RESIDENTIAL DEVELOPMENT
AND ITS
IMPACT ON SCHOOL ACCESS
IN
NEW YORK CITY

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ABSTRACT

Residential development in New York City has been increasing since 2010. This increase is due to both private and public players in the built urban environment, as developers try to push the limits of the luxury market, while the city has plans to increase and preserve the stock of affordable housing throughout the city. Such increases in residential development, however, have negative impacts on public amenities by adding pressure in the form of overcrowding, noise pollution, or traffic. This study seeks to explore such consequences of residential development, specifically its impact on access to schools in New York City. By looking at access as spatial accessibility, consulting publicly available data, and proposing a methodology adapted from others established in academic literature, this study reaffirms the notion that residential development has a negative impact on access to schools. The results of this study also shed light on the appropriateness of research methodologies to understand urban phenomena, as not a single method is deemed to be the best in revealing a relationship between residential development and spatial accessibility to schools. The answers found, as well as the process by which the thesis question is explored are helpful for urban planners as we seek to improve how we can better understand our built environments in order to create policies that improve people’s quality of life at various scales and contexts.
ACKNOWLEDGEMENTS

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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYC DCP</td>
<td>New York City Department of City Planning</td>
</tr>
<tr>
<td>NYC DOE</td>
<td>New York City Department of Education</td>
</tr>
<tr>
<td>2SFCA</td>
<td>2 Step Floating Catchment Area</td>
</tr>
<tr>
<td>NTA</td>
<td>Neighborhood Tabulation Area</td>
</tr>
<tr>
<td>CT</td>
<td>Census Tract</td>
</tr>
<tr>
<td>SD</td>
<td>School District</td>
</tr>
<tr>
<td>MAUP</td>
<td>Modifiable Areal Unit Problem</td>
</tr>
<tr>
<td>S.A.</td>
<td>Spatial Accessibility</td>
</tr>
<tr>
<td>R.D.</td>
<td>Residential Development</td>
</tr>
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</table>
1. CHAPTER ONE

1.1. INTRODUCTION

In New York City, the number of permits issued for new dwelling units increased by 176 percent from 2014 to 2015, the sixth consecutive year of increase in the city (New York City Rent Guidelines Board, 2016). This rapid growth of residential development in New York City, from both private sector motivations and public sector needs, is exerting a burden on public services and amenities, such as access to schools and other educational facilities. This study explores existing data from various sources, including the U.S. Census Bureau, the NYC Department of City Planning, and the NYC Department of Education to investigate how residential development affects access to education amenities in New York City.

The research expects to reaffirm that the growth in residential development has an impact on access to education amenities, but also sheds light on the process of conducting such studies with publicly available data and methods that are accessible to urban planning professionals and relevant stakeholders. The implications of this study may help planners address policy and set priorities that give attention to the public services and amenities that foster a better quality of life for whole communities.
1.2. RESEARCH QUESTION

Through quantitative analysis, this study seeks to answer the question: How is access to schools affected by the change in residential development in New York City? To this end, access is defined as the ability for people to reach their desired destination. Access can be given different attributes, such as amount, distance, time, safety, and physical conditions, which help facilitate or restrict the level of access to facilities. This study, then, uses a similar definition to that of ‘Spatial Accessibility’ (Yang, Goerge, & Mullner, 2005) or ‘Neighborhood Spatial Accessibility’ (NSA) (Hewko, Smoyer-Tomic, & Hodgson, 2002), discussed in existing literature and focuses on two main features of access: amount – of schools within a given area, and distance – from dwellings to schools.

As the main research question is explored, the methodological process considers various ways to measure spatial accessibility and change in residential development. While there have been various ways to measure spatial accessibility, as shown in existing literature, there is no single method considered to be the best (Talen & Anselin, 1998). Therefore, in order to create an appropriate methodology, it is also important to answer the question: what are appropriate indicators and methodologies when studying the relationship between residential development and spatial accessibility to schools?

Since there are various classifications of schools in New York City, it is also imperative to consider how the effects of residential development on access differ between school types and grades (public, charter, or private schools, and elementary, primary, middle, and high school).

Once these questions are addressed, the study seeks to identify the areas in New York City that exhibit the most significant impact from residential development on access to schools. A discussion on these findings puts them back in the context of urban planning, to see how such studies can contribute to the academic discipline and profession of urban planning.
1.3. LITERATURE REVIEW

The literature explored for this study is classified in three different categories: 1) Definition of Accessibility, 2) Residential Development, and 3) Methods. The first two categories provide background information to help understand the issues at hand and the environments in which they must be considered. The Methods category is used to assist in the conception of an appropriate methodology for this study. Scholarly articles account for most of this literature, but governmental reports and news articles are also consulted.

1.3.1. Definition of Accessibility

The concept of accessibility has been explored in many studies, including urban planning studies, by many scholars and methods. The definition of accessibility depends on the context by which such term is to be used, for instance, in analyzing traffic flows to evaluate transportation policy, as a means to compare rural versus urban development, or as a variable in location analysis (Geertman & Ritsema Van Eck, 1995). In our case, accessibility is analyzed and discussed as an externality to residential development in order to better understand how we can approach and write urban planning policy.

More specifically, this study seeks to explore the ways in which accessibility to schools is affected by residential development, and therefore, we adopt a similar definition to that of Neighborhood Spatial Accessibility (NSA). This term refers to “the ease with which residents of a given neighborhood can reach amenities” (Hewko, Smoyer-Tomic, & Hodgson, 2002), and so our definition of accessibility is: the potential for children to reach public or private schools in New York City. This reach is broken down into two factors: 1) amount of schools and 2) distance between dwellings and schools. While the number of children is considered as the overall demand for schools, the number of existing schools is essentially a measure of supply, and the distance to
schools is a measure of ease by which a child can reach a school. By this definition, an increase in accessibility may be attributed to a higher number of schools and/or a shorter distance between dwellings and schools. Subsequently, it is important to consider how we may measure such variables.

As previously mentioned, one way to look at access is by considering distance to the nearest desired amenity. Under this perspective, distance is intrinsically linked with travel time, but as Islam and Aktar (2011) suggest, the availability of transportation options may be a game-changing factor in measuring access, as well. In New York City, while there may be a wide variety of transportation options between dwellings and schools, including walking, bicycle, automobile, bus, and subway, some of these are restricted to certain students and some may be more favorable to others. For example, students in third grade and above, who live within half a mile from their schools, are not eligible for the General Education Transportation program (either a Yellow Bus or discount-fare MetroCards) (NYC Department of Education, 2016), and so these students are likely to walk or bike to their schools. This point directs us to consider additional factors that may affect access, such as building and road conditions (Jimenez, 2016), as well as traffic and pedestrian safety (Page, Petteruti, Walsh, & Ziedenberg, 2007). Other methods by which we can measure accessibility are discussed in the Methods section of this chapter.

