Creating mixed-income neighborhoods through middle housing infill development: A Case study of St. Louis

by

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Abstract

Infill development, missing middle housing, and mixed income neighborhoods have continued to be prevalent topics in American city planning and have only become increasingly more predominant topics in the past decades. Each type of development sets out to address a specific set of problems by offering unique solutions such as reinvestment, diverse housing form, or diverse housing stock. While these solutions can work on their own, for many Midwest cities in the United States homogeneous housing stock and lack of more affordable housing creates pressures on lower income populations and contributes to income segregation. Previous studies on both infill housing and middle housing have shown that the implementation of these developments can have positive effects on income mixing. Few studies have analyzed the impact of combining infill development and middle housing and whether their impact together makes a difference on the distributions of income strata. This study explores the connection between infill middle housing and income mixing through a case study of the City of St. Louis, as it is not only one of the fastest declining Midwest cities in terms of population, but also has a history of segregation and a fair amount of middle housing stock. By analyzing population and unit density levels from the 2010 ACS at the block group level, calculating indexes of income variation in 2019, and applying geospatial and statistical analysis, areas exhibiting certain attributes were tested for significance in the levels of income mixing. Ultimately what was found was that areas with new middle housing developments experienced significant increase in income mixing, and when they are combined with infill developments (i.e. already dense areas), their contribution is similar.

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Chapter 1: Introduction

1.1: Middle Housing Development

Middle housing is defined as housing stock between the traditional single family detached homes and large-scale apartment buildings. This includes anything ranging from duplexes to middle density apartments (as shown in Figure 1.1). Typical types of missing middle housing include row-housing; duplexes, triplexes, and quadplexes; stacked flats or stacked duplexes; and smaller scale apartment buildings. (Parolek, 2010). According to data from the most recent ACS survey (2021), middle housing units are at about seventeen percent of the total United States housing stock, though most of these developments reside on the coast in older cities. Midwest and Southern regions are severely lacking in middle housing which is unfortunate considering it can be used as an effective solution for cities that are trying diverse urban renewal strategies. Middle housing is a complicated issue to address when it comes to implementation as it is rightfully middling in potential incomes, housing and rental costs, and densities. Middle housing can be difficult to implement into the highly urban or typical suburban environments as it does not necessarily seem to fit with the character or values of existing neighborhoods, which could explain why it is already scarce (Parolek, 2020). However, middle housing could be an effective urban renewal strategy as it can be connected to infill efforts, influence property and rental values, and create mixed income neighborhoods (Parolek, 2020). If a connection could be found between the three, then missing middle housing could be easily implemented to solve a diverse set of issues. Middle housing could serve as an important bridge between the traditional detached living and apartment complexes that gives the consumer more options and individual choice to best fit their housing needs. Middle housing should be considered a more prominent style as it can work as a beneficial infill strategy for cities that need

to fill in gaps between dense areas and less dense areas. Middle housing could be used to create diversity in housing cost or rental costs within defined neighborhoods bringing people from different income levels (Parolek, 2020). Middle housing also comes in many forms which allows for flexible and unique home living situations that would be beneficial to both the consumer and the community. For these reasons, it stands that middle housing should be researched to better understand its advantages and disadvantages through the lens of infill development.

Figure 1.1: Missing Middle Housing Diagram (Opticos, 2020)

1.2: Research Objectives

The main research question for this study is how does middle housing infill development affect the income mixing levels of the local and surrounding areas? Additionally, understanding how middle housing developments are currently aligned with infill areas geospatially will allow for a deeper understanding of how infill development through middle housing can potentially promote mixed-income neighborhoods. This is completed through a statistical and geospatial investigation where housing and income mixing values serve as the key indicator of change and

exploring their correlations with the number of infill middle housing developments. The area of study for the project is the city of St. Louis. The primary reason for selecting St. Louis is that it is a Midwest area city that is losing its population and have opportunities for urban renewal through infill development. As previously mentioned, the middle housing stock in the Midwest specifically is extremely low, so not only does it make the area perfect for investigation, but it also means that there are relatively few studies conducted on the topic for the area. Additionally, St. Louis has easily accessible building permit databases from their open data portal, which contains all the necessary data for this analysis. St. Louis is an extremely important city in American history and served as the literal and figurative gateway to the west after the Louisiana Purchase. The city grew substantially after the Civil War up until the 1950's, when its population reached its max at over 856,000 people (World Population Review, 2024). A combination of white flight and diminishing jobs after the Second World War caused a mass exodus from the city into the surrounding suburbs and cities which resulted in a total drop of 64% from the 50s to modern day, the most out of any American city over the same period (World Population Review, 2024). Now the city faces similar struggles with housing stock that the rest of the nation faces as well as one of the higher per capita murder rates (World Population Review, 2024) and continues to struggle with bringing in a new population, as evidenced by its continual shrinking population. St. Louis in particular faces a unique situation with similar declining populations to many Midwest cities, but also with a fair amount of gentrification of older neighborhoods (Lee 2019). In an article from Forward Through Ferguson, talks with a county executive and equal housing specialist reveal that St. Louis has been having large scale gentrification issues since the 2008 recession with many low-income neighborhoods and affordable housing options being bought in large swaths and converted to more expensive homes (Lee, 2019). The topic of the southside of

the city being the safe place to be in St. Louis is also mentioned in the article, which reinforces the class divides within the city (Lee, 2019). Middle housing infill development has the potential to be a solution for creating more income integrated areas, as well as being a good strategy for repairing urban fabric within St. Louis. Middle housing is not a new concept for St. Louis, even in 2010, 340 of the 360 block groups of this city had at least one instance of housing stock between two and five units in one building (as later shown in this study). Infill middle housing development would not be new to St. Louis, and an empirical analysis of the outcomes of such development can help formulate policies that would create greater diversity in the housing stock both in style and price and foster more opportunities for more income mixing.

Chapter 2: Background

2.1: Introduction

Studies show that mixed income developments tended to not increase mixing between classes but did reduce the stigmas about other classes through more common interactions (PD&R, 2013). Additionally, these studies explored redevelopments of lower income housing, typically large apartment building projects, by introducing new middle housing developments to replace them (August, 2016). It was found that these were often unsuccessful and created higher tensions between residents and forced some residents out (August, 2016). While it has also been found that an introduction of middle housing in lower income areas can create better schooling and amenities through higher property taxes, there is a disconnect between low-income middle housing redevelopment and mixed income (Chaskin and Joseph, 2013). There does exist a better link between higher income neighborhoods and middle housing infill development, though these studies were frequently focused on only accessory dwelling units (Schechtman, 2020). As for the infill developments themselves, it was found that introducing middle housing tended to be marginally more expensive than single family alternatives due to the location of development, and only had an impact on a small area immediately around the development (Immergluck, 2007). Cities also frequently used middle housing infill to address problematic lots such as brownfields or oddly shaped areas (Immergluck, 2007). While it was inconclusive if middle housing infill reduced rent costs, it was found that they would reduce housing costs depending on the area (Johnson, 2003). Overall, this paints a generally positive picture of middle housing infill as a strategy that can be used to kindle inter-class relations and fill in areas of cities that have previously not been addressed.

2.2: Mixed Income Neighborhoods:

Mixed income neighborhood has been heavily criticized about its actual benefits and research has not been clear. Generally, there is a correlation between the prior income level of a neighborhood where mixed income redevelopment takes place (August, 2016). A study conducted on the redevelopment of one of Toronto's public housing projects demonstrates some of the problems that arise when previously low-income areas are targeted. The study was conducted in Don Mount Court where redevelopment replaced many existing affordable housing units for more upscale units (August, 2016). The number of low-income units was not returned to original levels, including the units being updated to reflect the new urbanist styles. Many residents reported that they felt the updated architecture took away from the sense of community, especially since it replaced single unit porches with four units sharing a porch. Sitting outside of a unit was understandably harder since it interfered with other residents, of which was a large part of the culture in the area as reported by interviewees (August, 2016). This study is not unique in its findings, as many similar studies on mixed income redevelopment in public housing have found that discord had been introduced into the community (Levy et al., 2013). The Levy study reviewed three different mixed use and mixed income developments that had all recently come to fruition, through a mix of statistical analysis and interviews (Chaskin and Joseph, 2013). What was found was that while tensions were higher between residents especially concerning income levels and social relations, property values and schooling generally improved (Chaskin and Jospeh, 2013). It would be incredulous to consider integration happening immediately, but the positive effects that mixed income developments can have on socio-economic factors like schooling shows that benefits are present. Levy et al. (2010) found similar results by pulled data from many other similar analyses to formulate a united conclusion on well implemented mixed

income developments. What was found was like the study conducted in Chicago by Chaskin and Jospeh (2013); tensions between residents tended to be higher in these areas with some level of increasing quality of schooling and property value and character (Levy et al., 2010). Another study conducted by PD & R of U.S. Department of Housing and Urban Development confirms similar findings (PD&R, 2013), though it also stated that there could be improvements to class stigmas long term, but not necessarily cross class interactions. While mixed income neighborhoods may not increase cross-class interactions, the benefits provided to reducing class stigmas are still valuable. Middle housing is not explicitly mentioned in any of these studies nor are the impacts or the connections between the two, but given the problems with mixed income neighborhoods, middle housing presents many opportunities. Middle housing could be implemented in higher income neighborhoods without disrupting the neighborhood character and would introduce residents of middle incomes which could ease tensions created by lower and higher classes (Adams-Schoen, 2019). Middle housing could also be implemented into lower income communities without disrupting the communities too much, though this approach still has problems as evidenced by the Toronto study. Mixed income and middle housing are not generally associated, though there is potential for overlap between the two to ease the challenges faced by both.

2.3: Middle Housing in Mixed Income Neighborhoods

Mixed income neighborhoods may have mixed results, but the area in which they are developed can ease introduction of such developments, especially if it is infill in a higher income neighborhood. A study on Oregon's recent changes to code that requires larger single-family developments to include ADUs provides some insight as to how to solve both missing middle

housing and mixed income at the same time (Adams-Schoen, 2019). The new law is described as having “numerous potential socio-economic-environmental benefits” on existing neighborhoods and infill in general (Adams-Schoen, 2019). If placing missing middle housing in higher income neighborhoods still creates mixed income communities without any of the negative effects seen in low-income redevelopments, such as displacement or conflict, then this is the best option available. However, research about this topic is still scarce, especially since it could be considered controversial. ADUs are already creating tension in many cities as they can create several problems (Adams-Schoen, 2019). Loopholes with the definition of what makes a family unit, but also placing the ADUs into established higher income neighborhoods could be seen as an infraction of sorts. The reverse has also been found true where missing middle housing can be used as a beneficial infill strategy in lower income neighborhoods in certain cases if it is done over a larger area in a comprehensive manner (Kim, 2017). A study conducted in Florida found that while there was no clear relation with interpersonal social improvements concerning new development in the low-income areas, those same areas did see an improvement in community cohesion due to the updates to infrastructure and the new tax dollars being invested in the area (Kim, 2017). This would mean that spot development of mixed income communities would be better suited to high income neighborhoods while sweeping comprehensive changes to previously vacant areas would work better for low-income environments. Middle housing would present opportunities for both these types of areas as it would act as a segway between both density and potentially income levels. By selecting the ideal type of missing middle housing for each area, mixed income housing could be achieved.

