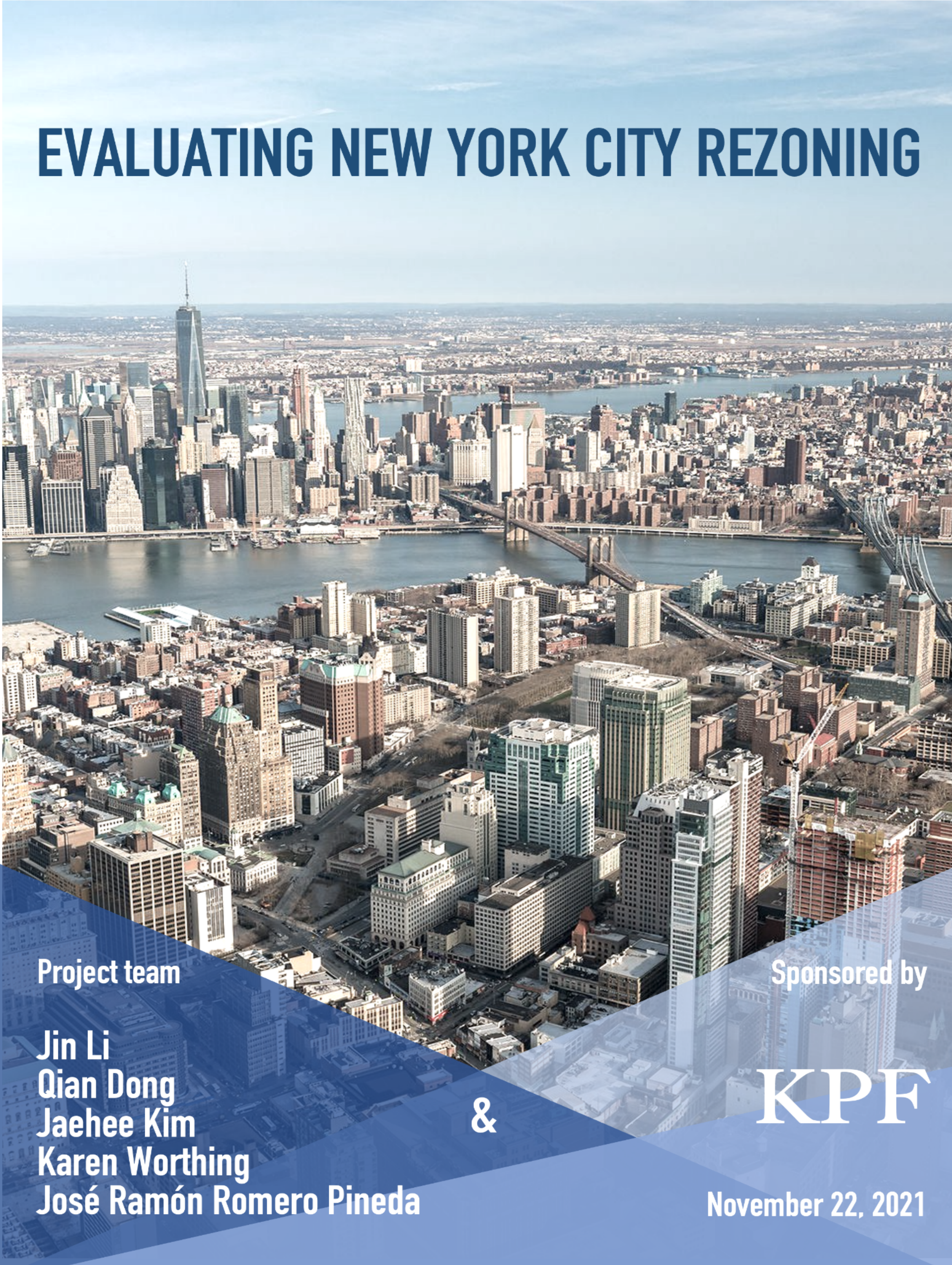

EVALUATING NEW YORK CITY REZONING

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Sponsored by

KPF

November 22, 2021

The Rezoning Capstone Team

would like to thank

Luc Wilson and Brandon Pachuca

of KPF

for their valuable guidance throughout this project

Abstract

Promoting optimal urban land use is critical to help neighborhoods thrive and make cities sustainable. While market forces encourage the most economic use of land, zoning serves as a check to assure the community is best served. Rezoning may be undertaken to create economic development, accommodate population growth, or respond to neighborhood needs and preferences. This study aims to determine what has caused results to deviate from intended goals in past rezonings to better anticipate and mitigate deviations in future rezonings.