1.3.2. Residential Development

The 2016 Housing Supply Report from the New York City Rent Guidelines Board (2016) illustrates the state of the city’s residential development environment. Pertinent to our study, the number of permits for new dwelling units increased by 176 percent (56,528 dwellings) from 2014 to 2015. While this is the sixth consecutive year of increase, it is a dramatic increase in the pace of residential development as the previous year only saw a 13.7 percent increase. Similarly, the number of new housing units completed from 2014 to 2015 increased by 24.7 percent (14,357 buildings),
while the previous year saw a decrease of 6.4 percent. Whether the figures from 2014 to 2015 are signs of a new residential market in place, or simply anomalies, remains to be seen in the years to come. What is clear is that both private developers and city-sponsored projects spur these rising figures for residential development. There is, then, some degree of alignment between the public and private sectors in providing the required supply of housing in the city, but rather than focusing on the relationship between the public and private sector to instigate residential development, this study questions how such activities affect access to public facilities, namely schools.

Therefore, we are more interested in the relationship between real estate development and access to schools. While academic literature in this particular field is scarce, this relationship is often discussed in news media and publications related to urban disciplines. For example, it is common to find news articles that shed light on how good schools (those that are high-performing academically, with better facilities, and in safer districts) are high in demand by practically everyone, yet only those fortunate enough to live in specific school districts, or those with adequate income levels benefit from them. This demographic may attract developers to carry out projects that cater for this affluent or privileged population, resulting in school-centered development (Johnson, 2015). The process by which real estate development increases, however, is not the focus of this study. Instead, we aim to look at residential development from an urban planning perspective, as mentioned before, to better understand how we can improve planning policy.

The most common lens under which urban planning examines residential development is through zoning and land use planning. Zoning and land use planning are concerned with the allocation of land between potentially conflicting uses to ensure that such land is developed in a rational and orderly manner (Thomas, 2001). This means that, to some degree, development – and in our case, residential development – is intrinsically linked with urban planning efforts to create human settlements. More specifically, planners are concerned with the control of residential
development to ensure that cities grow at the appropriate time and place as determined by urban regulations. So, as this study explores residential development and its impact on school access, it also aims to contribute to the way by which planners write urban development policy.

1.3.3. Methods

Many studies have measured access to urban amenities through both quantitative and qualitative approaches. In Maroko et al.’s paper, which looks at parks and physical activity sites in New York City, the authors present and discuss the complexities of carrying out spatial accessibility analyses. The measurement of accessibility in their study is density of park acreage and physical activity sites, and this is analyzed through a kernel density estimation, ordinary least squares (global) regression, geographically weighted (local) regression, and longitudinal studies consisting of field work and archival research. Furthermore, the authors take into consideration independent variables such as population ethnicity, socioeconomic status, education level, and population density to help illustrate the patterns of access to physical infrastructure in the city. Ultimately, the results of this study show how a qualitative analysis may yield contrasting results to a quantitative analysis, and so a mix of approaches and methods should be used when measuring access to urban facilities (Maroko, Maantay, Sohler, Grady, & Arno, 2009). It is also important to note that density studies, or ‘regional availability’ studies, are effective due to their simplicity, as they essentially provide a ratio between supply (amenities such as schools) and demand (population or number of dwellings) over a predefined area. However, they do not account for variability within or beyond the geographic boundaries used to calculate density (Luo & Whippo, 2012).

Another density-related method is the two-step floating catchment area (2SFCA) method, which produces an accessibility ratio that has been shown to be better than one obtained from a kernel density method (Yang, Goerge, & Mullner, 2005). The 2SFCA method, in our context,
consists of two steps: 1) for each school location, find the demand (population or dwelling units) within a given area and calculate a school-to-demand ratio, and 2) for each population location (census tract centroid), sum up the ratios of the schools that fall within a given distance to obtain a final accessibility ratio or index.

As a density-related method, the 2SFCA also has various limitations. Once again, it is dichotomous, meaning that the values that fall outside of the fixed areas are considered to be completely inaccessible. Furthermore, distance within the given study areas are considered equally accessible, and so there is no perception of distance decay (Luo & Whippo, 2012). However, various studies have been conducted to improve the 2SFCA method by varying the service area coverage depending on the type of neighborhood and determining an appropriate weighting system that considers distance variability (Yang, Goerge, & Mullner, 2005). This is particularly pertinent when considering studies regarding school districts in New York City, which define the service areas of public schools. Other methods to study access include a Standard Deviation Ellipse, Sargent Florence Quotient, Geostatistical Analysis, and analysis of education quality indicators. Spatial Auto-correlation analysis, in specific, has proved to be a valuable method in exploring spatial configurations of urban facilities and showing the differences that result from being close or far away from metropolitan areas (De la Fuente, Rojas, Salado, Carrasco, & Neutens, 2013). While this study focuses on New York City, rather than urban versus suburban areas, it is important to keep in mind that results may vary when looking at the city as a whole, rather than looking at individual boroughs first, and then comparing boroughs. The latter approach may provide results that take into consideration inherent differences between counties, such as population density, but these considerations could be further explored at an even smaller geography. This problem, the Modifiable Areal Unit Problem (MAUP), is expected to arise when choosing the appropriate
geographic unit of study and comparing results between areas in Manhattan and Staten Island, for example, and will be further discussed in the Discussion section of this paper.

Apart from looking at density as an accessibility indicator, we can also look at distance between the supply and demand of schools and residential development. A study by Baics and Meisterlin (2016) calculates the average distance from a dwelling to its thirty nearest industrial buildings to measure varying degrees of separation between residential and industrial uses. This method may be adapted to residential lots in relation to the closest schools around them, thereby, obtaining an informative measure of distance that goes beyond a measure to the nearest school, which may be ignoring issues pertaining to choice and school overcrowding. As an alternative to the previous density-related methods, a distance-oriented method does not suffer from the distance decay issue. However, the choice in the amount of supply points (schools) to look at may still be arbitrarily chosen. Therefore, as with the previous methods, this one should not be used on its own to give a proper indication of spatial accessibility.

Finally, it is important to note that the methods discussed above were used for measuring spatial accessibility to parks, physical activity centers, health facilities, and spaces for industrial uses. This variety in study subjects suggests that schools could also be studied under the same methodologies, but their effectiveness remains to be seen. Furthermore, the study areas from the past studies range from urban to rural, and from developed to developing countries. Therefore, while it is useful to refer to these methods as precedents for this study, adjustments must be made to carry out an appropriate methodology to measure access to schools and its relation to increased residential development in New York City. For the purposes of this study, we will focus on regional availability, a variation of the 2SFCA method, and the method used by Baics and Meisterlin to measure accessibility to schools. These are further discussed in the Methodology section of this paper.
2. CHAPTER TWO

2.1. DATA

Table 2.1 shows a list of the data consulted throughout the study in order to find relationships between residential development and spatial accessibility to schools. An important aspect of these data sources is that they are all publicly available online. There are advantages and disadvantages of using such public data. Since most of it is collected by public agencies, the coverage is expected to be good throughout the city, with no biases or focuses on particular areas. However, the detail of such data is also lower and aggregated to a point where no personal identifiers are available. In the case of NYC DOE data, for example, no data is linked nor traceable to a particular individual or family. Studies using these datasets, therefore, may present patterns and solutions to the questions we ask, but we must keep in mind that we are also looking at issues and answers at a general level. Furthermore, while all the data in Table 2.1 was explored during the creation of this study's methodology, most of it turned out to be ineffective or inapplicable for a variety of reasons.