2.4: Middle Housing and Infill Development:

Middle housing and infill development are slightly more synonymous than mixed income, but there are still some stumbling blocks. Most prevalent is the difficulty concerning the cost of development and city codes. The cost of developing missing middle housing in an infill context is a challenge as it tends to cost five percent more than traditional single-family housing, though this could be in part to the context of the site such as oddly shaped lots or brownfields (Steinacker, 2003). With only a five percent increase in development costs for both missing middle housing and land use problems, cities can incentivize their development to fill these troublesome lots quite easily. This cut for developers could be justified not only by the service the development itself is bringing by filling in on vacant or decaying lots, but also because the cities themselves need redevelopment. In a study conducted in 2000, the findings were that northeastern cities contained the most vacant buildings in need of restoration and midwestern and southern cities had the most vacant land (Pagano, 2000). The adaptability of missing middle housing to these areas could prove useful, especially given the range of densities and styles that it presents. Opportunistic developers could combine with city incentivized areas to bring in much needed infill or new refurbished structures. Cities would not have to worry about whether these developments would fit the character of the neighborhood as one study found that infill housing naturally mimics its surroundings in both style and price range (Kim, 2016). Another study concludes similar findings in that infill housing did not necessarily change the price of housing, but rather that rental prices of the redevelopment and the area around it did go up (Johnson, 2003). This could be worrisome to cities when considering gentrification, particularly in the case of low-income individuals that are reliant on rental structures. Rental controls and affordable housing restrictions could be an effective tool to negate the effects on surrounding areas. These

projects would already be a special case and require spot zoning or other exceptions to be made, and these practices could be implemented once it is understood how far the rental increases reach. A statistical analysis of Atlanta redevelopment projects found that while prices in the area did increase anywhere from fifteen to thirty percent, it was only in a quarter mile radius of the development, after which the prices steeply declined to return to their original levels (Immergluck, 2007). Overall, infill development presents an interesting opportunity for cities that need to fill or repair lots that have lost their purpose. Vacant areas that bring no economic activity or dangerous environments or decrepit buildings that need extra attention are all prime places in which infill middle housing could be implemented to solve various issues. While there needs to be precaution with infill development as to not cause any unwanted side effects, when properly developed it poses no threat to existing neighborhoods or their residents.

2.5: Middle Housing Infill Development and Mixed Income:

As previously stated, the literature and research regarding all three main topics are hard to come by, though not totally absent. A few studies have highlighted all three at once, though the connections between one topic to the other two tend to be hazy. The first example would be that of Rothwell (2010) that found evidence that zoning restrictions on density directly affected income diversity. This study was conducted over fifty major metropolitan areas using data from the US Census and a previous study conducted by Rolf Pendall (2006). The conclusions drawn through statistical analysis using Gini coefficients and least squares regressions demonstrated that the relationship between zoning and income is indeed causal (Rothwell, 2010). Essentially, in a void with no typical Euclidian zoning, housing units would vary in affordability based on density and the demand for all ranges of income (Rothwell, 2010). By separating out densities

with zoning this means that there is also a natural segregation of income diversity. This study demonstrates that there is a relationship between mixed income, infill development, and middle housing. By implementing various densities into existing neighborhoods and by using infill strategies, there would naturally be a diversity in income, including those middle-income individuals who would be looking for residences along the lines of middle housing. Middle housing would not only offer a seamless transition between lower and higher densities but also perform the duty of fitting characteristics of the existing urban fabric and styles of the neighborhoods, as previously discussed. Additionally, Felt, (2007) conducted a study in 2007 with Community Development Corporation (CDC) members and found that infill development can stimulate community relations. This study finds that while CDCs tend to develop mostly single family residential, that middle housing already tends to be a common solution for scattered or spot sites (Felt, 2007). The varied densities and forms of missing middle housing are attractive to these community development corporations since they are easily adapted to the existing area. If these properties can also act as a catalyst for community cohesion and revitalization, regardless of income, then once again the three topics have been connected. A final study was completed on the city of Hood River, Oregon, where the University of Oregon was tasked with finding the best way to address various city housing issues (Schechtman, 2020). What was found to be the best course of action was to first do away with density restrictive zoning and move to zoning based upon neighborhood type, and then to introduce middle housing to create mixed income areas (Schechtman, 2020). The study also suggested that since the city has an already limited supply of available land these new developments would infill in existing neighborhoods (Schechtman, 2020). As can be seen here, the three strategies come together to create a unique solution for the city of Hood River that addresses its problems with the lack of

affordable housing, creating diverse income environments, and filling in current vacancies with middle housing. These solutions can work together in achieving specific goals when thought of in cohesion, rather than in separate parts. These issues are very much interrelated, and as such can play on the other's weaknesses to create a solid foundation for redevelopment.

Chapter 3: Methodology

3.1: Introduction to Methods

This study is conducted at the census block group level for the city of St. Louis, one of the declining midwestern city of the United States (Figure 3.1). The basic process for this report's methods were such: acquire both American Community Survey data and City of St. Louis permit data, join the data tables together, calculate an index of income mixing as well as identify infill area parameters, and finally apply statistical tests to determine the influence of middle housing and infill development on income mixing.

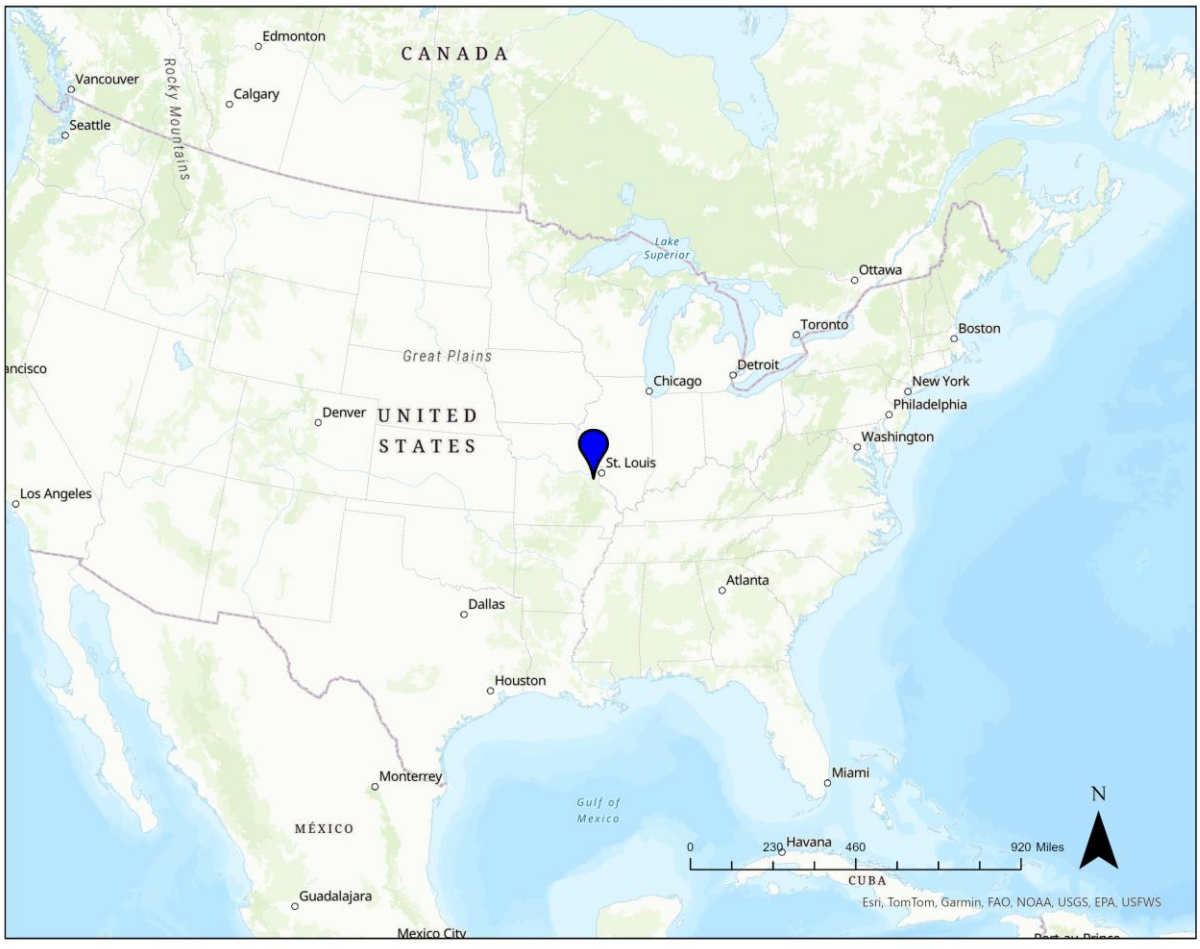

Figure 3.1: Location of St. Louis Missouri in United States

3.2: Data Acquisition

Starting with data acquisition, the American Community Survey was used to define both ends of the timeframe, that being two five-year surveys, one in 2008 to 2012 and one in 2017 to 2021. Since these are five-year surveys, the mid-years of these two time periods, 2010 and 2019 respectively, were considered to be the representative years for the study duration of this research. The surveys were taken at the block group level specifically in St. Louis city, as block groups are generally a good size to define neighborhoods, both in area and population (Kim, 2015) and socio-economic data from ACS is reported up to the block group level. The data categories taken from each survey are as follows:

Table 3.1: Starting Variables used in this study (2010 and 2019 ACS)	
FIPS	Individual identifier for each block group
Total Population	Total population for each block group
Population Density (Per Sq. Mile)	Population density, later converted from square miles to acres
Area (Land)	Area in square miles for each block group
Household Income	Levels of income broken into 16 categories by the ACS
Occupied Units (Number of Units in Structure)	Number of units in a singular structure (i.e. duplex = 2 units)

These were decided to be the primary variables for analysis. While other variables were initially considered for analysis such as race, transportation, housing values, and rental values, among others, ultimately these variables were not included in the analysis to make it more focused on income diversity. From the variables in Table 3.1, new variables were created to determine and identify block groups of each development type.

3.3: Identifying Infill Areas

Infill areas were identified using methods from the Kim (2015) study, which pulled its logic for finding infill areas from the Congress for the New Urbanism, Natural Resources Defense Council, and U.S. Green Building Council on the basis that infill areas were defined as previously developed areas that met certain density criteria for both population and number of units. The requirements to meet infill standards were a population density of at least ten per acre, and a unit density of at least one per acre. These density requirements ensured that areas identified for infill were adequately developed prior to the study timeframe and had population numbers that could justify potential developments as infill efforts. Population density was calculated using the population per square mile variables in table 3.1 and converted to population per acre. Unit density was calculated using the unit counts per block group and then divided by the number of square miles of land provided in the ACS dataset. These results were then also converted to units per acre like population density. Once both steps were completed, each block group was tested for fulfillment of these two criteria, and if a block group did meet both then it was given a one for infill status, with all others given a zero for non-infill status. Table 3.2 shows the variables used in identifying infill status for the block groups.

Table 3.2: Variables Used to Identify Infill Areas		
Variable Name	Function	Use in Identification
PopDensity	(Population per Sq. Mile)/(640 acres)	Used to determine if a block group had a population density larger than ten per acre.
UnitDensity	(Units)/(Land Area*640)	Used to determine if a block group had a unit density larger than one per acre.
InfillCheck	IF PopDensity > 10 AND UnitDensity > 1 THEN Infill = True	Used to assign infill status to all 360 block groups in St. Louis based on the two criteria.

