differences at Each Time Point

Variables	1990			2000			2016		
	Case	Control	*p*-value (t-test)	Case	Control	*p*-value (t-test)	Case	Control	*p*-value (t-test)
Population Density (persons/acre)	10.96	12.25	0.31	9.68	13.45	0.01	16.99	15.6	0.41
Job Density (jobs/acre)	-	-	-	7.05	6.92	0.95	21.21	10.76	<0.01
Percentage of Walking to Commute	10.23	6.22	0.08	15.93	7.39	0.14	8.2	5.6	<0.01
Percentage of Transit to Commute	15.15	12.03	0.01	15.34	11.73	<0.01	14.24	11.66	0.01
Automobile Use Percentage	72.31	76.01	0.11	75.4	79.77	0.01	74.88	78.55	<0.01
Average Travel Time to Work (minute)	25.07	24.02	0.18	27.34	26.51	0.11	29.3	28.03	<0.01
Vehicle Per Housing Unit	1.19	1.4	<0.01	1.22	1.44	<0.01	1.34	1.51	<0.01
Gross Rent (2018 adjusted dollar)	900	1038.33	<0.01	1073.51	1143.72	0.26	1589.15	1310.98	<0.01
Median Household Income (2018 adjusted dollar)	58606.34	66387.03	0.12	61450.02	74976.12	<0.01	83902.8	81658.67	0.52
Percentage of People with Bachelor's Degree or Higher	25.11	28.43	0.08	31.25	35.84	0.03	56.57	49.84	<0.01
Percentage of Non-Hispanic White	56.17	64.21	<0.01	49.26	56.54	<0.01	50.72	51.98	0.47

To evaluate the results and find any statistically significant changes among the projects, a t-test analysis was added to the analysis. A t-test uses two case-control comparison groups and compares the variables over two different periods. The project's values of each variable are compared with the control group in two different years. First, the difference in all values is calculated. For example, an increase in gross rent from 2000 to 2016 is a difference used by the t-test to analyze the data. After calculating all the differences for each variable in the project site and control group, the result is two different values for each variable in each project. The paired sample t-test uses all these values for every project and compares the changes by calculating a *p*-value. This number shows that the changes are statistically significant among the projects or are not consistent for most of them. A *p*-value of 0.05 and below shows a statistically significant result, and a *p*-value above 0.05 does not show a statistically significant result. After running the t-test analysis on the socio-demographic data, a *p*-value is calculated for each variable. According to Table 7, population density, job density, gross rent, median household income, percentage of people with a bachelor’s degree, and the percentage of non-Hispanic white people have statistically significant changes among all the projects.

Table 7

T-test Analysis for Socio-demographic Data

Socio-demographic variable \ Group		1990-2000 Differences in changes		1990-2000	2000-2016 Differences in changes		2000-2016
		Case	Control	*p*-value of t-test	Case	Control	*p*-value of t-test
Population Density		-1.08	1.2	.03	7.47	2.14	<0.01
Job Density		-	-	-	14.28	3.84	<0.01
Commute Percentage	Walking	5.94	1.17	.30	-7.47	-1.79	.28
	Transit	0.44	-0.3	.47	-0.84	-0.07	.46
	Automobile	4.24	3.76	.88	0.74	-1.22	.39
Average Travel Time to Work		2.65	2.5	.87	2.41	1.51	.23
Vehicle Per Housing Unit		0.05	0.03	.79	0.14	0.07	.18
Gross Rent		191.28	105.4	.20	533.53	167.26	<0.01
Median Housing Value		34475.64	29028.67	0.59	148590.84	122068.42	0.61
Median Household Income		3559.91	8589.09	.40	23476.95	6682.55	<0.01
Percentage of people with Bachelor's Degree		5.58	7.41	.38	25.85	14	<0.01
Percentage of Non-Hispanic white		-5.58	-7.67	.52	2.27	-4.56	<0.01

In the socio-demographic t-test analysis, all the variables with a statistically meaningful *p*-value are also projected to change in the study's initial hypothesis. Two analyses before (1990-2000) and after (2000-2016) the completion date are used to compare and identify sprawl retrofitting impacts on the changes. Job and population density have statistically significant increases after retrofitting. According to the t-test analysis, gross rent, median household income, and percentage of people with a bachelor's degree experienced significant changes. Changes in transportation, such as vehicle ownership and mode percentage, can be impacted by changes in household income and travel time to work. Percentage of the non-Hispanic white population has increased in the project sites and decreased in the control group, which is also statistically significant. These results show a high probability that sprawl retrofitting has contributed to higher property prices, less affordability, reduced social equity, and accommodated more population with more jobs in the retrofitted sites.