<table>
<thead>
<tr>
<th>DATASET</th>
<th>GEOGRAPHY</th>
<th>YEARS</th>
<th>FILE TYPE</th>
<th>SOURCE</th>
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</thead>
<tbody>
<tr>
<td>Class Size</td>
<td>Public School</td>
<td>2007-2016</td>
<td>Excel</td>
<td>NYC DOE</td>
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<tr>
<td>Public School Points</td>
<td>Public School</td>
<td>2011-2012</td>
<td>Shapefile</td>
<td>NYC DOE</td>
</tr>
<tr>
<td>NYC Public Schools</td>
<td>Public School</td>
<td>2015</td>
<td>Shapefile</td>
<td>Baruch CUNY</td>
</tr>
<tr>
<td>NYC Private Schools</td>
<td>Private School</td>
<td>2015</td>
<td>Shapefile</td>
<td>Baruch CUNY</td>
</tr>
<tr>
<td>Total Population</td>
<td>Census Tract</td>
<td>2010, 2015</td>
<td>Excel</td>
<td>U.S. Census Bureau</td>
</tr>
<tr>
<td>Age and Sex</td>
<td>Census Tract</td>
<td>2010, 2015</td>
<td>Excel</td>
<td>U.S. Census Bureau</td>
</tr>
<tr>
<td>School Enrollment</td>
<td>Census Tract</td>
<td>2010, 2015</td>
<td>Excel</td>
<td>U.S. Census Bureau</td>
</tr>
<tr>
<td>MapPLUTO</td>
<td>Tax Lot</td>
<td>2002-2016 (no 2008)</td>
<td>Shapefile</td>
<td>NYC DCP</td>
</tr>
<tr>
<td>Census Tracts</td>
<td>Census Tract</td>
<td>2010</td>
<td>Shapefile</td>
<td>NYC DCP</td>
</tr>
<tr>
<td>School Districts</td>
<td>School District</td>
<td>2017</td>
<td>Shapefile</td>
<td>NYC DCP</td>
</tr>
<tr>
<td>NTAs</td>
<td>NTA</td>
<td>2017</td>
<td>Shapefile</td>
<td>NYC DCP</td>
</tr>
</tbody>
</table>
In terms of schools or other education amenities, the Department of Education provides data about public schools, including charter schools, that is aggregated to a level that is void of personal identifiers and other sensible information. With regards to this study, the main problem with these data was not their level of detail, but their compatibility with other data, for example: the Class Size Reports provide the number of students enrolled in every grade per school from 2007 to 2016, and uses the NYC DOE’s school identifier codes. However, they have no geographic information to help us locate these schools on a map. On the other hand, the DOE also has a point shapefile with public schools and similar identifier codes, but this data is only available for 2011-2012, which restricts us from making studies across a longer period of time. The City University of New York has shapefiles for schools in 2015, so a study could be performed from 2012 to 2015, but as discussed next, these years are not compatible with other sources, namely census data.

With regards to data from the U.S. Census Bureau, the main type of information we require is population by age. Since this study is about schools, we need population of children who can potentially attend school. Out of the three datasets shown in Table 1, the Age and Sex datasets from the American Community Survey 5-year Estimates for 2010 and 2015 (ACS_10_5YR_S0101 and ACS_15_5YR_S0101) are the most appropriate, providing an age breakdown for children between 5 and 19 years of age. This age break matches the public and private school’s K-12 programs, and the data is available at the census tract level. The only downside to using such data at this level is that this is only available for 2010 and 2015, limiting our study to a comparison between these two years if we desire to use census data.

Lastly, the NYC DCP provides us with polygon shapefiles for different geographic boundaries. The School District and Neighborhood Tabulation Area shapefiles are pertinent to our studies regarding public schools and residential development, since real estate development relates to
neighborhoods, rather than census tracts or other geographic boundaries. However, census tract shapefiles are also used in order to incorporate the previously mentioned census data.

The most important and useful data source for this study from the NYC Department of City Planning, however, is the PLUTO (and MapPLUTO) dataset, available from 2002 to 2016, excluding 2008. In the case of the MapPLUTO shapefiles, data collected by the NYC DCP and other agencies, such as the NYC Department of Buildings, are merged with tax lot data from the Department of Finance’s Digital Tax Map (DTM). Amongst the wide array of data in the MapPLUTO files, the following fields could be used to explore residential development and schools: Building Class; Floor Area, Residential; Units, Residential; Year Built; Year Altered 1; and Year Altered 2.

The Building Class field describes the major use of the main structure on a tax lot. The ‘W’ classification pertains to Educational Structures, and this is further broken down into nine categories. In this study, we use W1 (Public Elementary, Junior or Senior High) to represent public schools, and combine W2 (Parochial School, Yeshiva) with W8 (Other Private School) to represent private schools. The other categories are not used as they include specialized schools and upper education facilities, as well, such as colleges and universities. The W1 (public school), and W2+W8 (private school) data for all PLUTO datasets is summarized in Figure 2.1 below, with more detailed information presented in Appendix A.

<table>
<thead>
<tr>
<th>Field</th>
<th>2002</th>
<th>2016</th>
<th>% Change</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1-W9</td>
<td>2,477</td>
<td>2,913</td>
<td>17.60%</td>
<td>44%</td>
</tr>
<tr>
<td>W1</td>
<td>1,078</td>
<td>1,194</td>
<td>10.76%</td>
<td>41%</td>
</tr>
<tr>
<td>W2, W8</td>
<td>676</td>
<td>772</td>
<td>14.20%</td>
<td>27%</td>
</tr>
</tbody>
</table>

Figure 2.1. Summary of the W. category under the Building Class field in PLUTO datasets from 2002 to 2016 (NYC Department of City Planning, Information Technology Division, 2016).
Figure 2.1 shows how the amount of education facilities in New York City has been consistently increasing since 2002, and while public schools account for more than 40 percent of the schools, this figure has decreased since 2002. This could indicate a lack in the provision (undersupply) of public schools. Private schools, on the other hand, have remained at 27 percent of the total amount of school facilities in the city, and have grown at a higher pace, as well (14.20 percent against 10.76 percent for public schools). This may suggest that private schools can adapt or react better to a changing demand for schools.

To look at residential development, we can explore the fields of Floor Area, Residential, and Residential Units. Figure 2.2 shows a summary chart of these two fields. While we might expect similar trends between the fields, the opposite is true. The residential floor area data shows a sharp increase, 66.23 percent, in floor area from 2003 to 2004, and thereafter the change is mostly within 1 percent. The year of the sharp increase in floor area coincides with the commencement of Mayor Michael R. Bloomberg’s New Housing Marketplace Plan, an initiative to bring a considerable amount of affordable housing in New York City by 2014 (NYC Department of Housing Preservation and Development, 2013). However, it seems unlikely that the PLUTO data would reflect such plan before the dwellings were even provided. Another characteristic that makes this field unreliable is that many lots appear to have 1 square foot of residential floor area. This is an unrealistic area when discussing residential dwellings, and so, it may be better to look at residential units instead.