3.4: Identifying New Middle Housing Developments

To identify block groups with new middle housing developments it was necessary to bring in the location and unit data for developments which filed for building permits from 2010 to 2019. The City of St. Louis's open data portal provided a database of all permits filed with the city from the 1990's to the present year, which made data acquisition quite easy. Data cleaning of the permits was as follows:

1. Filter to only include new building permits.
2. Filter to only include building permits for residential projects.

3. Filter the residential building permits to the study timeframe.

4. Remove any building permits that were for alterations, façade updates, etc. to only include new developments.

5. Remove duplicate entries to avoid cases in which developers had to reapply for a building permit.

6. Reduce information for each entry down to address and number of units, either 2 to 5 or 1 and 6 or more.

After these data cleaning steps were completed, the housing data could be joined to the St. Louis Street network. Using GIS software, the housing data was joined to a St. Louis Street network file. The geocoding was done with the GIS geocoding tool, and was mostly effective, with only a little over one hundred addresses requiring manual matching using Google Maps to locate the address points. After completing the geocoding, the developments were then split into two categories, being those with two to five units, and those with one unit or more than five units. These two layers were then spatially joined to the block group layers and the unit counts were summated for each type at block group level. These new layers were then exported back into excel to calculate additional variables that were important to the analysis. First, the number of middle housing permits and other permits were totaled for each block group, and then divided to find the percentage of middle housing permits with respect to the total number of permits. Additionally, block groups were given a one or a zero based on if they contained new middle housing development permits or if they did not have new middle housing development permits, respectively.

3.5: Identifying Infill Areas with New Middle Housing Developments

After the block groups were identified for having infill status or new middle housing developments they were then checked to see if they qualified as infill areas with new middle housing developments. This process was like the previous two processes, with each block group being checked against a set of criteria and being given a one or a zero depending on if it qualified. If a block group had both infill status and presence of new middle housing developments then it was given a one, and if it failed to meet both requirements then it was given a zero.

3.6: Indexes of Income Variation

To test the levels of income variation, the ACS income brackets were selected as they gave counts of households who fell into each category, rather than average or median income statistics. Average income and median income statistics were not specific enough to draw conclusions on changes in levels of income mixing, whereas the income categories provided exactly the data necessary. The ACS breaks income categories into 16 different brackets, which means that they are a categorical variable, and so an index of variation was required to calculate distribution means. To make sure that comparisons of actual distribution means were fair, two different indexes were selected for the study, the index of qualitative variation (IQV) and the Simpson index. These indexes compare categorical variables by taking the total count of instances in the distribution and comparing the actual distribution to the expected distribution (Guajardo, 2024). The expected distribution is the ideal scenario, in which all categories would have the same number of instances, whereas the actual distribution contains the observed values for each categorical variable (Guajardo, 2024). Each index takes the actual distribution and

generates a value between zero and one, with zero being an instance in which the actual distribution is the most unlike the expected distribution as possible, and with one being the expected distribution (Guajardo, 2024). As Guajardo explains "a score of 0 indicates the absence of diversity and a score of 1 indicates absolute diversity" (Guajardo, 2024). Two of these indexes were selected for the analysis so that the diversity scores could be compared to ensure that the scores were generally accurate, though there were slight differences between the indexes due to differences in calculations. Additionally, both these indexes can handle counts of zero within the categories they are comparing (Guajardo, 2024), which was a common occurrence as not every block group had at least one person per income bracket. The equations for both these indexes can be seen in figures 3.2 and 3.3.

$$\frac{K(N\text{^}2 - -\sum F\text{^}2)}{N\text{^}2(K-1)}$$

K = number of categories

N = number of individuals in a population

F = number of individuals in a category

Figure 3.2: Equation for Index of Qualitative Variation

$$1 - \frac{(\sum n(n-1)}{N(N-1)}$$

n = number of individuals in a category

N = number of individuals in a population

Figure 3.3: Equation for Simpson Index

3.7: Statistical Analysis

To compare infill block groups, block groups with new middle housing developments, and infill block groups with new middle housing developments, Welch T-tests were applied to compare diversity index scores and whether the types of developments caused significantly different diversity scores. Each of the development types – infill areas, new middle housing developments, infill areas with new middle housing developments – were calculated against two of these T-tests, one comparing the diversity scores found in the index of qualitative variation, and the other comparing the diversity scores found in the Simpson index. For each of these tests the t-value and its associated p-value, and the difference in diversity score between the two types of block groups being compared.

$$t = \frac{\Delta \overline{X}}{s_{\Delta \bar{X}}} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{s^2_{\bar{X}_1} + s^2_{\bar{X}_2}}}$$

$\overline{X}_i$ = sample mean

$\overline{{}^{s}X_i}$ = standard error

N_i = sample size

Figure 3.4: Equation for Welch T-test

Chapter 4: Study Results

4.1: Analysis Overview

The analysis for this report is broken into three main components, those being analysis of infill block groups, analysis of block groups with new middle housing developments, and infill block groups that had at least one new middle housing development permit filed with the city between 2010 and 2019. Each one of these variables was mapped in GIS first, and then the data was exported to R to conduct T-tests and compare average means for each kind of block group. Some additional analysis was done for each specific type of block group with the goal of interpretation in mind to address the findings of the analysis.

4.2: Infill Block Groups Analysis

Infill Block Groups were identified using the methodology from the Kim (2015), which described infill areas as having at least a population density of ten and a unit density of one. The Kim study also used block groups as its level of analysis as they contain generally the population levels to be a reasonable representation of a neighborhood or neighborhood area. Using the same methods for this report, it was found that 208 of the 360 block groups in St. Louis met the qualifications to be considered an infill block group. The locations of these infill block groups can be seen in Figure 4.3 and when compared to Figure 4.1, the zoning map of St. Louis, this makes sense as many of these areas are primarily residential and as such would be able to support both the population and unit densities required to qualify for infill status. In the unique case of St. Louis, population density played a very important role in determining the infill status for the block groups. Comparing Figure 4.2 to Figure 4.3 it can be seen that most of these infill block groups are found in neighborhoods such as Tower Grove, Hampton, Kingsway, or the

Ville. As can be seen in Table 4.1, of the 152 identified non-infill block groups, none met the population density requirements for infill status, but 134 of these did meet the unit density requirements. Only 18 block groups in St. Louis did not meet the population density requirements and the unit density requirements, with one of these being an entirely commercial district and having zero for both densities. This means that 17 block groups that have some residences did not meet either of the density requirements, while 134 did meet unit density requirements but not population density requirements, with the average population density of those 134 being 6.82 people per acre, and 23 of those block groups having a population density over nine. For St. Louis, this is not necessarily a surprising finding, given that the city has had major population declines for some time, but it does mean that a large portion of block groups that would have proper unit density and likely ideal structure density did not qualify for infill analysis. This also means that these 134 block groups that did meet unit density requirements were not considered for infill areas that had new middle housing developments, which means that later results could also face these same implications.

Despite the unique problems that St. Louis presents with population density, over half of the block groups were able to qualify for infill status, which was more than enough to complete the income distribution analysis. As can be seen in Figure 4.3 and Figure 4.4, infill block groups when compared to their non-infill counterparts exhibit higher levels of income distribution mixing for both the Simpson index and index of qualitative variations, respectively. The sample means as can be seen in tables 4.2 and 4.3 are higher than their counterparts by two to three percentage points, meaning that block groups identified for potential future infill developments already exhibit higher levels of income distribution mixing, which would make them good areas for implementing more diverse housing stock, due to there being likely less opposition from

neighbors and having an already diverse set of incomes present. However, when infill areas were tested for significance against the income distribution mixing indexes, it was found that in the case of both the Simpson index and the index of qualitative variations, that infill status was not a significant factor in the level of income mixing ($p = 0.07227$ and $p = 0.06988$). Tables 4.2 and 4.3 present both t-test results for infill status and show that both have relatively low t-values and insignificant p-values ($t = -1.8042$, $p = 0.07227$ and $t = -1.8197$, $p = 0.06988$). This means that infill status was not statistically significant for the higher diversity scores of income mixing for either index.

There are various factors that could be playing a role in the lack of significance on income mixing for the infill block groups. One of the obvious factors could be the block groups that were on the cusp of qualifying for infill status, being the 134 that had the unit density but not the population density. St. Louis clearly has a generally dense residential capacity given that only 18 block groups did not have a unit density over one per acre, but this also means that these 134 areas would have a disadvantage when it comes to income distributions. With lower population densities there would be less of a chance for equal income distributions, but as the sample mean estimates show in table 4.2 and 4.3, there was not much of a notable difference between areas that qualified for infill status and those that did not. What could be contributing more to the lack of significance is that the infill status does not represent infill developments, but rather that potential development within these areas could be considered as infill developments. Without any tangible differences between infill and non-infill areas, besides population density in the case of St. Louis, it becomes clearer that income mixing in infill areas may be attributed to the higher levels of unit and population density, rather than the potential for future developments or past developments that could be considered infill developments. Given the complex nature of the

City's population decline, these results were not unexpected, but did give important insights into the problems with identifying infill areas based solely on their densities and not based on actual infill developments. This does indicate that infill areas would not necessarily pose problems for developers or planners that are wanting to foster mixed income developments as they already have slightly elevated but ultimately similar income distributions as non-infill areas.

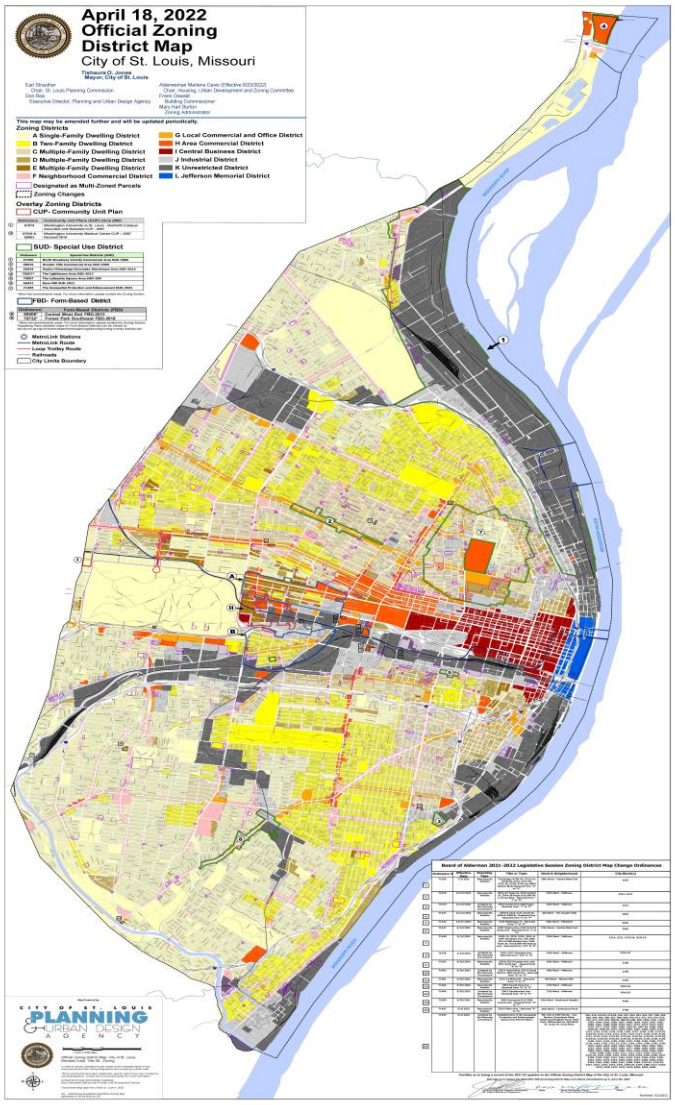

Figure 4.1: Zoning map of the City of St. Louis: [Zoning Map]