Urban Form Changes

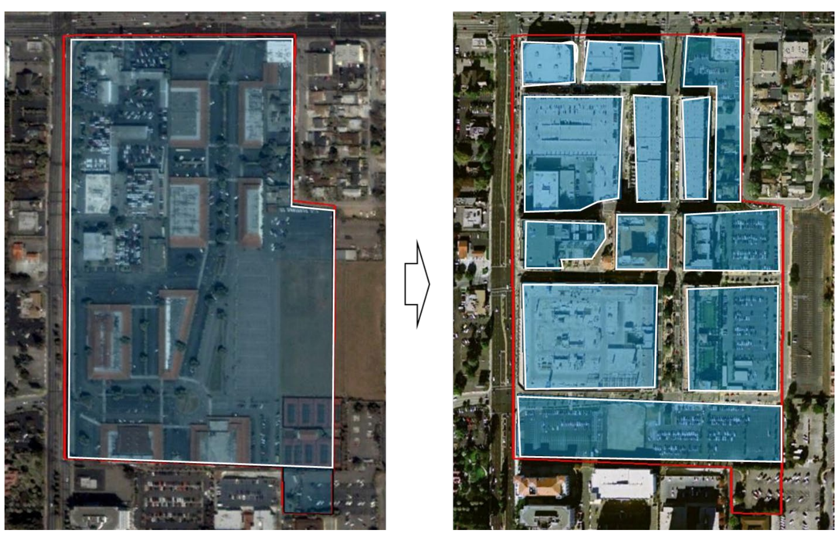
Urban form was analyzed to demonstrate the physical changes of sprawl retrofitting projects. The variables used to evaluate changes in the physical attributes of the sites are average block size, percentage of green space, and intersection density. After data compilation, each variable was compared to the previous condition before the project completion date. Satellite imagery is the source of the variables used for measuring the dimensions and forming a dataset for the analysis. Urban form analysis was implemented on the project site, and a single group interrupted time series design was used to analyze data.

- Average block size

Average block size is one of the urban form indicators that defines the urban environment and establishes a space between streets for building and open space development. This variable is measured by dividing the total area of the blocks by the number of blocks on the project sites. Acre unit is chosen (due to the project size and extent) to measure the area. After project completion, the average block size was reduced by 26.68 acres from an initial average size of 29.73 acres. The number of blocks changed from 256 to 890 blocks in total after retrofit projects. Newly added streets and roads divided the blocks into a higher number of smaller blocks in most projects. Figure 29 shows changes in the number and size of blocks before and after the project in a dead mall retrofit. The site used to have a single block with low accessibility. After the project, new streets were added, and smaller blocks changed the form of the district.

Figure 30

Average Block Size Change Over Time (Santana Row, CA)