The bottom chart in Figure 2.2 shows the trend in residential units from 2002 to 2016. In general, we can see how the amount of units increases for a number of years before it decreases or increases at a slower pace. This may be indicative of real estate market cycles and shows how, while residential development may be cyclical, the overall trend, just like school supply, is an increase over time.
Lastly, the fields: Year Built, Year Altered 1, and Year Altered 2 are useful as they are another indication of when residential development happened. This data, obtained from the NYC Department of Buildings, can be obtained solely from the 2016 version of PLUTO, since the versions build upon each year progressively. When looking at the change in residential development from one year to another, these fields may be used to see the new increase in housing supply, but it does not indicate whether the supply in a particular lot decreases. Therefore, an alternative for comparing residential units from one year to another would be to look at different year versions of

Figure 2.2. Top: Residential Area in square miles from PLUTO datasets from 2002 to 2016. Bottom: Residential Units (in thousands) from PLUTO datasets from 2002 to 2016 (NYC Department of City Planning, Information Technology Division, 2016).
PLUTO and calculate differences or percent changes between them. This would indicate increases or decreases in the total supply of residential units in the city.

### 2.2. METHODOLOGY

As seen in the literature review section of this paper, there are many ways to measure spatial accessibility to amenities within a city or region, and it is difficult to state which one method is the best or most accurate when performing such a task. While some methods may be simple, such as density measures, they are also the most straightforward and easy to understand. Furthermore, the methodology chosen for this study must be able to work with the available data mentioned above. Therefore, in creating a methodology that is compatible with the available data and suitable for analysis in an urban planning setting, various measures of spatial accessibility are used at different geographic scales, and these are compared to measures of residential development changes under the same geographic scales. In general, the methodology consists of five steps that are carried out separately for public and private schools:

1. Measure spatial accessibility in 2010.
3. Find the difference between 2010 and 2015.
5. Compare the results from Step 3 and Step 4.

These steps, along with the variables measured are also shown graphically on Figure 2.3 below. As depicted on the chart, the first three steps were carried out for all private and public schools, and at different geographic scales. Then, residential development changes were also studied at the SD,
NTA, and CT levels. Finally, these changes in residential development where compared with changes in spatial accessibility of schools. More detail regarding each step is provided below.

Figure 2.3. Methodology Diagram showing the five key steps of the process to study spatial accessibility and residential development change.

2.2.1. Measuring Spatial Accessibility – Private Schools

As previously mentioned, the simplest way to measure spatial accessibility is by looking at regional availability, that is, density of schools. Since private schools are not affected by the school district boundaries, their area of influence is as far as people would be willing to travel to reach such schools. However, real estate is often seen and discussed at the neighborhood scale, and people are willing to move to neighborhoods that have good schools (Bonislawski, NYers are Shelling Out Millions to Live Near this Private School, 2016). Therefore, the Neighborhood Tabulation Areas are used as the base geographic units for this part of the methodology. Density of schools is then
measured by the area of NTAs in square miles, by population between 5 and 19 years of age from the ACS data per NTA, and by the number of residential units from the PLUTO data per NTA.

The next method of measuring spatial accessibility is the Two-Step Floating Catchment Area. Since this method is essentially an enhanced density measurement of supply and demand, we attempt to obtain a finer level of detail by working at the census tract level. The supply component is the number of private schools (W2+W8 lots from the PLUTO data), while the demand will be population between 5 and 19 years of age per census tract, and number of residential units per census tract (the 2SFCA method is performed twice). Since various scholars suggest different ways to improve on the shortcomings of the 2SFCA method, this study also proposes a slight enhancement on the method. The two steps used are as follows (shown graphically on Figure 2.4):

1. \[ \frac{1}{\text{population (ages 5-19) in catchment area}} \]
   \[ \text{of school} = \text{index1} \]

2. \[ \sum \text{index1 for all schools within catchment area of dwelling/CT/NTA} \]

**Figure 2.4. The 2 Step Floating Catchment Area, with the variation account for distance decay.**

Step 1. For each school location, find the 5 to 19 year old population/number of residential units within a 1 mile radius catchment area. To account for distance decay, the 1 mile radius area is broken into three segments with proportional areas of \( \pi/9, 3\pi/9, \) and \( 5\pi/9 \). These proportions are assigned weights of 1, 0.6, and 0.3, respectively. So, the population/residential units in each catchment area is modified to suggest that people living further away from a school are less likely to
want to go to such school. The end of Step 1 is obtaining an accessibility index for each school by dividing 1 (school) over the population/residential units in each catchment area.

Step 2. For each census tract centroid, create a 1 mile radius catchment area and sum up the indices from Step 1 of all schools that fall within the census tracts’ catchment areas.

The third way to measure spatial accessibility is to calculate the average distance between census tract centroids and schools. An Origin Destination Cost Matrix, from the ArcMap Network Analyst extension was used to obtain the 10 closest schools to each census tract, and then an average distance was assigned to each tract (See Figure 2.5 below). The opposite of this method, looking at the ten closest census tracts or the population within these tracts from each school, is not carried out because this is essentially the first step of the 2SFCA. Once these three methods are done for the year 2010, they were repeated with data from 2015.

![Figure 2.5](image)

**Figure 2.5.** Method proposed by Baics and Meisterlin, taking the distance of the 10 closest schools to a dwelling, CT, or NTA.
2.2.2. Measuring Spatial Accessibility – Public Schools

The fundamental difference between private schools and public schools, pertinent to our study, is the limitation imposed by the NYC DOE that prevents students from attending any public school of their choice. While school districts are further broken down into three types of school zones: elementary, middle, and high school zones, the PLUTO data used for public schools, Building Class W1, combines all school grades together. This allows us to use school districts as the base geographic unit to study spatial accessibility to public schools.

Similar to the method used for private schools, regional availability is obtained by finding the density of public schools over the area in square miles, population aged 5 to 19 years old, and number of residential units per school district. Unfortunately, this method is the only one that works with the school district limitation.

The 2SFCA method for private schools relies on the catchment areas of each school and census tract, resulting in differences, albeit minimal at times, between all schools and tracts. With public schools, however, the catchment area of a school is the area of the school district it is in, and the available schools for each census tract are only those within the same school districts. In effect, the 2SFCA’s first step would be the same as calculating the density of schools by school district area, and the second step would be a count of schools per school.

We encounter the same problem with regards to the distance-based method, which requires that all schools surrounding a residential location can be taken into consideration. However, this is not the case with public schools and school districts. Since public schools are assigned to students, the question of choice or availability based on distance is no longer relevant, and only the amount of schools available for students matters, which is why, for the purposes of this study, only density-related methods are appropriate for public schools.
2.2.3. Finding the Differences between 2010 and 2015

Once the processes above are carried out for 2010 and 2015, we calculate the differences by subtracting the 2010 accessibility indices from those of 2015. To account for the large variability between certain areas in New York City, such as Midtown Manhattan or Downtown Brooklyn versus Staten Island, we try to obtain percentage differences, rather than absolute differences between the indices. However, since some areas begin with no schools or residential units at all, percentage increase calculations for these areas are meaningless. Therefore, we normalize each method by dividing the indices over the maximum value for each method. This way, all of the methods used so far can be compared with one another and the following step becomes more straightforward, as well.