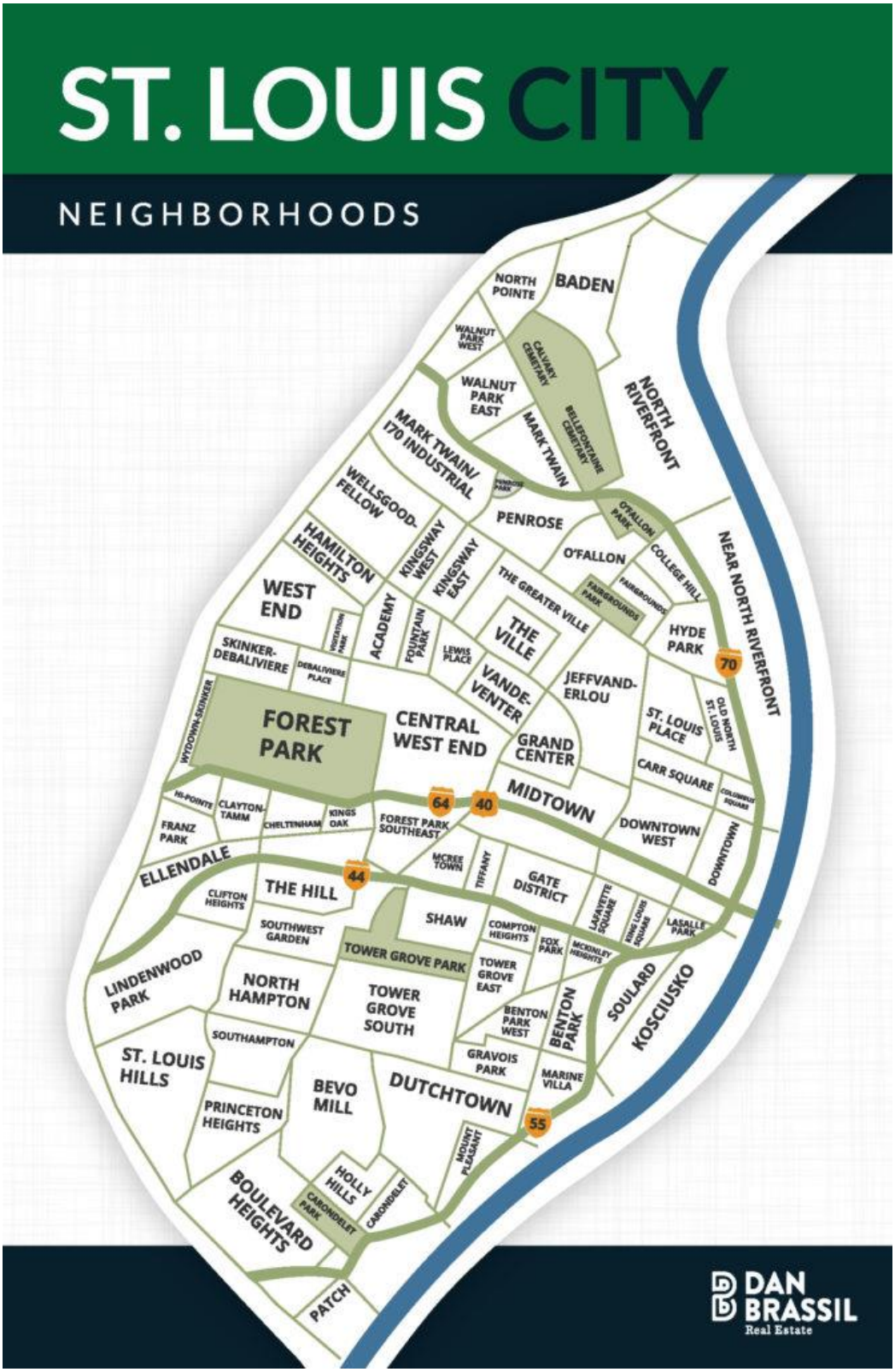
ST. LOUIS CITY
NEIGHBORHOODS
NORTH POINTE
BADEN
WALNUT PARK WEST
CALVARY CEMETARY
BELLEFONTAINE CEMETERY
WALNUT PARK EAST
MARK TWAIN
NORTH RIVERFRONT
MARK TWAIN/ I70 INDUSTRIAL
WELLSGOOD-FELLOW
PENROSE
O'FALLON PARK
HAMILTON HEIGHTS
KINGSWAY WEST
KINGSWAY EAST
O'FALLON
COLLEGE HILL
NEAR NORTH RIVERFRONT
WEST END
THE GREATER VILLE
FAIRGROUNDS PARK
HYDE PARK
70
SKINKER-DEBALIVIERE
ACADEMY
FOUNTAIN PARK
LEWIS PLACE
THE VILLE
JEFFVAND-ERLOU
DEBALIVIERE PLACE
VANDE-VENTER
ST. LOUIS PLACE
OLD NORTH ST. LOUIS
FOREST PARK
CENTRAL WEST END
GRAND CENTER
CARR SQUARE
MIDTOWN
64
40
DOWNTOWN WEST
DOWNTOWN
FRANZ PARK
CLAYTON-TAMM
CHELTENHAM
KINGS OAK
FOREST PARK SOUTHEAST
ELLENDALE
44
THE HILL
TIFFANY
GATE DISTRICT
CLIFTON HEIGHTS
SHAW
COMPTON HEIGHTS
FOX PARK
LASALLE PARK
SOUTHWEST GARDEN
TOWER GROVE PARK
TOWER GROVE EAST
LINDENWOOD PARK
NORTH HAMPTON
TOWER GROVE SOUTH
BENTON PARK WEST
BENTON PARK
SOULARD
KOSCIUSKO
SOUTHAMPTON
ST. LOUIS HILLS
GRAVOIS PARK
MARINE VILLA
BEVO MILL
DUTCHTOWN
55
PRINCETON HEIGHTS
MOUNT PLEASANT
HOLLY HILLS
CARONDELET
BOULEVARD HEIGHTS
CARONDELET PARK
PATCH
DAN BRASSIL
Real Estate

Figure 4.2: Map of St. Louis Neighborhood Districts by Dan Brassil

Table 4.1: Block Groups by Population and Unit Density			
	Pop. Density < 10	Pop. Density > 10	Totals
Unit Density < 1	18 Block Groups	0 Block Groups	18 Block Groups
Unit Density > 1	134 Block Groups	208 Block Groups	342 Block Groups
Totals	152 Block Groups	208 Block Groups	360 Block Groups

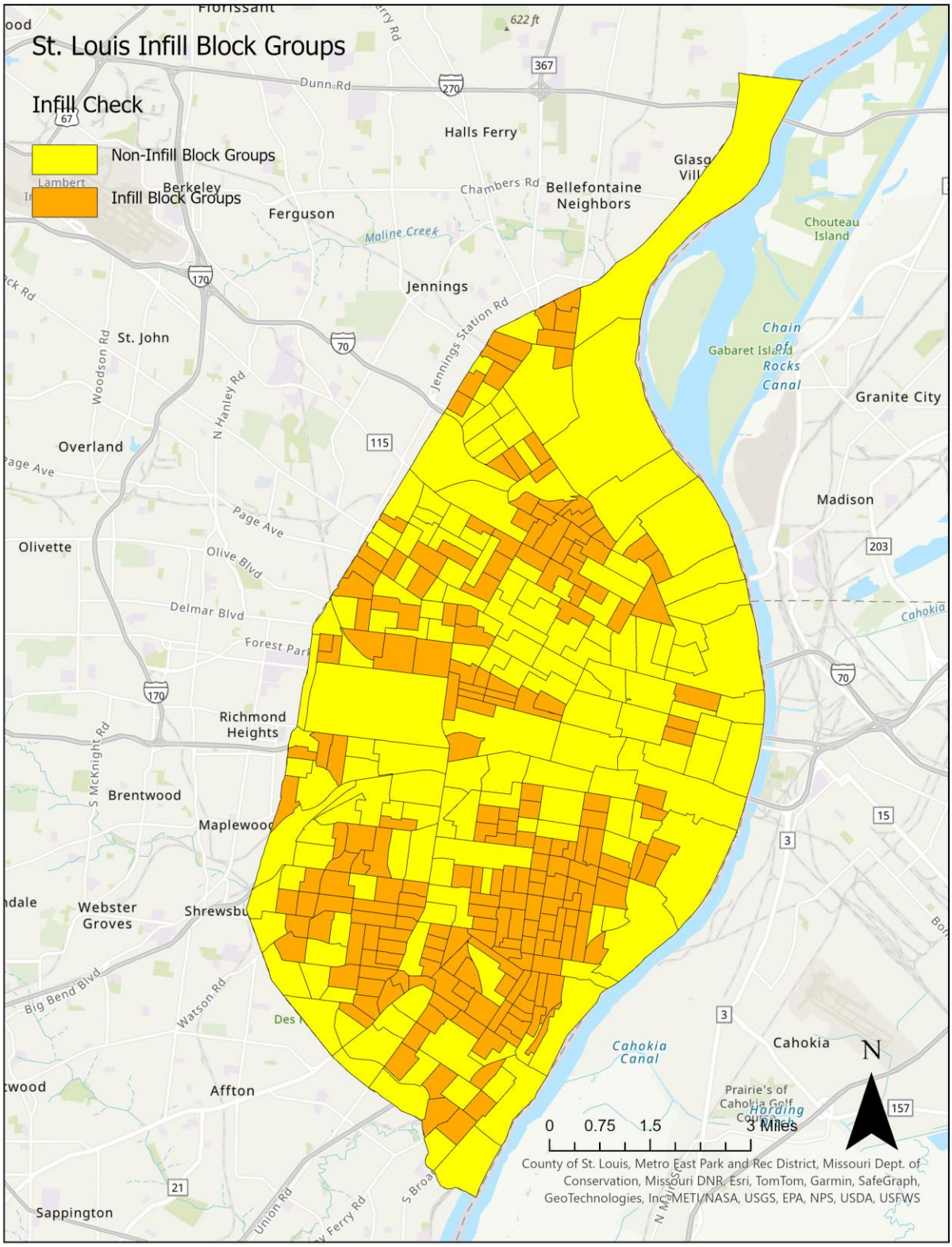

Figure 4.3: Locations of identified infill blocks groups

Table 4.2: T-Test Results: Infill Block Groups for Simpson Index (2019)						
	t-value	Degrees of Freedom	p-value	95% upper	95% lower	sample mean estimates
Infill vs non-infill	-1.8042	279.4	0.07227	0.724139886	0.671830891	0.7219561
				0.700155786	0.647846791	0.697972