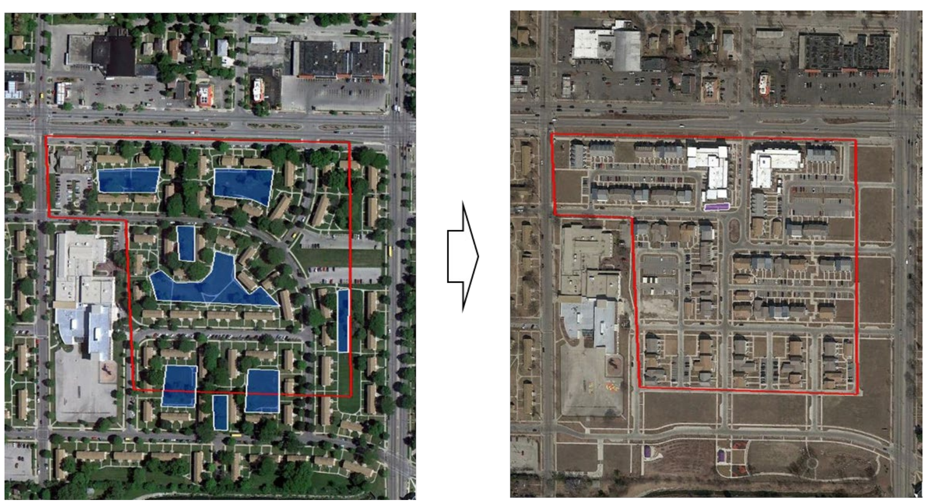


- Percentage of green space

Green space is one of the urban form indicators analyzed in this study to show the changes over time. The percentage of green space is calculated by the total green space in a project site divided by the area in acres. Overall, green space has been reduced in the project sites by 1.91 percent after the retrofits. Many projects have been developed on vacant lands or lots, including green open spaces, which reduced the projects' total green area. Fewer retrofits have added parks and open spaces to the sites. In the figure below, green space decreased significantly after the retrofit, and most open space was left vacant. This project used to have tall trees with turf grass in between the building lots. After the retrofit, buildings formed dense shapes adjacent to the streets, which restricted green space development.

Figure 31

Green Space Changes Colored in Purple; After the Retrofit, All Green Spaces Were Removed from the Site (Westlawn Gardens, WI)



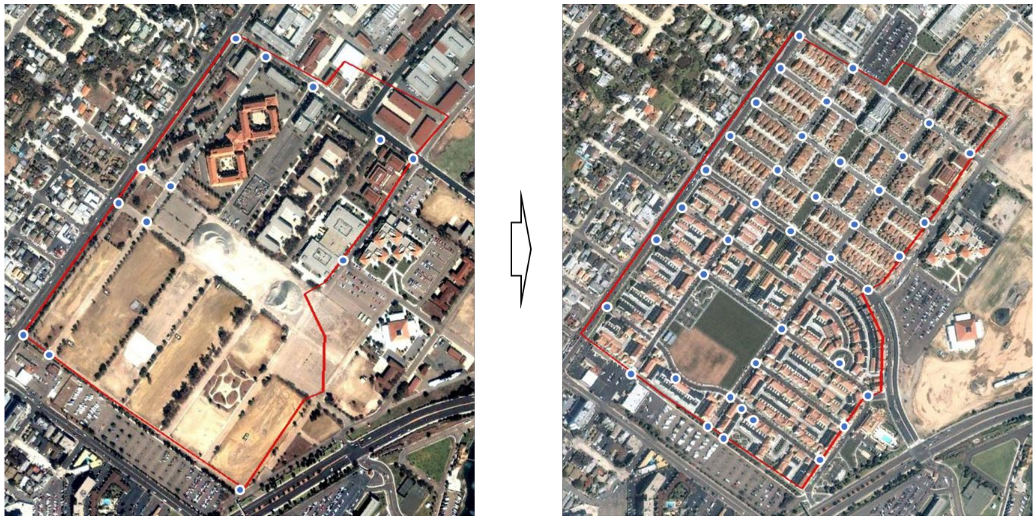
- Intersection density

Intersections are spots in which two or more streets converge. To calculate intersection density in a project, number of intersections is divided by the acreage of land. The projects' intersection density is increased by 0.25 intersections per acre in the project sites. The following figure shows an example of number of intersection changes in

Liberty Station completed in 2005.

Figure 32

Intersection Changes Are Shown in Blue Circles (Liberty Station, CA)



After analyzing the urban form indicators, t-test analysis was used to identify any significant difference between the means two groups, in this case, mean values before and after project completion. A paired sample t-test was used, and the mean values of the variables for 59 projects were analyzed in Table 8.