2.2.4. Measuring Residential Development Change

We have already discussed the various ways in which we can explore the change of residential development. However, based on the data available, we will focus on the change in residential units from one year to another, and we can look at this by school districts, NTAs, and census tracts. We can also look at population change as an alternative method that is close to residential development change. A change in population does not necessarily translate to a change in residential development, though, so this method is expected to be less reliable. The final values of residential development change are normalized in the same way as for the spatial accessibility values, this allows for a more suitable comparison.

2.2.5. Comparing Spatial Accessibility with Residential Development

This study takes place under the assumption that residential development does affect, to a certain extent, the spatial accessibility to schools in the city. Therefore, while the current
methodology could lead to an investigation on the correlation, and the strength of such correlation, between residential development and access to schools, we aim, instead, to find ways in which one affects the other. The strength of geographic information systems is such that it allows for data analysis with regards to location. Therefore, a comparison between the previous steps can be carried out to find relationships between our variables. By superimposing spatial accessibility maps on top of residential development maps, we can look at the areas that have experienced a large change in residential development, and then match this with the spatial accessibility maps to see what the effects may have been in such areas. The threshold for what is considered a large residential increase may vary, so we can look at the top 5 percent of areas or geographies that show an increase in residential development.
3. CHAPTER THREE

3.1. Results

The nine maps from Figures 3.1 to 3.9 show the results of step 2.2.3 on the Methodology above. They show the differences in spatial accessibility between 2015 and 2010, normalized by each method’s highest value.

Figures 3.1, 3.2, and 3.3 indicate the relative change of spatial accessibility from 2010 to 2015 based on density measures. Figure 3.1 is based on densities of public schools over the area of their respective school districts. The greatest increase is seen in School District 6, which consists of Hamilton Heights, Washington Heights South and North, and Marble Hill-Inwood. School Districts 9 and 12 are next, showing a concentration of areas where spatial accessibility has increased in terms of regional availability. On the other hand, School District 1, which cover the Lower East Side, East Village, and part of Chinatown shows a decrease in the spatial accessibility to public schools.

If we compare these results with Figure 3.2, where density is based on population of ages 5-19, we find that once again, SD6 experienced the highest increase in spatial accessibility, while SD1 suffered the greatest loss. These matching results may indicate a close relationship between the amount of children aged 5-19 years old and the area available per School District. While this observation seems trivial, this is not the case for all the result obtained.

The last results looking at public schools, shown on Figure 3.3, use residential units as the density’s denominator, and present very different results. In this case, SD13 experienced the highest growth of spatial accessibility, while SD11’s index decreased the most. SD13 covers Greensburg, Williamsburg, Bushwick South, and parts of Bedford, which were some of the most attractive real estate markets for residential development from 2010 to 2015 (Bonislawski, 2015). On the other hand, SD11, which covers the northeast corner of the Bronx saw the greatest decrease in spatial accessibility based on residential units.
Figure 3.1.
DENSITY: Public Schools/School District Area
Normalized Change from 2010 to 2015

Highest Positive Change: SD 6
Lowest Negative Change: SD 1

Figure 3.2.
DENSITY: Public Schools/Population Ages 5-19 by SD
Normalized Change from 2010 to 2015

Highest Positive Change: SD 6
Lowest Negative Change: SD 1

Figure 3.3.
DENSITY: Public Schools/Residential Units by SD
Normalized Change from 2010 to 2015

Highest Positive Change: SD 13
Lowest Negative Change: SD 11
Figure 3.4.
DENSITY: Private Schools/Neighborhood Tabulation Area
Normalized Change from 2010 to 2015

Highest Positive Change:
1. Homecrest
2. Bedford
3. Gramercy
4. Lincoln Square
5. North Side-South Side

Highest Negative Change:
1. Kew Gardens Hill
2. Kensington-Ocean Parkway
3. East Elmhurst
4. Hamilton Heights
5. Washington Heights North

Figure 3.5.
DENSITY: Private Schools/Population Ages 5-19 by NTA
Normalized Change from 2010 to 2015

Highest Positive Change:
1. North Side-South Side
2. Homecrest
3. Carroll Gardens-
   Columbia St.-Red Hook
4. Lincoln Square
5. Bedford

Highest Negative Change:
1. Kew Gardens Hill
2. East Elmhurst
3. Kensington-Ocean Parkway
4. Glen Oaks-Floral Park-
   New Hyde Park
5. Greenpoint

Figure 3.6.
DENSITY: Private Schools/Residential Units by NTA
Normalized Change from 2010 to 2015

Highest Positive Change:
1. Homecrest
2. Bedford
3. New Brighton-Silver Lake
4. DUMBO-Vinney Hill-
   DT Brooklyn-Boerum Hill
5. Sunset Park East

Highest Negative Change:
1. Kew Gardens Hill
2. East Elmhurst
3. Manhattanville
4. Kensington-Ocean Parkway
5. West Farms-Bronx River
Figure 3.7.
2SFCA: Private Schools to Population Ages 5-19 by Census Tract
Normalized Change from 2010 to 2015

Highest Positive Change:
1. New Springville-Bloomfield-Westleigh
2. Carroll Gardens-Columbia St.-Red Hook

Highest Negative Change:
3. Kew Gardens Hill-
Pomonok-Flushing Heights-Hillcrest

Normalized Change
-100% -80% -5% 0% 20% 70%

Figure 3.8.
2SFCA: Private Schools to Residential Units by Census Tract
Normalized Change from 2010 to 2015

Highest Positive Change:
1. New Springville-Bloomfield-Westleigh
2. Grassmere-Arrochar-Ft. Wadsworth
3. Carroll Gardens-Columbia St.-Red Hook

Highest Negative Change:
4. Annadale-Huguenot-Pine Bay
5. Kew Gardens Hills

Normalized Change
-100% -65% -5% 0% 15% 60%

Figure 3.9.
DISTANCE: Average 10 Closest Private Schools to Census Tracts
Normalized Change from 2010 to 2015

Highest Positive Change:
1. Rickers Island
2. East New York
3. New Springville-Bloomfield

Highest Negative Change:
4. Park/Cemetery
5. Park
6. Kew Gardens Hill
7. East Elmhurst
8. Douglas Manor-
Doughaston-Little Neck

Normalized Change
-100% -15% 0% 5% 15% 100%
For the regional availability studies that look at private schools and Neighborhood Tabulation Areas, Figures 3.4 to 3.6, we look at the five NTAs that experienced the most change, either positive or negative. In particular, Homecrest and Bedford, both located in Brooklyn, experienced a relatively higher increase in density of private schools over the three different denominators. Similarly, three neighborhoods show the greatest decrease in density over NTA area, population, and supply of residential units: Kew Gardens Hills, East Elmhurst, and Kensington-Ocean Parkway. While Kew Gardens Hills and East Elmhurst are both located in Queens, and are mostly surrounded by other NTAs that experienced a decrease in density, Kensington-Ocean Parkway is located in the center of Brooklyn, and it is surrounded by NTAs that generally show an increase in school density instead.