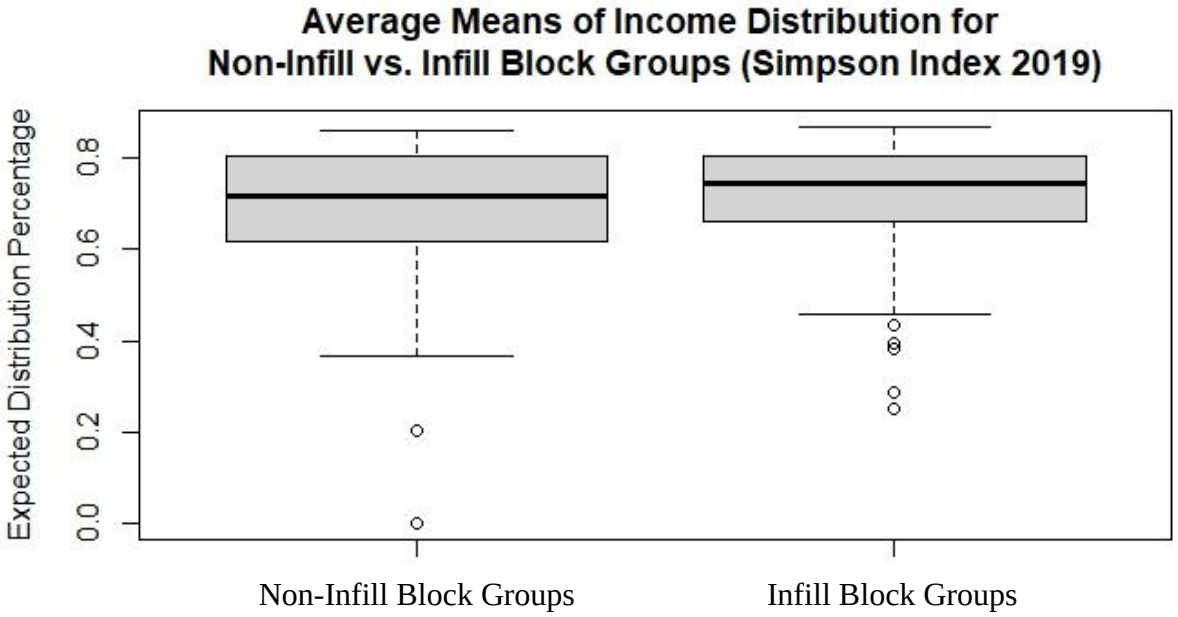

Figure 4.4: Comparison of average means for income distributions for infill block groups (Simpson Index 2019)

Table 4.3: T-Test Results: Infill Block Groups for IQV (2019)						
	t-value	Degrees of Freedom	p-value	95% upper	95% lower	sample mean estimates
Infill vs non-infill	-1.8197	279.36	0.06988	0.769907873	0.714064936	0.7677969
				0.744097373	0.688254436	0.7419864

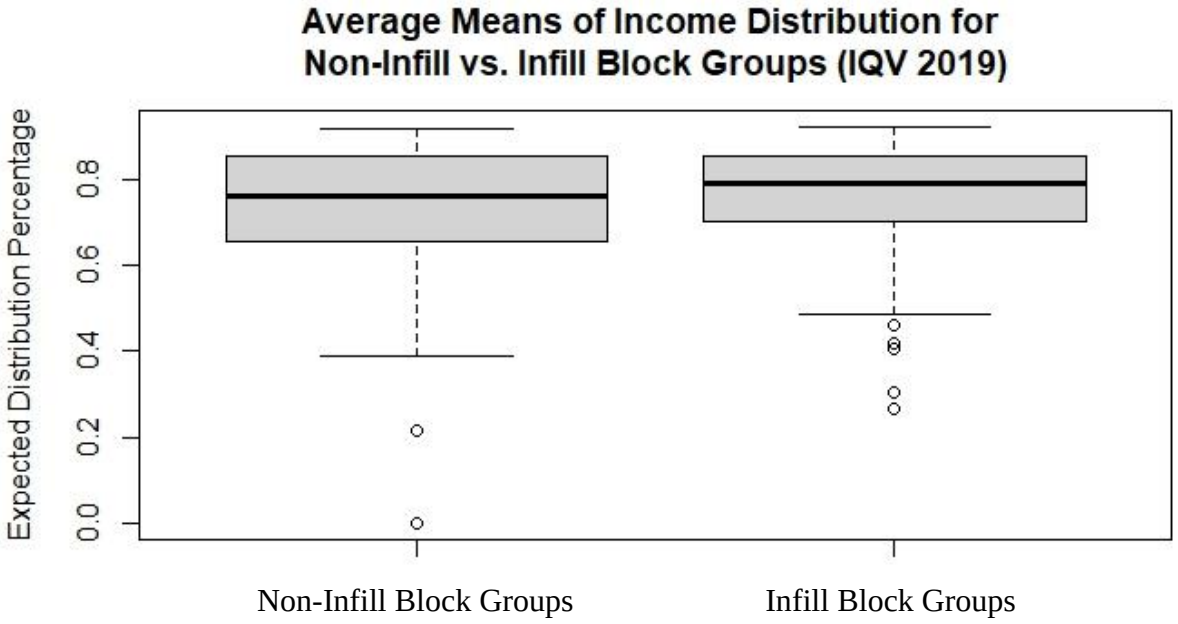

Figure 4.5: Comparison of average means for income distributions for infill block groups (IQV 2019)

4.3: New Middle Housing Development Analysis

Block groups with middle housing developments were identified in one of two ways for the study timeframe. Block groups that had at least one unit of middle housing in the 2010 American Community Survey were considered to have prior middle housing developments. Block groups that had at least one building permit for a new residential structure between two and five units filed with the city between 2010 and 2019 were considered to have new middle housing developments. Of these two types, 340 of the block groups in St. Louis had prior middle housing development, with 111 of these block groups also having new middle housing developments as can be seen in table 4.4. This means that the middle housing stock in St. Louis is already quite widespread, but that almost two-thirds of the block groups did not have any new middle housing developments. As can be seen in Figures 4.5 and 4.6, most of the new developments are in areas that have had previous middle housing developments but are specifically clustered in specific parts of the city. When considering Figure 4.1, the most recent zoning map of St. Louis, it becomes more obvious as to why these new middle housing developments are clustered in certain parts of the city, since most of the city is already zoned for single family and not allowing multifamily residences. Additionally, figures 4.9 and 4.10 show the significance of new middle housing clusters in the City by use of a LISA cluster map (Anselin, 2020). High-Low cluster cores tended to have smaller p-values which means that they were more statistically significant than other areas identified in the map, though all areas identified were statistically significant. While this does make sense for southeastern areas since they align with multifamily districts seen in figure 4.1, other block groups that were high-low have small multifamily districts. This would indicate that most of the middle housing is being built in neighborhoods with multifamily zoning, such as Tower Grove, The Ville, Midtown, and

Walnut Park (Figure 4.2), and that there is not much in the way of mixed zoning for the city. Ultimately, there were 119 block groups with new middle housing developments, which accounted for roughly a third of block groups in the city.

The T-tests that were completed for block groups with new middle housing developments yielded similar results with higher mean averages like that of the infill tests, but these tests had significant t-values and p-values, being t = -4.221 and p = 3.26E-05 for Simpson index, and t = -4.2378 and p = 3.04E-05 for IQV. As can be seen in tables 4.5 and 4.6, the t-values for both the IQV and the Simpson index are over four, and the p-values for both tests are significant at $p < 0.05$. Additionally, the diversity scores were six to seven points higher than block groups that did not have new middle housing developments, with block groups with new middle housing developments at a 0.74 average for the Simpson Index, and a 0.79 average for the IQV, while block groups without new middle housing developments having averages of 0.69 and 0.73 respectively, as can be seen in tables 4.5 and 4.6, and in figures 4.7 and 4.8. This means that there is statistical significance between new middle housing developments and block groups exhibiting a higher average level of income mixing across income categories.

These results are encouraging for middle housing development as they are correlated with higher levels of income mixing and could be a good solution to create more mixed income neighborhoods. Additionally, the new development aspect appears to be an important factor in these results, as 340 of the 360 block groups had prior middle housing developments, and 229 had prior developments but no new developments. With a difference of diversity scores of six to seven points between new developments and prior developments without new developments, it makes a clear case that new middle housing developments could play a major role in creating

higher levels of income distribution and mixing, even in areas with previous middle housing developments.

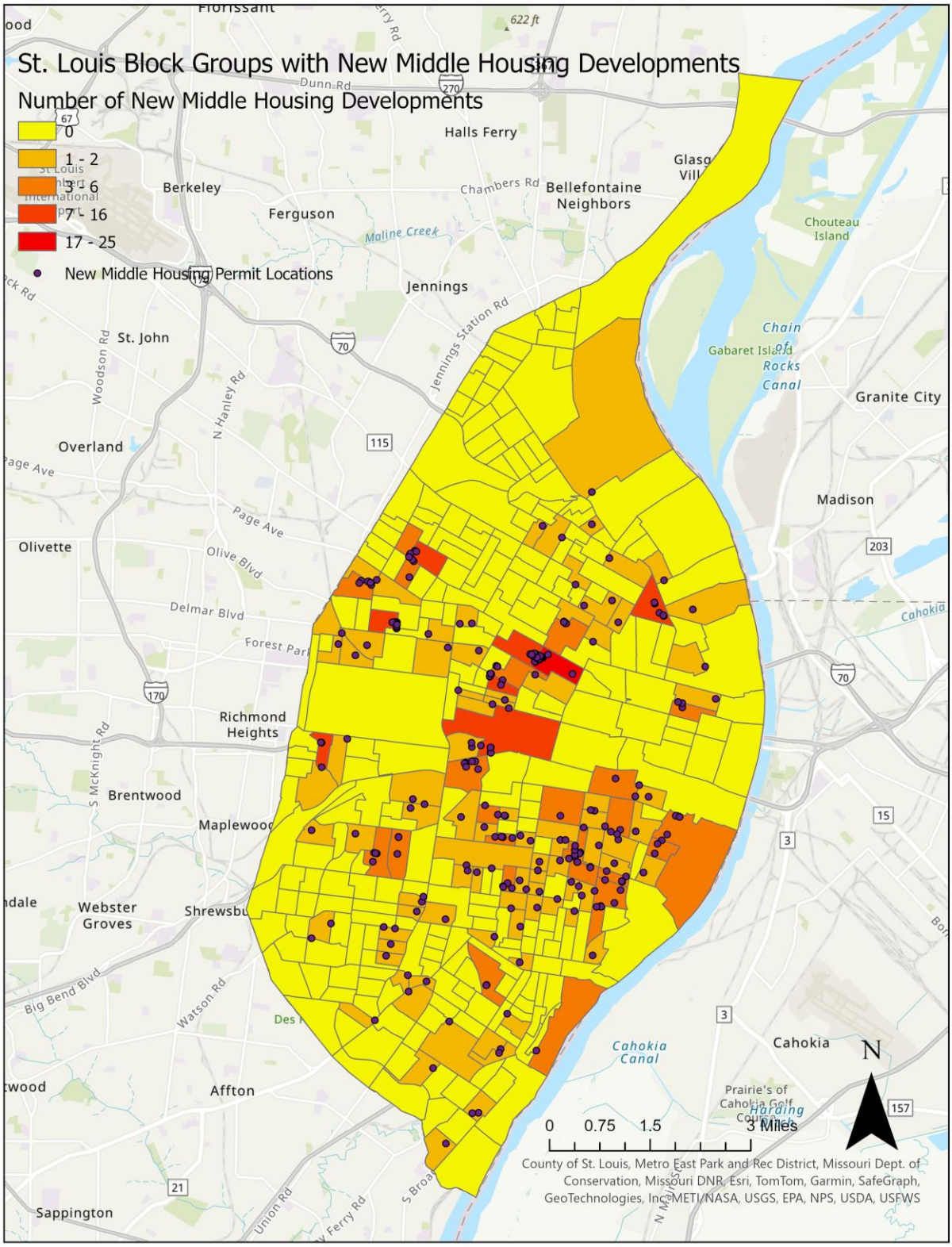

Figure 4.6: Locations of block groups with new middle housing developments (2010 – 2019)