Table 8

Urban Form Analysis Results - T-test Analysis

	Before the project completion	After the project completion	*P*-value
Average Block Size (block size acreage/ number of blocks)	29.73	3.05	<0.01
Percentage of Greenspace (greenspace acreage/ project area)	7.11	5.20	0.12
Intersection Density (number of intersections/acre)	0.28	0.53	<0.01

P-value is an indicator of the t-test that shows the significance of the comparison. *P*-

values lower than 0.05 show the significance of the difference in mean numbers of a specific variable. Average block size has a *p*-value lower than 0.05, indicating that average block size has decreased in most projects. Intersection density has a meaningful *p*-value as well. Changes in the block numbers and street formation have led to an increased number of intersections on the majority of the project sites. The *P*-value of percentage of green space indicates that the difference in means of this variable is not statistically significant over time. Thus, it can be interpreted that green space acreage does not have the same consistent change in the project sites. However, it has decreased overall in the neighborhoods after completion. Block size and intersection density changes show that the projects have impacted the form to increase walkability, access, and density in the project sites.

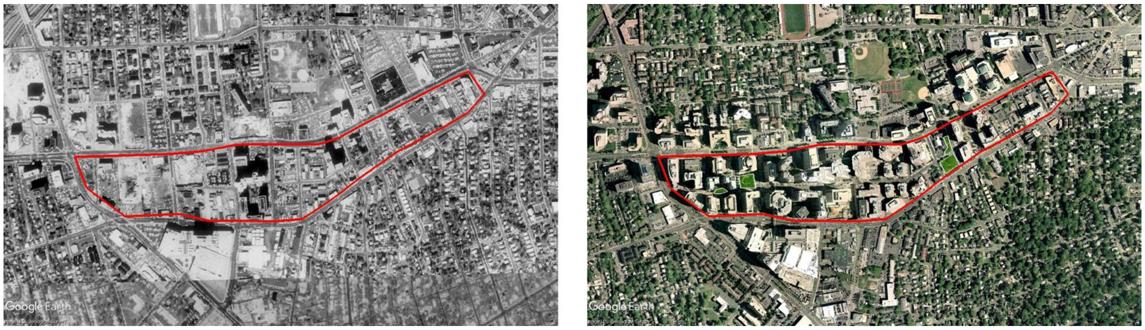
Socio-demographic and urban form comparisons reveal different results among the projects. Some projects show positive changes while others show negative changes. These changes are revealed by comparing the difference in changes of variables after the project completion. The following examples are the projects representing different levels of changes in socio-demographic and urban form indicators.

- **Cases 1: Ballston Corridor, Virginia**

Ballston Corridor is a 69.6-acre sprawl retrofitting project located along the MetroRail corridor in the heart of Arlington County in Virginia. This project is a dead mall retrofit completed in 2006 (Figure 32). It is an example of neighborhood preservation with a mix of new and historic buildings leveraging its location next to MetroRail on the Rosslyn-Ballston Corridor. This project has high-density urbanism along with transit and walking improvements. It also includes office spaces and commercial facilities in a walkable, transit-oriented corridor.

Figure 33

Successful Sprawl Retrofitting Example - Ballston Corridor, VA (Google Earth aerial imagery 1988 and 2006)



Ballston Corridor is an example of a successful sprawl retrofitting project due to several socio-demographic and urban form identifiers. The analysis before and after the project with the control group shows decreased gross rent ($92) and the average percentage of the non-Hispanic white population (7.5 percent). Also, as shown in figure 32, percentage of the green space area (highlighted green area) has increased (0.5 percent) on the map after the project completion. A combination of new public and private green space and parks has contributed to this change (Figure 33).

Figure 34

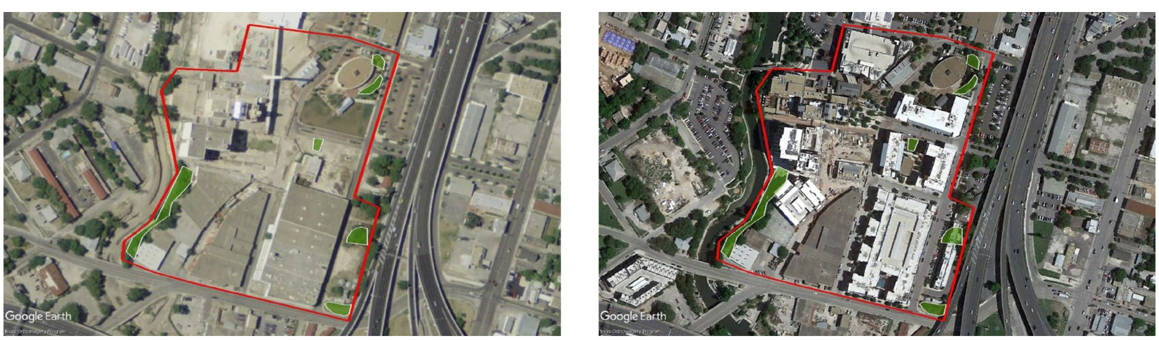
Successful Sprawl Retrofitting Green Space Example - Ballston Corridor, VA