Figures 3.7 and 3.8 show the results of the 2SFCA method used with population values, and residential units, respectively. As explained earlier in the Methodology section, this method is meant to provide a better measurement of spatial accessibility, while still having density as the primary measurable function. Since these tests are done at the Census Tract Level, rather than looking at individual tracts, we look for clusters of the ten tracts that experienced the greatest change over time. With this method, the largest increases in accessibility indices are seen in New Springville-Bloomfield-Westerleigh, on Staten Island, and in Carroll Gardens-Columbia St.-and Red Hook, Brooklyn. On the other side of the spectrum, we find that Kew Gardens Hills is once again the most affected neighborhood with a greater decrease in spatial accessibility to private schools.

Lastly, Figure 3.9 shows the results from the third method used in this study. Since this method is based on distance, the higher the positive value, the lesser the spatial accessibility it connotes (hence the color scheme is inverted). This is because a larger number indicates a greater distance between dwellings and schools, and as established earlier, this study assumes that people are less likely to choose a school that is further away from them than other closer alternatives. In this
map, we can see how most parks, including Central Park, Van Cortlandt Park, and Prospect Park, and the edges of the city show higher distances between schools and dwellings. This result is expected for areas that experience a lower spatial accessibility index, but it is interesting to find that once again, New Springville-Bloomfield appear as an area of greater increase in spatial accessibility, supporting the previous results obtained from the 2SFCA method.

Figures 3.10 to 3.15 are the results for the Methodology’s part 2.2.4, showing how residential development has changed over time under three different variables and three different geographies. Contrary to the spatial accessibility results, however, there are not many overlapping or similar results between methods this time. For example, looking at Figures 3.10 and 3.11, the change in residential development shown for the Bronx varies from negative to positive change. This, in fact is noticeable for each pair of figures 3.12 with 3.13, and 3.14 with 3.15, whereby the dominant colors on the map pairings seem to be the inverse of one another. What is consistent, however, is that the tests that use population seem to provide a decrease in the amount of residential development (more blue on the maps), while the calculations using residential units show an increase in residential development. This reinforces our previous concern that population does not necessarily indicate an increase in residential development, and we should be careful when making such assumptions.

To check on these results, the population data used for these studies was revisited and, indeed, the population of children between 5 and 19 years of age has decreased from 1,483,570 in 2010 to 1,435,558 in 2015, a 3.2 percent decrease. This is in contrast to Figure 2.2., which showed an overall steady increase in residential units available from 2002 to 2016.
Figure 3.10.
Residential Development Change:
Population, Ages 5-19 per School District
Normalized Change from 2010 to 2015

Highest Positive Change: SD 20
Lowest Negative Change: SD 6

Figure 3.11.
Residential Development Change:
Residential Units per School District
Normalized Change from 2010 to 2015

Highest Positive Change: SD 11
Lowest Negative Change: SD 13
Figure 3.12.
Residential Development Change:
Population, Ages 5-19 per Neighborhood Tabulation Area
Normalized Change from 2010 to 2015

Highest Positive Change: Lowest Negative Change:
2. Gramercy 7. Flatbush

Figure 3.13.
Residential Development Change:
Residential Units per Neighborhood Tabulation Area
Normalized Change from 2010 to 2015

Highest Positive Change: Lowest Negative Change:
1. Bronxdale 6. DUMBO-
2. Battery Park City- 7. Far Rockaway
   Lower Manhattan
Figure 3.14.
Residential Development Change:
Population, Ages 5-19 per Census Tract
Normalized Change from 2010 to 2015

Highest Positive and Negative changes are spread across the city

Figure 3.15.
Residential Development Change:
Residential Units per Census Tract
Normalized Change from 2010 to 2015

Highest Positive and Negative changes are spread across the city
The final step in the methodology consists of comparing the previous results that we have obtained so far. As we just saw from the last step, population growth (of people aged 5-19 years) is inversely proportional to the growth of residential units available. Furthermore, the first density studies that calculated the amount of schools over a geographic area cannot be compared with residential growth maps, as the area for the geographies used is always fixed. This is also the case with the distance-based maps; there is no residential development study that pertains to distance. Therefore, the following results for methodology part 2.2.5 compare and contrast the growth of residential units and the spatial accessibility change that corresponds to the areas of increased development.

Figure 3.16 shows the top 5 percent of School Districts showing an increase in residential development according to an increase in residential units. School Districts 2 and 11 show the greatest change from 2010 to 2015. By looking at the spatial accessibility map for schools and residential units (bottom on Figure 3.16), we first notice that the same School districts indicate a decrease in spatial accessibility from 2010 to 2015. The second observation with these two maps is that residential development seems to happen at a greater pace in a centralized area: most of Manhattan, the areas of Brooklyn and Queens that are closest to Manhattan, and the southern part of the Bronx. However, the spatial accessibility map shows that there are more than one center with a large change in accessibility. School Districts 19 and 21, for example, may be affected by factors other than an increase in residential development.

Next, Figure 3.17 shows the same type of comparison but at a Neighborhood Tabulation Area level. The inverse relationship between residential development and spatial accessibility to schools is not as clear in this case, with some NTAs showing both an increase in residential development and an improvement in the accessibility to its schools.
Lastly, Figure 3.18 delves into the Census Tract level for a much finer-detailed investigation. The highlighted census tracts on this figure are once again the top 5 percent of tracts that showed an increase in residential development. This time, however, the residential development map appears to show a more random distribution of tracts that are increasing in residential development, compared to the previous two study scales. On the other hand, the spatial accessibility map at the CT level appears to show clear patterns and clusters of tracts that enjoy high spatial accessibility to schools. Most of these areas are located in Brooklyn, with a large, individual area situated in Staten Island, as well. We will discuss this discrepancy further in the following section.
Figure 3.16.
Comparing Change in Residential Development with Change in Spatial Accessibility at the School District Level
Normalized Change from 2010 to 2015
Figure 3.17.
Comparing Change in Residential Development with Change in Spatial Accessibility
at the Neighborhood Tabulation Area Level
Normalized Change from 2010 to 2015
Figure 3.18.
Comparing Change in Residential Development with Change in Spatial Accessibility at the Census Tract Level
Normalized Change from 2010 to 2015

Residential Development Change

Normalized Change

-100% 0% 2% 10% 25% 65%

Spatial Accessibility Change

Normalized Change

-100% -65% -5% 0% 15% 60%
3.2. Discussion

Following the findings in the previous section of this chapter, we could start seeing the finer
detail of our study, the more unreliable or indirect the relationship seemed between residential
development and spatial accessibility. That is, at a more general level, the chances to see
relationships and correlations are higher due to the presence of other not-studied factors that may
affect access to schools, as well. There is, therefore, a very important point to be said about studying
urban phenomena, and that is that geography matters. Fortunately, we were able to perform our
study at three different geographic unit scales that are relevant to the topics at hand. However, it is
also important to note that our study dealt only with New York City as a whole, single entity.