The project's theoretical value is to understand how various land uses (e.g., residential, commercial) complement and compete with one another. The social value reflects the rezoned community's needs. Data was collected based on interviews with residential and commercial real estate developers who explained what drives the economics of developing an urban parcel, and includes demographic, land use, and neighborhood quality data. The data was loaded into a supervised machine learning model in which the dependent variable was land use. In addition, a second model was developed to predict future built floor area ratio (FAR) by land use. We developed a visualization tool which could be used to understand current trends and anticipate future needs of neighborhoods.

Introduction

New York City neighborhoods have continually evolved due to changes in demographics, mobility, and quality of life preferences. The city has experienced an unprecedented period of growth over the past twenty years, resulting in over 200 citywide and neighborhood rezonings.[1] The Bloomberg administration rezoned over 40%[2] of NYC, and Mayor de Blasio has continued the process. In each case, neighborhood needs are identified, and projects are planned to align with the goals.[3]

Proposed NYC rezonings are studied and evaluated via the City Environmental Quality Review (CEQR) process.[4] City planners must produce an extensive Environmental Impact Statement (EIS) detailing the specific changes expected by the rezoning across nineteen impact areas[5] (*Appendix 1*), and consider a Reasonable Worst Case Scenario. Implemented rezonings do not always achieve the intended results, however, as the EIS sometimes fails to account for iterative developments during the build process. Moreover, a rezoning focused on a particular type of development may not account for inequitable outcomes for others affected by the rezoning. For instance, a National Institutes of Health (NIH) study found that cities that restrict the density of residential construction are more segregated based on income, perpetuating racial and class inequality.[6] Our project used the 2004 Downtown Brooklyn rezoning as a case study, comparing the goals for the project's "build years" (expected time from approval to completion of the project) to the actual results by identifying, collecting and analyzing data from before and after the build. Even as rezonings aim for specific outcomes, planners may allow leeway for deviations to contito attract development in the event of changes over time. Our project includes a predictive tool which could allow city planners to 1) consider more extreme scenarios and their effects on the neighborhood; 2) build a mitigation plan for possible deviation based on the scenarios; and 3) monitor during the build and set breakpoints at which mitigation would be implemented.

Literature Review

Prior studies identify NYC rezonings in which results have deviated from the intended goals. The Municipal Art Society of New York (MAS) examined the Long Island City and Downtown Brooklyn rezonings. Both areas were intended to become new Central Business Districts but ultimately resulted in primarily residential development.[7] Churches United for Fair Housing did a similar study of the unintended effects from the Greenpoint/Williamsburg and Park Slope rezonings.[8] The Brooklyn Borough President's Office reviewed the Downtown Brooklyn rezoning eleven years later, in 2015. It determined that the EIS failed to address several surrounding neighborhoods which had concurrent zoning changes, and called for updating needed infrastructure, including schools, health care, open space, transit, and pedestrian safety.[9]

It is useful to look at how other urban centers have handled rezoning. Washington DC, for instance, enacted one zoning code for the entire district, and later created more detailed neighborhood zoning by block to carve out community-focused commercial streets. Rather than rezoning certain areas for commercial use, the Washington model created mixed-use zoning district-wide, and encouraged residential development by allowing greater density for housing.[10] Vancouver took a different approach, altering housing specifications citywide to increase residential density. Without community buy-in, the plan resulted in unwanted changes in the character of some neighborhoods.[11]

The primary source for Downtown Brooklyn is the Final EIS approved by the City Council in 2004[5]. It analyzes broad topics including socioeconomic conditions, community facilities, urban design, and neighborhood character, as well as specifics such as solid waste, energy, parking, and transit (full list in *Appendix 1*). Additional literature was reviewed regarding rezoning ethics (included under Data Ethics) and data methodology (included under Methodology).

Problem Definition

The intentions behind rezoning do not always align with the resultant rezoned environment.