- **Case 2: Pearl Brewery, Texas**

One of the examples of sprawl retrofitting in terms of socio-demographic and urban form changes is a former industrial zone located in San Antonio, Texas. This project revealed some negative results in terms of the difference in changes. The Texas Pearl Brewery has introduced mixed uses and activities, including some retail, commercial, residential, and office buildings, to become a center for local activities after completion in 2016 (Figure 34). Despite all these changes, the analysis shows inconsistency with the retrofitting practices by comparing socio-demographic and urban form identifiers. Housing and rental price changes show that the Pearl Brewery district has added to the value of residential buildings and possibly led to gentrification. The property tax increase can substantially impact fluctuations in housing market. Besides, an increase in the average percentage of the non-Hispanic white population also substantiates the project failure hypothesis, since it changed by 37 percent after the retrofitting completion date.

Figure 35

Unsuccessful Sprawl Retrofitting Example - Pearl Brewery, Tx (Google Earth aerial imagery 2008 and 2016)



Percentage of green space shows a consistent amount of greenery in theneighborhood; however, this project has contributed to local events and gatherings by providing public open space, plazas, and parks.

CHAPTER V

CONCLUSIONS

Summary of findings

This study has implemented socio-demographic and urban form analysis on the sprawl retrofitting project sites for 59 locations. Socio-demographic data initially showed differences in changes in all the variables. The variables either changed according to the hypothesis or demonstrated different results than those primary assumptions. Confirming the hypotheses, direct project outcomes such as population and job density have increased (Table 9). These changes were anticipated based on residential development and an increased mix of uses in retrofitting sites. New retail shops, offices, commercial buildings, and housing units resulted in more residents and employees working and living in those neighborhoods. Changes in floor area ratio in some projects have influenced the population being occupied in the neighborhoods and consequently increased job and population density.

Sprawl retrofitting projects are subjected to provide sustainable transportation and walkable communities. High-density, mixed-use areas with corresponding transportation alternatives are features known to slow down the process of sprawl. Transportation identifiers, such as travel time, mode share, and vehicle ownership, are measured and compared in different years to evaluate possible changes after retrofitting projects. However, some differences in transportation outcomes have changed unexpectedly compared to the primary hypothesis. In mode share, percentage of automobiles used to commute increased between 1990 and 2000 with a slight decrease after 2000. Percentage of transit used to commute has decreased after 2000, although it increased slightly during

1990 decennary. Percentage of walking to commute followed the same pattern with a sheer drop from 16 to eight percent after the projects. Other variables changed as opposed to the hypothesis. Mode share (walking and transit percentage) were unexpected results in some projects. Population density, job density, gross rent, median household income, percentage of people with a bachelor's degree, and percentage of the non-Hispanic white population are among the variables with statistically significant changes. Percentage of non-Hispanic white population changed, opposing the initial hypothesis.

Table 9

Hypotheses (not-)Supported by the Study Results

	Outcomes*	Variables		Hypothesis	Supported by the results
Socio-Demographic Data	1	**Population Density**		More Increase or Less Decrease	Yes
		Job Density		More Increase or Less Decrease	Yes
	2	**Mode Share Percentage**	**Transit to Commute Auto**	More Increase or Less Decrease	No
			Walking	More Increase or Less Decrease	No
			Automobile	More Decrease or Less Increase	No
		Average Travel Time to Work		More Decrease or Less Increase	No
		Average Vehicles per Housing Unit		More Decrease or Less Increase	No
	3	**Median Gross Rent**		More Increase or Less Decrease	Yes
		Median House Value		More Increase or Less Decrease	Yes
		Median Household Income		More Increase or Less Decrease	Yes
		Percentage of People with Bachelor's Degree		More Increase or Less Decrease	Yes
		Percentage of Non-Hispanic White		Unsure	No

* The numbers are direct population, transportation, and economic and social outcomes.