The implications of carrying out a spatial study over a defined geographic area forces us to
bring the Modifiable Areal Unit Problem to the table. As seen throughout this study, the amount of
residential development and schools varies greatly throughout the city. Moreover, they vary greatly
between boroughs, districts, and any other type of geographic boundary. Looking at the amount of
development in Staten Island at the same time as we look at development in Midtown Manhattan
presents problems as Midtown Manhattan’s real estate market will skew all results to become
Manhattan-centric. While our study focused on issues and findings for the whole city of New York,
we would certainly have to perform our studies at a smaller scale, such as by borough, to obtain a
more meaningful conclusion as to how spatial accessibility differs across New York City.

One of the ways to help ameliorate the MAUP, though, is to work with percentage changes.
This way, all absolute values, for which Manhattan’s residential development may well surpass the
rest of the city alone, are now considered in the their own context, rather than in the greater context
of the rest of the city. Unfortunately, we encountered the issue of zero-value denominators, which
render percentage change calculations meaningless. The solution used in this study, which
normalizes all values per method by the highest absolute change over time in each method, is
effective as a comparative tool. However, in order to compare methods or maps, all results had to be converted under the same normalization procedure.

In terms of the methodology used to answer our thesis question, we created it in a way that would allow for a streamlined procedure, while at the same time, being able to test different data through different methods. While the methodologies researched in the literature review include many ways to obtain spatial accessibility, the topic of schools and residential development is not as commonly addressed. Since the demand factor in most studies performed so far are humans or patients, population is the most common denominator factor for all density studies, including the 2SFCA. In going a step further and suggesting the replacement of population by residential units, this study had already looked at one way in which residential development could affect spatial accessibility to schools, albeit still being a simple density function.

Table 3.1 summarizes the methods used in this study, the most effective ways of using such methods, and the results of this study. Overall, the best data source used to look at residential development change, at all scales in this study, were the PLUTO files’ Residential Units. The main reason for this was because an increase or decrease in residential units, by definition, indicate a change in residential development. The other methods used in this study were carried out with population change as an indicator of development, but as we found out earlier, there has actually been a decrease in the amount of children aged 5-19 years while the number of residential units has increased from 2010 to 2015. The density (regional availability) method was not used at the census tract level because the vast majority of tracts have either one or no schools at all, making comparisons between areas practically meaningless. Table 3.1 also shows that the 2SFCA was not compatible with the school district or neighborhood tabulation area scales. The strength of this method is its ability to ignore boundary lines (as discussed regarding the MAUP), and it works best when looking at finer grained data, so it was best used with private schools and census tracts.
However, between population and residential units, we used residential units once again. This time, for consistency, in addition to the previously mentioned reasons. Similarly, the distance method was only effective at the census tract level for private schools, but this was to be expected and we had already mentioned this issue in the Methodology section of this paper.

Table 3.1. Summary of Methods Used, Effective Variables, and Results.

<table>
<thead>
<tr>
<th>METHODOLOGY</th>
<th>SD</th>
<th>NTA</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Accessibility</td>
<td>Public Schools</td>
<td>Private Schools</td>
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<tr>
<td>Density</td>
<td>Residential Units</td>
<td>Residential Units</td>
<td>Private Schools to Residential Units</td>
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<td>2SFCA</td>
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<td>n/a</td>
<td>Avg. 10 closest Private Schools</td>
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<td>n/a</td>
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<th>Density</th>
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<th>Residential Units</th>
<th>Residential Units</th>
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<td>Area</td>
<td>Area</td>
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<table>
<thead>
<tr>
<th>RESULTS</th>
<th>Spatial Accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greatest Increase</td>
<td>SD 13</td>
</tr>
<tr>
<td>Greatest Decrease</td>
<td>SD 11</td>
</tr>
<tr>
<td>Greatest Increase</td>
<td>n/a</td>
</tr>
<tr>
<td>Greatest Decrease</td>
<td>n/a</td>
</tr>
<tr>
<td>Greatest Increase</td>
<td>n/a</td>
</tr>
<tr>
<td>Greatest Decrease</td>
<td>n/a</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact of S.A. on R.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship</td>
</tr>
</tbody>
</table>
Looking at the results from the Spatial Accessibility studies, we can see that only the density method was effective to study public schools. The main limitation here was the clearly defined school district boundary and the assumption that no children outside of the SD would be able to attend a school within such district, thereby, having absolutely no spatial accessibility to those schools. With this method, SD 13 showed the greatest increase in spatial accessibility. This district includes Brooklyn Heights, Fort Greene, Clinton Hill, and Bedford Stuyvesant. Apart from being home to Brooklyn Tech, a highly-regarded high school, the district has seen declining enrollment in recent years and it also lacks middle schools (School, 2017). The increase in spatial accessibility, however, may be due to another observation in our result, which show SD 13 with the greatest decrease in residential units, thereby allowing for more schools per residential unit.

As for decreasing accessibility, SD 11, in northeast Bronx and covering Pelham Parkway, Eastchester, and Woodlawn, showed the lowest results. The look into residential development change showed that the increase in units in SD 11 was among the highest in the city, possibly accounting, once again, for the decrease I accessibility to schools here.

In terms of accessibility to private schools, Kew Gardens Hills showed up as one of the neighborhoods with the greatest decrease in spatial accessibility. This was seen with all methods used in this study. Kew Gardens Hills is located in central Queens, and it houses a large Jewish population. As such, apart from many public schools, it also houses large Yeshiva Schools, which our study took into account as private schools. If we consider the main variable we have been using so far to attempt to explain changes in spatial accessibility, we may attribute the increase in residential development at this neighborhood to developments such as the renovation of one of the neighborhood’s largest residential complexes, which had 1,270 apartments (Murtha, 2015).

However, if we are to look at the neighborhoods with the greatest increase in spatial accessibility to private schools, we are unable to see such strong concurring results from our study.
In this case, all three methodologies provided different results, shaking the effectiveness and reliability of the methodologies we implemented in the study.

Furthermore, while we could see from our results that residential development was inversely related to spatial accessibility to schools, the results’ precision varied between geographic units scales. At the school district level, for example, there was a clear decrease in accessibility in SD 2, which also showed the greatest increase in residential development in the city. SD 2 includes most of Midtown Manhattan, excluding the Lower East Side. This area encompasses many different neighborhoods, and real estate development occurs in different ways at these places. For example, there are large scale, luxury ground up developments spurring in the Midtown North area, and these are clearly catered to a wealthy population. On the other hand, Chelsea has seen many conversions and redevelopments that are catered to a less wealthy demographic. While there are differences between the residential developments that happen in these areas, though, the effect on access to schools is the same: a general decrease in accessibility.

Nonetheless, we previously saw how this result was not as clear as we moved on to the census tract level. In particular, the concentration of places where spatial accessibility was affected by residential development were not as well-defined as at the school district or NTA levels. This does not necessarily mean that the results are wrong, though, nor that the results are negative in terms of how planning policy should be approached regarding this topic. For example, the spread shown in the maps at the census tract level may suggest how city planning efforts have been spread throughout the city, without concentrating in one area or demographic target in particular. In terms of equitable planning, or distribution of resources and access to school, this may be a positive outcome.