What is causing the disconnect between the stated goals and the actual outcomes of NYC rezonings? Why did the Downtown Brooklyn rezoning, intended to create a commercial district, become a mainly residential neighborhood, and why were the resultant residential problems such as school overcrowding not mitigated?

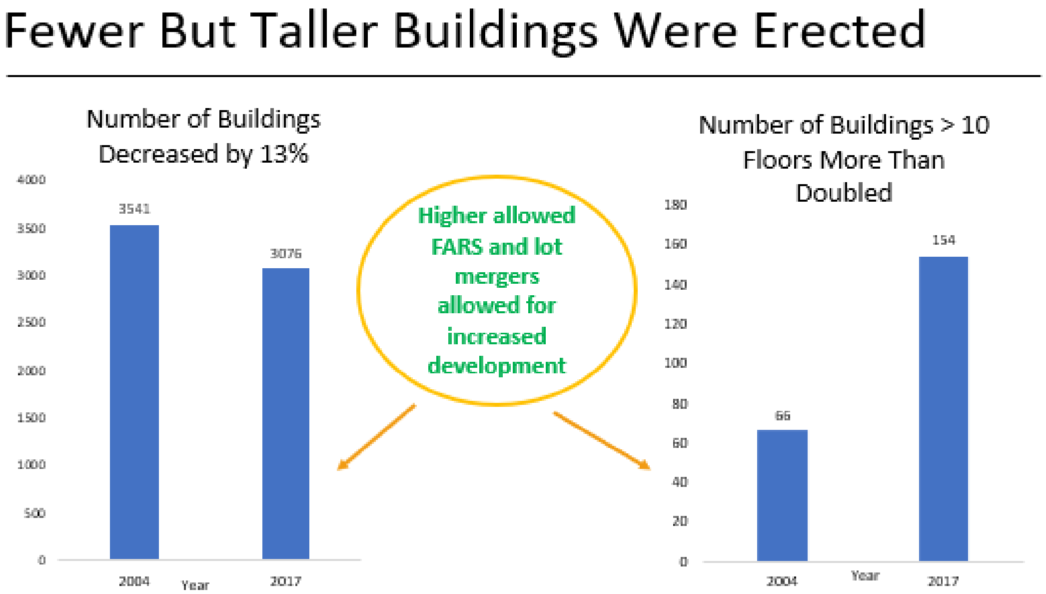
The problem occurs because goals are decided in a process that is not re-evaluated over time. Moreover, planners are not held accountable to meet the goals and do not have an incentive to monitor the results over the course of the build. Zoning provides incentives to developers through tradeoffs such as increased height restrictions and tax breaks in return for community benefits such as affordable housing or schools. However, outside influences such as economic, technological, and cultural changes can upend the goals of a rezoning during and after the build years. *Appendix 2* identifies the leading causes of the problem.

Hypothesis: Quantifiable Problem

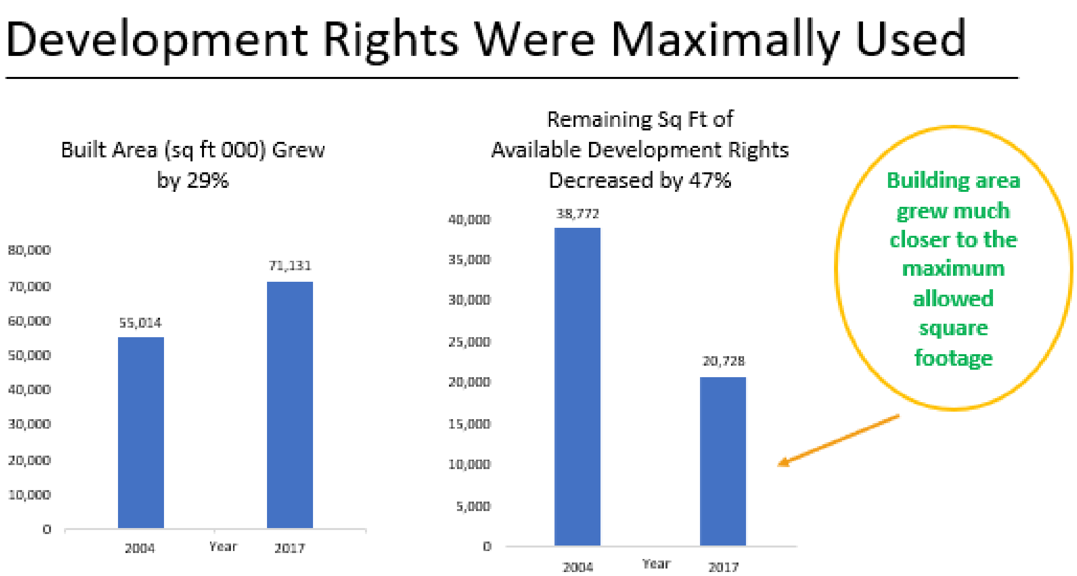
Merged data from different sources and years informed our hypothesis and metrics. As shown in *Figure 1*, the rezoning changes to FARs and allowance for lot mergers in Downtown Brooklyn created incentives to erect taller buildings, resulting in builders' maximizing available development rights.