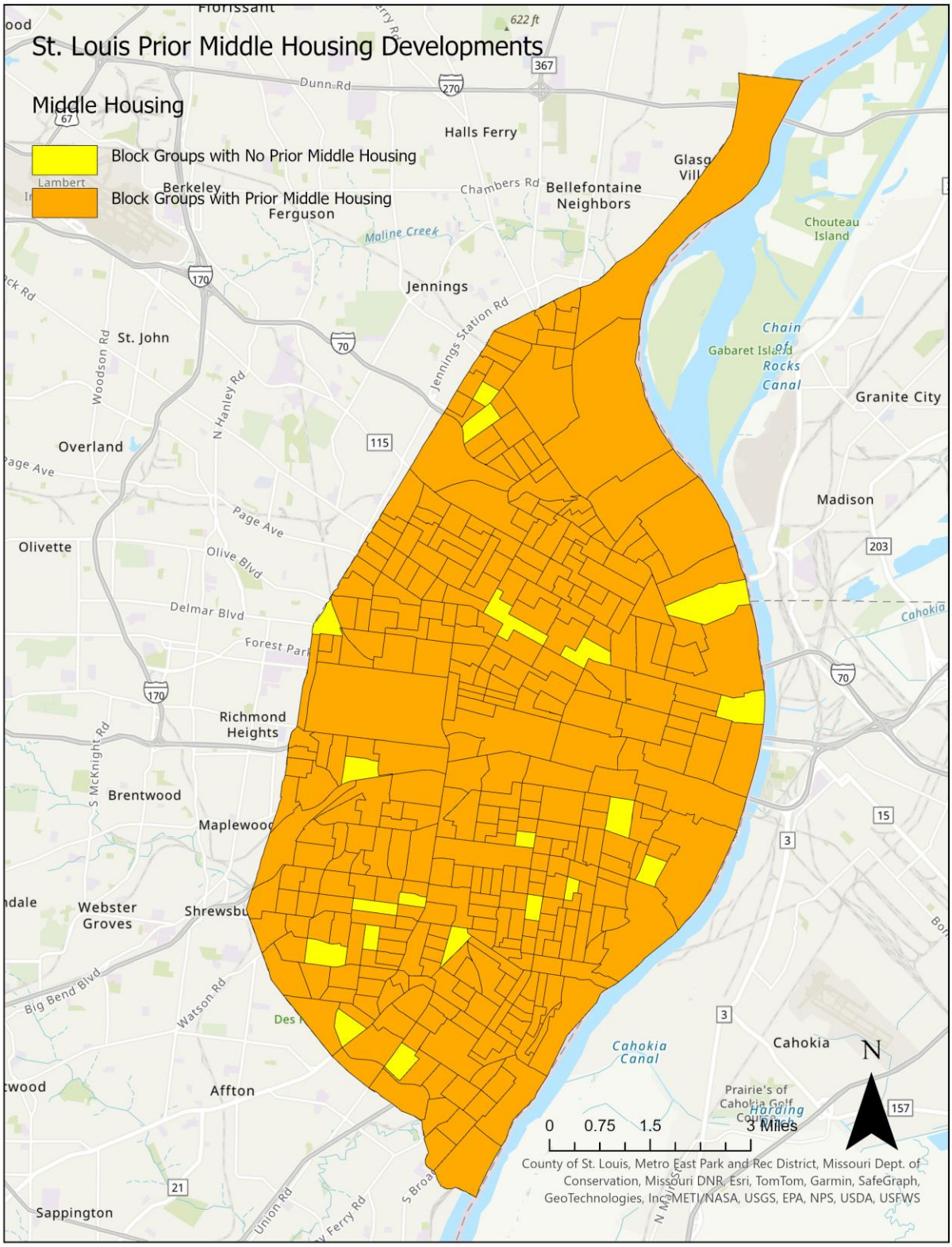

Figure 4.7: Locations of block groups with prior middle housing (2010 ACS)

Table 4.4: Block Groups by Prior Middle Housing and New Middle Housing			
	No Prior Middle Housing	Prior Middle Housing	Totals
No New Middle Housing	12 Block Groups	229 Block Groups	241 Block Groups
New Middle Housing	8 Block Groups	111 Block Groups	119 Block Groups
Totals	20 Block Groups	340 Block Groups	360 Block Groups

Table 4.5: T-Test Results: New Middle Housing Developments for Simpson Index (2019)						
	t-value	Degrees of Freedom	p-value	95% upper	95% lower	sample mean estimates
New Middle Housing vs No New Middle Housing	-4.221	290.47	3.26E-05	0.71884309	0.67065327	0.7464226
				0.66716869	0.61897887	0.6947482

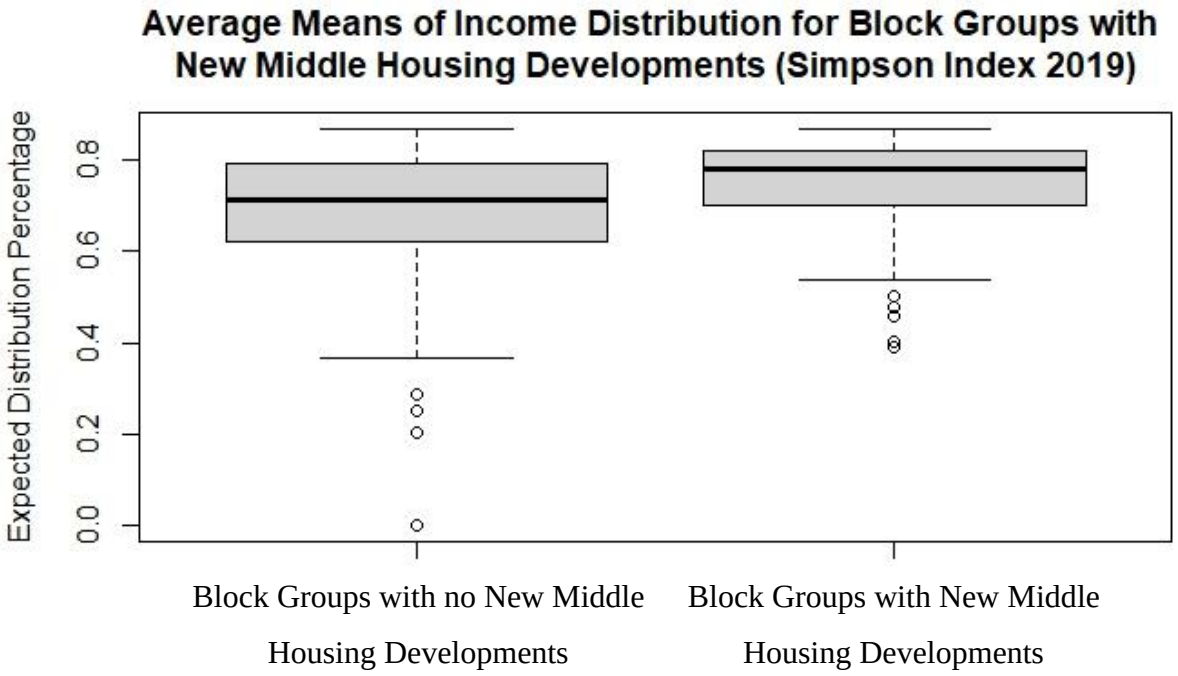

Figure 4.8: Comparison of average means for income distributions for block groups with new middle housing developments (Simpson Index 2019)

Table 4.6: T-Test Results: New Middle Housing Developments for IQV (2019)						
	t-value	Degrees of Freedom	p-value	95% upper	95% lower	sample mean estimates
New Middle Housing vs No New Middle Housing	-4.2378	290.2	3.04E-05	0.76431182	0.71287998	0.793967
				0.70894072	0.65750888	0.7385959

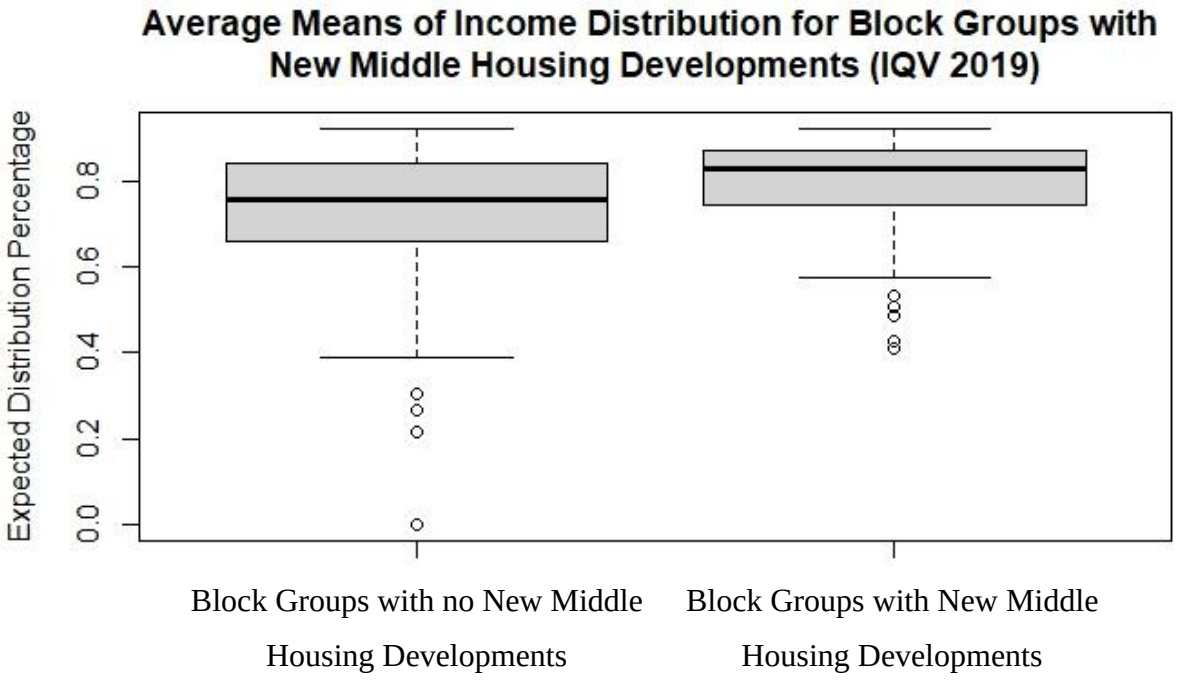

Figure 4.9: Comparison of average means for income distributions for block groups with new middle housing developments (IQV 2019)