Therefore, the results gathered from our investigation into how we could measure spatial accessibility, and how this could be affected by an increase in residential development, show that
while a variety of methods can be used to explore these topics, it may be hard to pinpoint one single method that is superior to the rest. The factors that should be taken into consideration are also essential considerations. In our case, the scale of the study had a big impact on the precision of our results, for example.

Finally, it is important to note that while the data analysis carried out in this study was mostly quantitative, the results may be more appropriate and useful if analyzed and presented in a qualitative manner. We have seen how the Density method provides us with a ratio, the 2SFCA with an aggregated index, and the distance method with an indicative distance. However, comparing these numbers and trying to put them together to obtain a measure of spatial accessibility is problematic. If we look at the studies discussed in the Literature Review section of this paper, only a few papers apply more than one methodology, and their conclusions often include all results separately, without converting them into a single measure of accessibility. This idea was considered for this study, perhaps by having a weighted index of accessibility. However, as we already saw how different results may differ across the city, even when using the same methods, an aggregation of values may in turn generalize results even further. Essentially, exacerbating the problem that we had regarding a lack of variables studied. This is the same issue with statistical analyses and regression models that attempt to encompass the whole study and distill it into a single number. Such focus on a number oversees the possibility that the answer should not be a number, and that complex urban phenomena may not be explainable through such a number. This opens the door to more qualitative data analysis, which should be one of the key areas for further research in this topic.

3.3. Limitations

Early on in Chapter 2, we encountered a key limitation to our study, that is, the available data to perform a spatial accessibility analysis and an investigation into the patterns of residential
development growth. The use of publicly available online data certainly has its merits, it is readily available and simple to understand, but the degree to which one carries out an exploratory investigation relies heavily on the available tools one possesses. While geographic information systems allow us to perform powerful and quick analyses, these do not mean much unless the data analyzed is worth using. In the end, this study made great use of the PLUTO datasets provided by the NYC Department of City Planning and demographic data from the U.S. Census Bureau, but we must keep in mind that our findings, then, are only as good as the accuracy of the data provided by the DCP and the U.S. Census Bureau.

In terms of methodological limitations, this study did not seek to find and use the one process that would provide the definitive answer to our thesis question. As mentioned by various authors in the literature review, a mix of methods is often the best solution to complement methodologies. Further considering the purpose of this study, it is important to keep in mind that this is first and foremost an urban planning paper. As such, the intricacies surrounding mathematically sound methodologies, similarly to the detail of school performance by students, is beyond the scope of the traditional role of urban planners, and hence, out of the scope of this paper. In creating and applying proper methodologies, then, our focus is to be able to perform a study that allows us to see patterns and draw conclusions that can lead to policy recommendations or other planning action. This is why there are a few parts of our methodology that remain arbitrary. For example, the catchment area radii used in the 2SFCA method were set to 1 mile because a longer 3 mile radius provided even worse results – Parks, such as Central Park, which are surrounded by dwellings and schools, showed an extremely high accessibility index when using a 3 mile radius, yet properties in Upper West Side, regardless of whether they were next to a school or not, showed significantly lower indices because half of their 3 mile buffer area fell on the Hudson River.
4. CHAPTER FOUR

4.1. Implications for Urban Planning

While this study focused on residential development and accessibility to schools, it is not a real estate paper, and neither is it an education essay. The issues that arise from the relationship between these two elements can have a great impact on the urban environment. As we mentioned Mayor Bloomberg’s housing plan, we could see how such an event could come to affect the lives of school children in the city. While the links between certain occurrences in the city and our lives may be hidden or obscure, perhaps this is part of the urban planner’s mandate to explore and investigate how we relate to the city and its happenings.

This study provides an example of how planners could explore an issue pertinent to housing, education, transportation, and even ethics. Furthermore, it shows how methodologies and techniques used in the planning profession can shed light on topics that are often mentioned, but are rarely taken seriously as an urban and social issue. The decision to use percentage changes versus absolute values, for example, is something that planners must take into consideration when comparing analysis between two different areas. The way data is treated, collected, and presented is essential for planners to effectively communicate their findings to others. While there are many maps presented in this study, it is the author’s intention for these figures to be easily absorbed and manageable for a reader that is not necessarily a planning professional.

The decision to look at certain issues at the city scale is another point that planners may take away from this study. There are advantages and disadvantages when performing studies that are city-wide in scale, versus studying a single city block or lot. Urban planners should always keep in mind that they work under different contexts at all times. The results obtained from a citywide study like this one do not guarantee identical results for a smaller scale study. However, planning policy tends
to be set at the city scale, so perhaps it may help to start from here and then delve into finer detail, provided we have the tools, data, and capability to do so.

Lastly, as we strive to understand urban phenomena in our cities, it is not only important to understand and apply the best methods and tools, but we must also be aware that in some cases, the quantitative results from such studies may not offer a comprehensive explanation to our problems. Therefore, as planners, we must always keep in mind that there may not be a right solution for the urban issues affecting our cities today, but our expertise is still required to analyze and find meaning and reason behind the numbers we see. Only then will we be able to effectively use such studies for the benefit of our society.

4.2. Conclusion

Rapid residential development growth in New York City seems to be a given characteristic to this city in recent years. The effects of such development, however, may extend far beyond the comprehension of most people. As planners, we explore the interactions between influential forces in the city to ensure that policy is written in a way that can benefit the most people. This study is an example of such explorations. By using publicly available data and geographic information systems, we explore the relationship between residential development growth and spatial accessibility to schools in New York City.

Through a methodology that incorporates various ways of measuring spatial accessibility, we are able to answer the question: how does residential development impact access to schools in New York City? Residential development shows an inverse relationship with spatial accessibility to schools. This was true for both public and private schools, even when considering the School District limitations. However, we also found that the results from our studies varied depending on the methods and the geographic unit scales that we used in our analyses. Results seemed to vary
across the city, even when using the same methods, and in general, they were also less reliable at a smaller scale. This suggests how further studies should be carried out that incorporate a wider array of variables to investigate, and also serves as a precaution to future studies that attempt to explain urban phenomena through quantitative analysis.

The research ultimately reaffirms that the growth in residential development has an impact on access to education amenities, but also sheds light on the process of conducting such studies with publicly available data and methods that are accessible to urban planning professionals and relevant stakeholders. The implications of this study may help planners better understand the way they look at urban issues, and how they use and interpret data, to subsequently address urban policy and set priorities that give attention to the public services and amenities that foster a better quality of life for whole communities.
5. BIBLIOGRAPHY


NYC Department of Buildings. (2016). Metrics & Reports. New York City, NY, USA.


NYC Department of Education. (2016). Data About Schools. New York City, NY, USA.


NYC Department of Transportation. (2016). Data Feeds. New York City, NY, USA.


# 6. APPENDIX

Public and Private School data, as defined in this study, for all of the available PLUTO datasets.

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