We expected that the extensive building was due in part to the more generous FARs allowed by the rezoning. However, mixed use FARs intended for commercial space but ultimately developed as residential may also be due to external factors. Our hypotheses included the following: 1) NYC's high corporate tax rates created incentives for businesses to leave the city. 2) Housing prices at the time of the rezoning were lower in Brooklyn than in Manhattan, increasing residential demand in the rezoned area. 3) Amenities that attract commercial usage (such as open space and multiple transit options) likely also attracted residential customers to this area.

Figure 1



Source: PLUTO Data – NYC Department of City Planning



Source: PLUTO Data – NYC Department of City Planning

Problem Question

How do we learn from a prior rezoning after it was built and did not meet its intended goals to improve the results of future rezoning?

We researched the NYC rezoning process (*Appendix 3*). We interviewed a Downtown Brooklyn Community Board member to understand the Board's vetting process for rezonings, and interviewed three real estate developers to learn what factors they consider when choosing whether to build on a particular lot. These factors became the variables in our model.

Data

Primary Land Use Tax Lot Output (PLUTO) was the primary data source.[13] To understand whether decisions made at the lot level would match the aims of an overall district rezoning, we collected data the developers deemed most important to driving property valuation: demographics (income, education, population), subway stations, open space, noise, crime, and street tree data (*Figure 2*). We tried to use a consistent time frame, subject to limitations for which data was available: the PLUTO data changed over the timespan of the analysis, lengthening the steps required to merge and model (*Appendix 4*), and only one decade of census data is currently available. By visualizing the trend and spatial pattern of the data, and comparing the results with the rezoning goals, we developed an interactive tool for policy makers, urban planners, and the general public to assess urban evolution, thus facilitating more evidence-based urban decision-making.

Figure 2

Class	Variable	Time Period	Source
Infrastructure and land use	Type of property (residential, commercial)	2002-2017	PLUTO
	Land use	2002-2017	PLUTO
	Housing unit	2000-2018	US Census
Demographic	Population	2005-2018	US Census
	Income level	2005-2019	US Census
	Educational level	2005-2019	US Census
Safety	Crime data	2005-2018	NYPD
Environmental	311 noise complaints	2010-2018	NYC Open Data
	Street tree data	2015	NYC Open Data
	Built green area	2010-2018	Google Earth Engine
Traffic	Transport access	2021	MTA

Analyzed Variables

Methodology

Spatio-temporal land-use changes are a critical issue for cities. Due to uncertainty, multiple urban forces acting simultaneously (complexity), data integration, spatial correlation among the underlying factors, and a relevant temporal relationship, various empirical approaches have been used to better understand this urban phenomenon. Machine learning approaches to simulate land-use changes are chosen for their capability to identify non-linear relationships among the independent variables. Support vector machines have been used to simulate urban sprawl and land-use dynamics in Shenzhen, China.[14] Multinomial logistic regression has been used to assess the relative risk of a parcel's being upzoned or downzoned.[15]

Because the goal of a rezoning is to plan for a particular outcome, we wanted to see whether a predictive model matched this outcome. Hence, we studied the problem using two approaches:

1) **Regression**: The predicted factor is the built FAR for the main land uses (residential and commercial) based on the analyzed variables and their spatial and temporal patterns. We tried various regression models (random forest, linear regression, lasso and ridge regression, and other ensemble methods) for each variable. We fit the linear regression to understand the relevance of each variable, and as a descriptive model to demonstrate the relationships across variables. Random forest and the other ensemble methods were the models with expected higher performance based on their ability to capture nonlinear relationships that were identified in the variables.
2) **Classification**: The predicted factor is the lot land use. We ran different classification models (multinomial logistic regression, random forest, ensemble methods) to see whether the underlying trends would give us enough predictable power to identify a possible land use or to assign a certain probability to a specific event. Random forest works well with high dimensional data and is faster to train than decision trees since we were working with subsets of data and many features.