Among all variables, the variables which show significant changes could be possible consequences of selected sprawl retrofitting projects. As mentioned earlier, gross rent and median household income have increased significantly among the projects. This can be due to the newly placed residential amenities, property tax increase, and eventually migration of a higher income population to the area. Another significant change is the increasing non-Hispanic white population in the study area. These two changes indicate that the upper-class population has resided in the retrofitted area and possibly restrained other demographics (financially or with other life consequences, such as employment opportunities) from staying in or moving into the neighborhood. The property tax increase is another factor subjected to change and might have impacted housing value, therefore attracting higher income populations to these neighborhoods. This issue can be defined as gentrification, which results in the displacement of the lower- and middle-class populations in these areas. The growing white population can also have resulted in diversity and social equity issues. Accordingly, these changes might convey that most sprawl retrofitting projects have not considered the existing context and population structure of the neighborhoods during the implementation.

Urban form analysis resulted in changes that can be explained by retrofitting projects. Average block size, percentage of green space, and intersection density were among the urban form physical changes analyzed and induced relevant changes following sprawl retrofitting objectives. Average block size has decreased, and intersection density has increased after project completion. These changes align with the hypothesis changes and expected urban form outcomes of sprawl retrofitting projects. Although sprawl retrofitting tries to increase green space area, the average percentage of green space has decreased by 1.91 percent in the project sites. Despite an increase in green space acreage percentage in some projects, others have used up the green space to develop urban physical elements, such as buildings and parking lots. Urban form t-test analysis showed significant differences in average block size and intersection density, while green space percentage had no significant changes after the projects.

Limitations and Suggestions for Future Research

This study completed explanatory research from online resources, relevant literature, and books to identify the changes based on an inventory of 59 sprawl retrofitting projects. The inventory could be incomplete despite efforts to include as many examples and projects as possible. A project implemented before 2000 or after 2016 can be an example not included in the list. Data availability, on which this research attempted to rely for the analysis, was one factor that limited the time span. Some data, such as job information, were unavailable before 2000, and 2015 Census data was the latest resource for the project.

Another time-related issue is the time taken for each project to be completed. Some cases took longer than others, providing more time for socio-demographic and transportation changes and more opportunities for other outside factors to influence the treatment locations. Another issue was related to data acquisition for the project sites and aligning the project boundaries to the block groups. Some projects overlay more than one block group, which causes an issue in distributing data to the project sites. To get a more precise scope and data for each project site, each data entity should be dispersed proportionally and according to the building footprints so that data can be accurately analyzed in future research.

Another limitation is the comparability between case and control groups. The socio-demographic characteristics of the control group might be different from those of the sprawl retrofitting neighborhoods. This matching issue can be addressed by using advanced methods, such as propensity score matching. Additionally, there might be a need to control other factors (completion, typology, and size) in the analysis that can be better utilized in regression models.

In the analysis part of this research, socio-demographic and urban form are analyzed regardless of the project typology. It could be beneficial for future research to more accurately evaluate the projects according to the typology. Socio-demographic changes could also result from other larger-scale developments, regional economy, land-use type, and transportation outcomes that are not discussed in this research. Also, assessing a correlation among different variables (e.g., vehicle ownership and increased household income) can provide more distinct results for future research.

Planning and Policy Implications

The results from this study could be incorporated into the field to make better decisions and enhance sprawl retrofitting efforts. First, socio-demographic analysis indicates possible gentrification and social inequity. Although population and job density have increased, higher household income and more non-Hispanic white populations might have replaced some of the previous residential areas, possibly resulting in population displacement. Examining the current population needs, and planning for the incoming population that may reside in these neighborhoods after retrofitting, can prevent these population displacements. Providing jobs and homes regarding the existing population structure and financial ability can slow down gentrification. Also, the role of private developers, investors, and real estate and local authorities are subjected to impact these neighborhood changes. By detecting the rent gaps, creating incentives for affordable housing, and providing a balance of land use and zoning distribution in the retrofitted neighborhoods, these stakeholders can prevent displacement by reflecting the needs of diverse demographic groups.