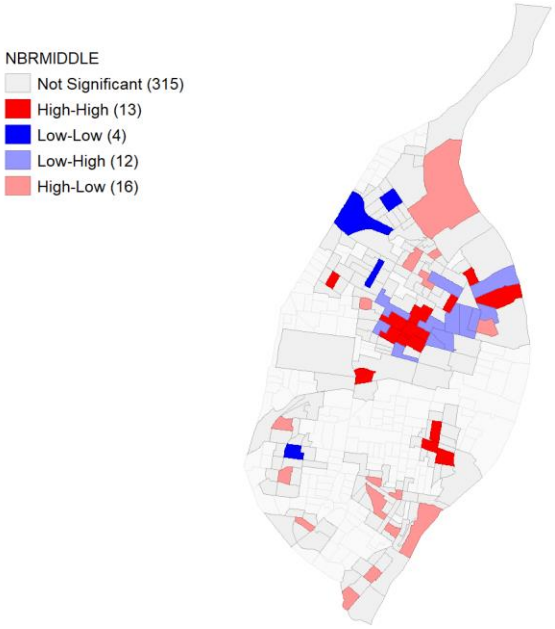

Figure 4.10: Local Moran's I Cluster Map of New Middle Housing Developments

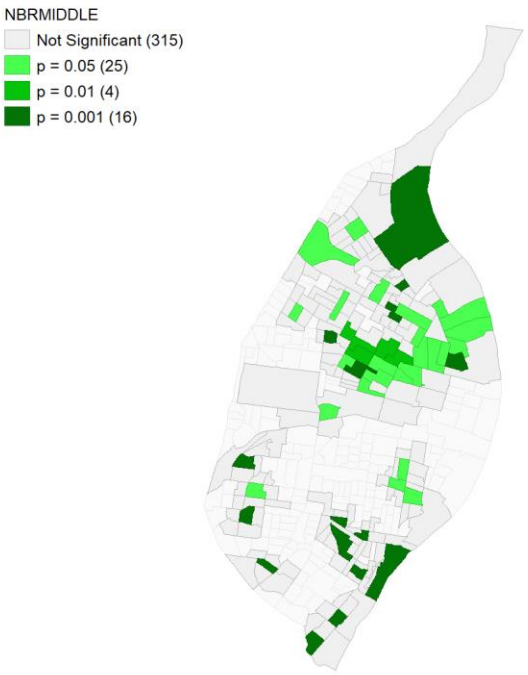

Figure 4.11: Local Moran's I Significance Map of New Middle Housing Developments

4.4: New Middle Housing Infill Developments Analysis

Block groups with infill middle housing developments were identified by combining the previous two classifications. This means that for a block group to qualify for infill middle housing development it had to have a population density greater than ten, a unit density greater than one, and at least one building permit filed with the city of St. Louis between the years 2010 and 2019 for a structure containing two to five units. Table 4.7 demonstrates the counts of each type of block group when using these criteria. Of the 208 infill block groups and the 119 block groups that had new middle housing development, 74 of these had overlap between the two categories, which represents about 20% of block groups within St. Louis. This amount was not necessarily surprising as meeting all the criteria for a block group could be difficult when taking into consideration obstacles like zoning districts or declining population, but this still accounted for a good amount of the city, though as can be seen in figure 4.11 they are noticeably more scattered than previous analyses. Part of this lower percentage of infill middle housing block groups could be the methods used to identify infill block groups, as mentioned in chapter 4.2. There were 134 block groups that met density requirements but did not meet population densities, with 23 of those 134 block groups having a population density of nine or more. Without further analysis on whether population decline played a major role in the number of valid infill areas, it is not possible to attribute the smaller amount of infill middle housing developments to this specifically, but there is potential it contributed to it.

The T-tests that were applied for block groups with infill middle housing yielded similar sample mean estimates to that of infill block groups and block groups with new middle housing developments, with the diversity scores being five to six points higher than block groups that were not infill areas with new middle housing developments, as can be seen in tables 4.8 and 4.9,

as well as figures 4.12 and 4.13. This places it above infill areas, but below new middle housing developments based on means found in the study, though these results were also statistically significant. These results yielded similar t-values to that of new middle housing developments and likewise had p-values at significant levels (t = -4.2378 and p = 3.04E-05 IQV, t = -4.221 and p = 3.26E-05 Simpson Index; t= -4.2378 and p = 3.04E-05 IQV, t = -4.0896 and p = 6.99E-05 Simpson Index) as can be seen in tables 4.8 and 4.9. This suggests that there is a strong and statistical significance between new infill middle housing developments and levels of income distribution mixing, and while not that of just new middle housing developments, the results are quite similar.

These results could indicate a few different important notes on infill middle housing and their effects on levels of income mixing. It is possible that new middle housing developments play a larger role in the significance of these results, and this would be supported by the fact that infill areas were not statistically significant, but these new developments were. Regardless, these results do further demonstrate the idea that new middle housing developments have a statistical significance with income mixing despite the presence of previous middle housing developments. These results are also encouraging in the fact that these new middle housing developments can have similar income mixing effects even if they are placed in areas where unit and population density are already high.

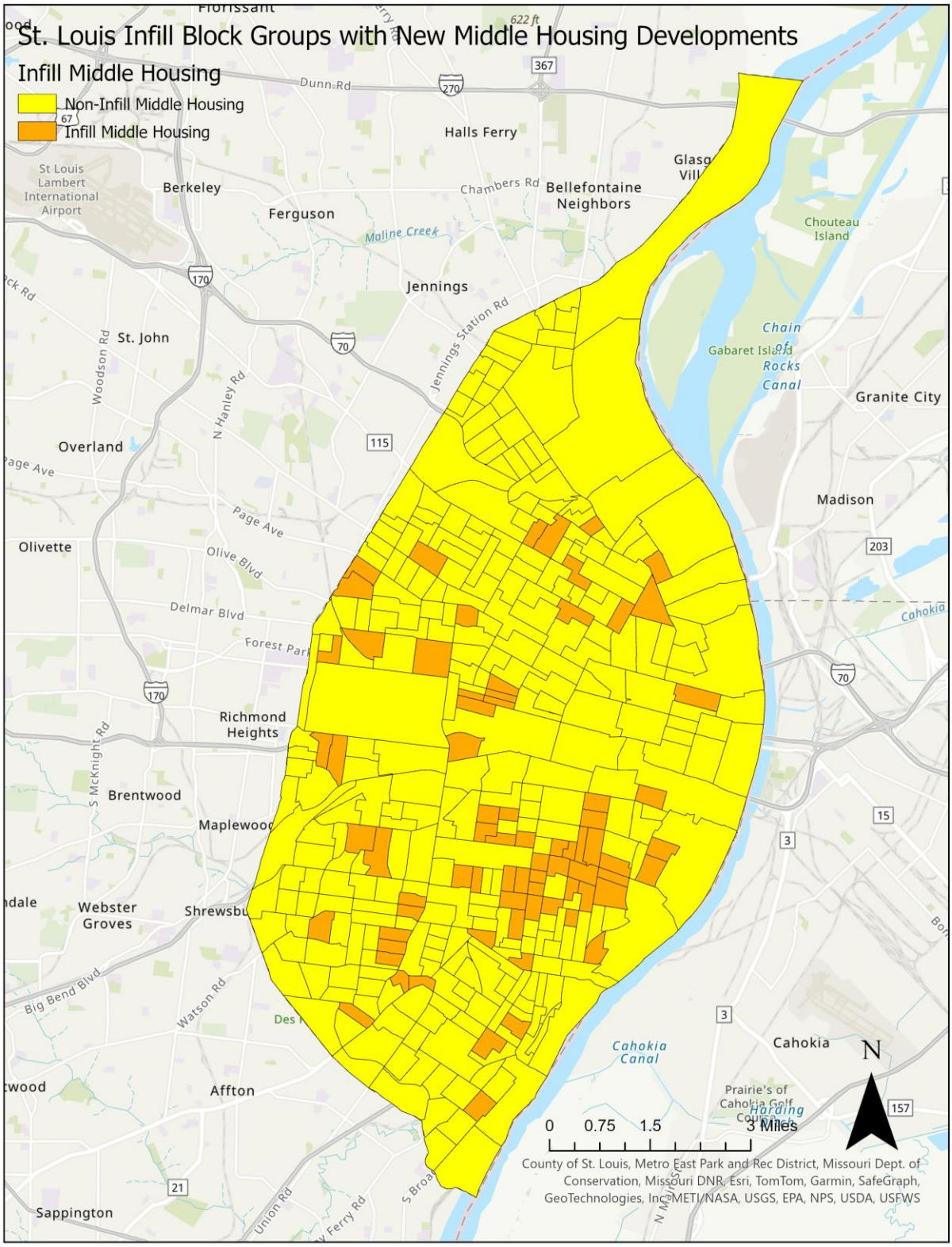

Figure 4.12: Locations of Infill Block Groups with New Middle Housing Developments

Table 4.7: Block Groups by Infill Status and New Middle Housing			
	Non-Infill	Infill	Totals
No New Middle Housing	107 Block Groups	134 Block Groups	241 Block Groups
New Middle Housing	45 Block Groups	74 Block Groups	119 Block Groups
Totals	152 Block Groups	208 Block Groups	360 Block Groups

Table 4.8: T-Test Results: New Middle Housing Developments for IQV (2019)						
	t-value	Degrees of Freedom	p-value	95% upper	95% lower	sample mean estimates
New Middle Housing vs No New Middle Housing	-4.2378	290.2	3.04E-05	0.76431182	0.71287998	0.793967
				0.70894072	0.65750888	0.7385959

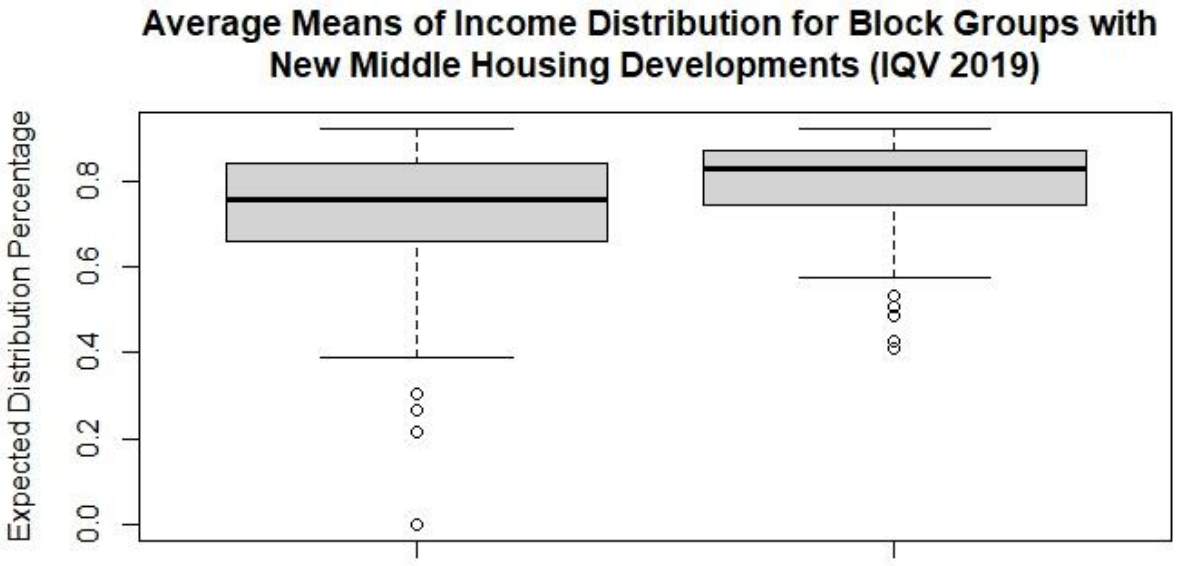

Figure 4.13: Comparison of average means for income distributions for infill block groups with new middle housing developments (Simpson Index 2019)