Project risks, reviewed in detail in *Appendix 5*, included the availability of data to be specific enough for our analysis, and whether visualization tools existed for the variables examined.

Data Ethics and Algorithmic Impact

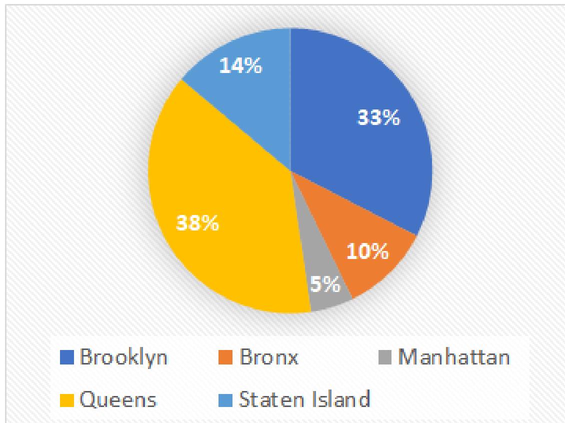
Rezoning has ethical implications, as changes to neighborhood land use may result in displacement or otherwise favor certain demographic populations. Restricting residential density can exacerbate income inequality, as shown in the NIH study[6]. This was not addressed by the Downtown Brooklyn EIS as they were focused on commercial development; however, the increase in affluent residents over the build years suggests that it should have been. Gowanus is a current example in which affluent residents are paying for litigation to fight the proposed rezoning[16]. Our project does not address the ethical implications of zoning decisions; however, the tool allows planners to understand which variables might result in inequitable outcomes.

Regarding data privacy, data collected at the lot level, such as building height, number of floors, and land use, did not include information from individuals. Income and education data were aggregated at the census block level and therefore not traceable to individuals. Finally, the model itself is not inherently biased as the outcomes are based on city-wide real estate value determinants. However, a user of the tool could introduce bias by emphasizing variables discriminatory to vulnerable populations. For instance, undocumented immigrants, who make up a significant segment of New York's population, may choose to not complete the census, thereby biasing the data toward other demographics. There is precedent for discriminatory outcomes: in the 2009 Brooklyn Broadway Triangle rezoning, a private developer initially focused on building large units in low-rise buildings, favoring the Hasidic community, whose members have large families and do not use elevators on the Sabbath. A judge later ruled that the development was inequitable to the nearby Black and Hispanic communities in need of affordable housing.[17]