Figure 36

Affordable Housing Provided in the Retrofitted Neighborhood, Assembly Row, Sommerville (Source: thesomervillenewsweekly.blog)

Another issue with the sprawl retrofitting projects was the lack of green space development in the sprawl retrofitting neighborhoods. The retrofitted areas have mostly undergone new constructions, which did not increase the overall green space that can enhance the quality of the urban environment. Accommodating more population without providing enough green space or usable open space could result in environmental issues, such as air pollution and health issues, and create a less attractive place to live. It could be beneficial to consider green space development along the built environment. Most of the projects were implemented in a size of one, or more than one, neighborhood block or a whole neighborhood. This provides enough space for planners to include parks and open spaces in the retrofitted sites. Further, the green space could be enhanced in different places, such as street medians, parkway trees, and small pocket parks next to residential and commercial buildings.

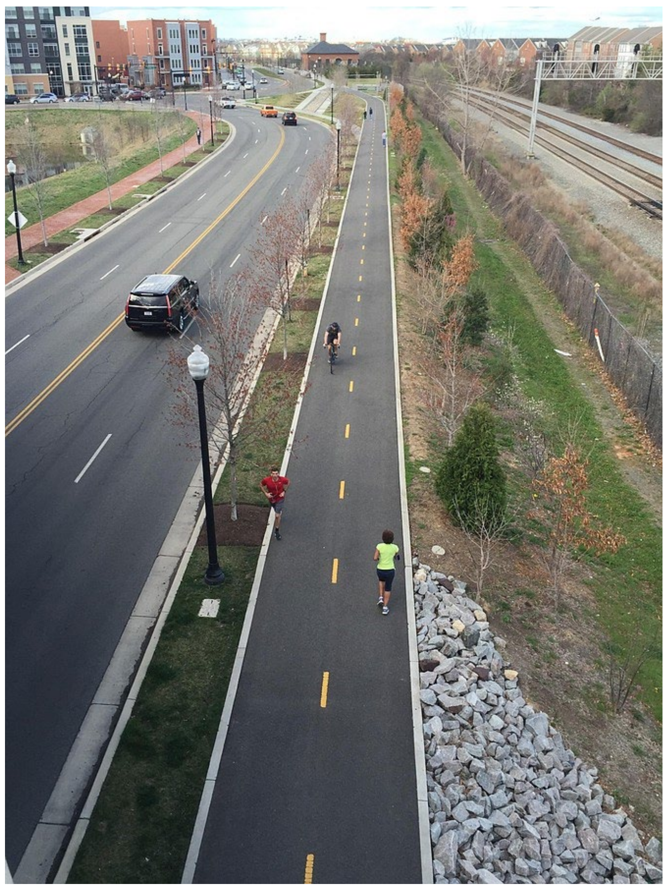
Figure 37

Modifying the Hardscapes into Green Spaces and Playgrounds, Station Center, CA (Source: Cnu.org, Bruce Damonte)

Transportation indicators, including three commute types and travel time to work, can be addressed by examining public transit and urban infrastructure issues. Although urban form shows a positive difference in changes (average block size and average intersection density) in the neighborhoods, variables related to transportation indicate less travel by public transit and more car dependency among the residents in those neighborhoods. This issue can be addressed by creating an environment that integrates different modes of transportation and prioritizes pedestrian activity over other means of transportation. Creating transportation hubs and connecting walking, biking, and public transit can encourage sustainable transportation. Some implications of the transportation aspect of this analysis are providing designated biking paths, revisiting land-use planning element for more efficient distribution and assessing public transportation coverage to promote active transportation in the sprawl retrofitting neighborhoods.

Figure 38

Integrated Transportation System Including Bike and Pedestrian Trails, Potomac Yard, Alexandria (Source:connectionnewspapers.com, Vernon Miles)



Incorporating more research and evaluation on the projects can significantly impact the planning and designing processes of the urban environment regarding the population needs. The policy and planning recommendations in this chapter are based on the socio-demographic and urban form analysis, which can help future planning and research practices regarding the retrofitting aspects of urban development.

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