Table 4.9: T-Test Results: Infill Block Groups with New Middle Housing Developments for Simpson Index (2019)						
	t-value	Degrees of Freedom	p-value	95% upper	95% lower	sample mean estimates
Infill with New Middle Housing	-4.0896	151.64	6.99E-05	0.72652514	0.6753672	0.753892
				0.67357934	0.6224214	0.7009462

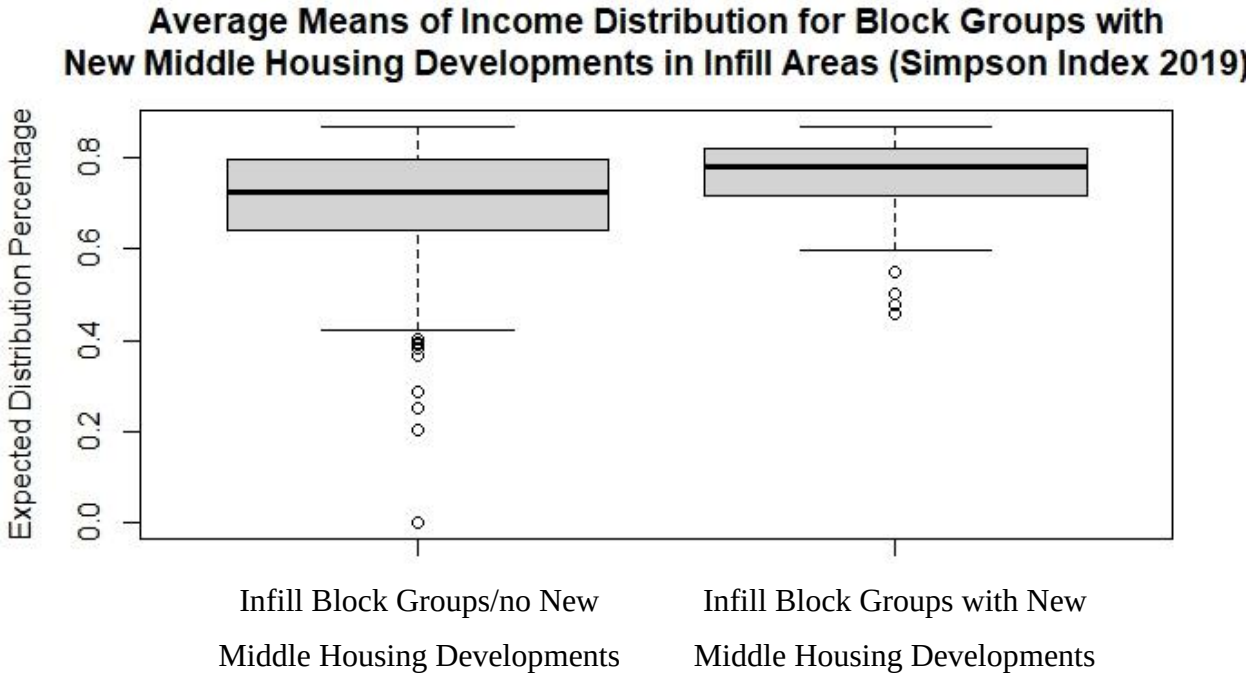

Figure 4.14: Comparison of average means for income distributions for infill block groups with new middle housing developments (IQV 2019)

Chapter 5: Discussion, Interpretation, and Conclusions

5.1: Discussion of Results and Limitations

While the results of the study were consistent with the current literature on middle housing and infill development and their effects on income diversity (Rothwell, 2010; Felt, 2007; Schechtman, 2020), there were some interesting problems with the approach that may be pertinent to future studies on the topic. The t-test results on income mixing and the three types of block groups were expected for new middle housing developments and the combination of infill areas and new middle housing developments, but it was not necessarily expected that infill areas by themselves would contribute to higher levels of income diversity. While the identified infill areas had a higher mean of income diversity, these results were not found to be statistically significant (at 95% confidence interval) and had a lower t-value than the other two tests. Multiple studies found that infill housing had the ability to increase housing values and rental values in the immediate area around their developments (Johnson, 2003; Immergluck, 2007), which could potentially raise the overall average income of an area and price out lower income individuals. This means that infill areas having higher levels of income mixing was unexpected since they would raise surrounding housing values and could potentially price out lower income residents, but that their statistical insignificance was not surprising. These results combined with the positive results of the middle housing and infill area makes infill development in St. Louis a potential solution for developers and planners, specifically with the idea that infill development could work to create higher levels of income mixing when paired with certain forms of housing developments. This means that infill middle housing could be an effective strategy for higher levels of income mixing in the case of St. Louis, but that new middle housing developments on their own could work as well, regardless of infill status or previous middle housing

developments. Another possible reason for the insignificance between infill areas and income mixing could be the methods used for identifying infill areas. While the methods for finding and identifying infill areas were in line with previous studies and multiple planning authorities, there still is the potential issue of the declining population creating situations in which areas would not qualify for infill according to the demographics but could reasonably qualify in form. For example, much of St. Louis is urbanized area, with good unit density, but many areas have seen a population decline as demonstrated by the 134 block groups that met unit density requirements but not population density requirements to be considered as infill areas. This means that they could be good locations for infill but cannot be identified with a high-level analysis, like the one used in this study. A longer study timeframe could aid in identifying infill areas as it would show areas that may have once qualified as infill block groups but have seen a decline in population density. This is complicated by the fact that census geography changes and so spatial analysis would have to be conducted to incorporate older data.

5.2: Limitations

Some of the unique problems with the approaches in this study were primarily concerned with the levels of analysis and the conflicts it had with zoning. While the level of analysis was completed at the block group level as previous studies have done, these studies did not run into problems with zoning and did not account for zoning in their methods. Not being able to consider zoning was a large problem with the methods in this study as it restricted the areas in which middle housing developments could be built during the study period. While this would make it easier for a comparative analysis, it made it difficult to accomplish any geospatial analysis without running into any further problems with results or finding any consistent effects

on income mixing in neighboring block groups. Bivariate Moran's I tests were originally considered for the final analysis portion of this study but were found to be too inconsistent for interpretation. With a more normalized distribution of these types of developments across the city, this type of analysis would have been better suited to the study, rather than the actual clustered distribution that was found in St. Louis. A city that does not have form-based zoning codes, but rather density-based zoning codes may have a more even distribution of housing types across all its neighborhoods, which would work better for geospatial analysis. Additionally, considering other variables for limitations such as race, poverty levels, land value, transportation, distance from amenities, and other potential impacts on housing for future studies could also be pertinent. An important aspect of the results within the context of zoning was not just the significance or difference of means, but also locations that these types of developments were in the city of St. Louis. Most of the infill areas and new middle housing developments were noticeably clustered in the southeast and north central portions of St. Louis. Areas like the Tower Grove area, The Ville, Midtown, and Walnut Park were frequently highlighted as areas that had both new middle housing developments and proper population and unit densities to qualify as infill areas, as can be seen in figure 5.1. Given that much of the city had previous middle housing developments, it stands to reason that the pressures that were discussed in chapter 1.2 from developers buying and converting large amounts of land could be a primary factor in the almost holistic change of St. Louis to a single family dominated city with respects to zoning. If the city were to attempt at bringing middle housing developments to other areas within the city there would be marginal, but positive impact on income mixing, and these developments would work in both infill areas and areas with previous middle housing.

While the methods were not perfect for the study, they did allow an important view into how zoning and identification methods for infill areas could be potentially problematic for future studies. Cities that have done away with restrictive zoning practices, such as Minneapolis, would not work as case studies using the infill methods from the Kim study, as generally the entirety of the city could be considered an infill area, depending on how much residential mixing exists during the timeframe. Given that the infill methods already caused problems within this study due to the declining population, it is reasonable to assume that in cities with residential mixing could experience density problems, either being too high in all areas or too low in all areas.

Additionally, the study did not consider any demographic data or historical aspects of St. Louis. This meant that redlining practices and white flight were not considered and could have impacted population levels due to declines in certain neighborhoods and perception-based choices on where to live in a city. For any future studies, it would be pertinent to look at demographics of each area based on race/ethnicity, historic redlining, and crime and poverty rates and compare these identified areas to population trends. Knowing that north St. Louis is perceived as an unsafe place, this could have had a large impact on infill areas, though most of the city had population problems for the infill methods. Other considerations that could have been included would be housing prices, age of structure, and transportation methods or times, given that these all are factors frequently used in housing and neighborhood evaluations and regression studies on housing practices. With these considerations in mind, the study may have been able to draw stronger conclusions on why these development types had these effects on income mixing, or why certain parts of St. Louis did not have these types of developments, besides looking at how zoning influenced results.

Being able to consider housing values would have been quite valuable to the study as well, though there were problems with acquiring this data. St. Louis did not have appraiser data or sales data publicly available, which meant that alternative sources were considered for housing data. While these data sources would have been the best option for housing price data, ACS data was initially considered as a replacement, though the margins of error for St. Louis during the study timeframe were too large to consider the data reliable. The housing data would have allowed for a greater conclusion to the study with more depth to the variables that could have impacted the results.

5.3: Recommendations

Ultimately what was found was that new middle housing developments can potentially influence income mixing regardless of whether the development could be considered infill. Additionally, new middle housing developments can create more even income distributions even in areas that already have prior middle housing developments. This means that while middle housing efforts are less likely to cause negative effects on income mixing, infill developments do not have a significant effect on income mixing. These findings indicate that both can be viable strategies to create more mixed income neighborhoods, but that these efforts should be carefully investigated and implemented in areas that would benefit the most from these development types. This also means that cities may want to consider creating more opportunities for new middle housing developments in areas that already have decent levels of income mixing, or in neighborhoods where communities would be more amicable to adding in different types of housing stock. What planners and developers should note with these results is that while new middle housing developments are correlated with higher levels of income mixing that they only

had means higher by five to six points, which is enough of a change to call income mixing an effect, but not enough to completely change the character of a neighborhood. Further research on these development types would be best focused on cities that do not have density-based zoning as St. Louis currently does, but rather in cities that have form-based zoning, which could enable a more even distribution of housing developments to not cause clustering.

5.4: Conclusions

Middle housing, mixed income developments, and infill development may all seem unrelated, however, each provides a unique set of strengths and weaknesses that can be maximized and minimized respectively by combining all three approaches into one renewal strategy. Existing literature suggests that middle housing works well in both infill and mixed income scenarios, and that using it when both scenarios are present can reduce the negative impacts that both have. With many cities needing to tackle the issue of income segregation and solve problems of lots that are odd out or in need of redevelopment, missing middle housing could be the key. Its flexible and adaptable styles are easily integrated into existing neighborhoods and its various density levels can similarly provide seamless transitions between housing options. Some studies already provide linkages between these three topics and speak on their combined benefits to both housing stock, income diversity, and community revitalization. Combining middle housing and infill development could fix jarring or sprawling density changes while not interrupting existing neighborhoods in character, income levels, or value. The ability to adapt to various settings both in style and price means that this urban renewal strategy could be a powerful tool for planners to use in the future. Middle housing also provides citizens with more flexibility for housing costs and living situations, and given current housing and rental markets,

this would be a massive benefit. Cities can also benefit from this strategy as it can be used to restore vacant or decaying lots that currently serve no purpose, while simultaneously bolstering housing diversity and price.

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