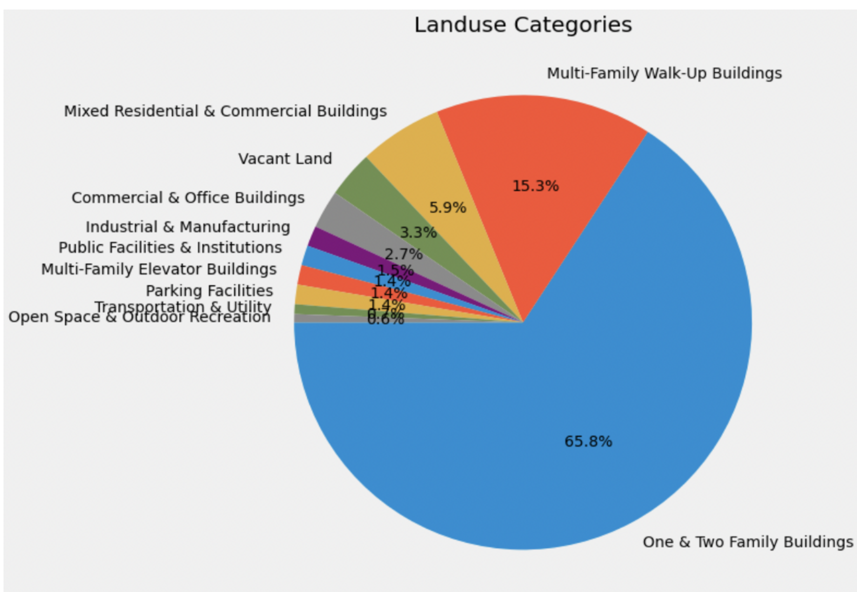
Results

The final dataset has over 800,000 rows and 66 variables. To save training time and improve accuracy of the model, we divided it into boroughs (*Figure 3*) and modeled using Manhattan (5% of tax lots), Brooklyn (33%), and Queens (38%), and considered eleven DCP land use categories.

Figure 3



Tax Lots by Borough (Source: PLUTO)



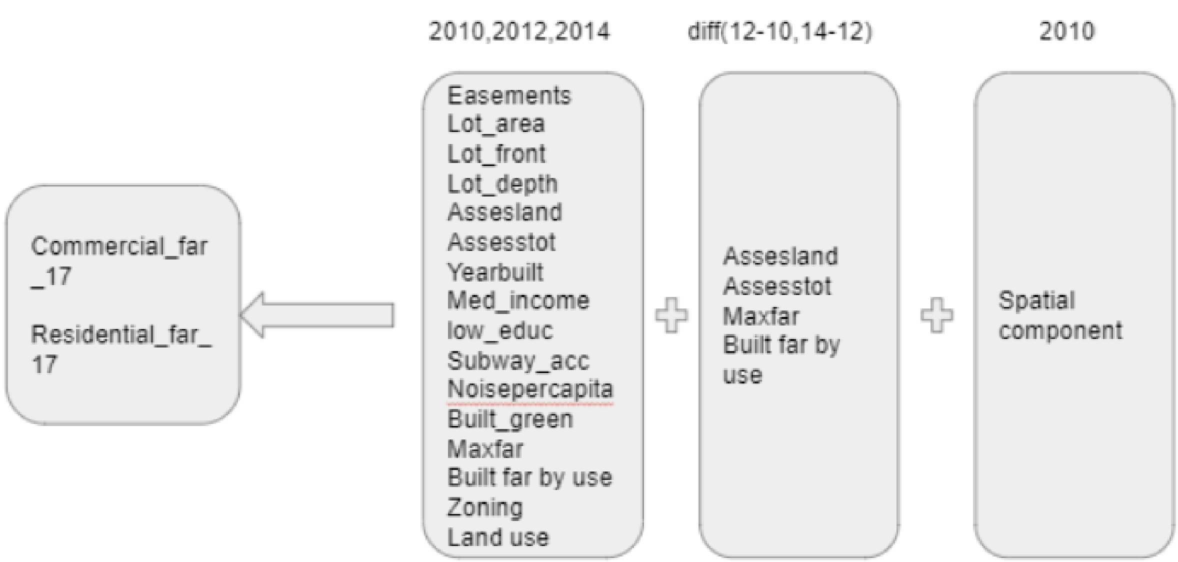
Land Use Categories (Source: PLUTO)

Built FAR Model

We built a dataset composed of three components (*Figure 4*). To understand whether the commercial and residential built FAR had spatial patterns, we used the global and local Moran's I spatial autocorrelation metric. For the global metric a high positive autocorrelation (0.92) showed that the spatial autocorrelation was an important pattern to consider for both variables. *Figure 5* shows the results of the local test. Each lot is classified in one of four possible categories (High-High(HH), High-Low(HL), Low-High(LH), Low-Low(LL)) if the spatial trend is statistically significant; if not, the lot is classified as non-significant (ns). The local positive autocorrelation was significant mainly in Manhattan and western Brooklyn (the area closest to Manhattan), showing the need for independent models across boroughs. We ran the same test for the five boroughs independently finding a high spatial autocorrelation for all of them, with a coefficient around 0.85. This test shows the importance of including the spatial trend in the model, accomplished by including variables that consider the change across time of the neighbors of each lot. Those neighbors were found in the autocorrelation calculation, achieved using the inverse distance method.

The best results were obtained with a tuned random forest using the PCA components that were able to explain 80% of the total variance of the model. However, we used a non-PCA model to

Figure 4

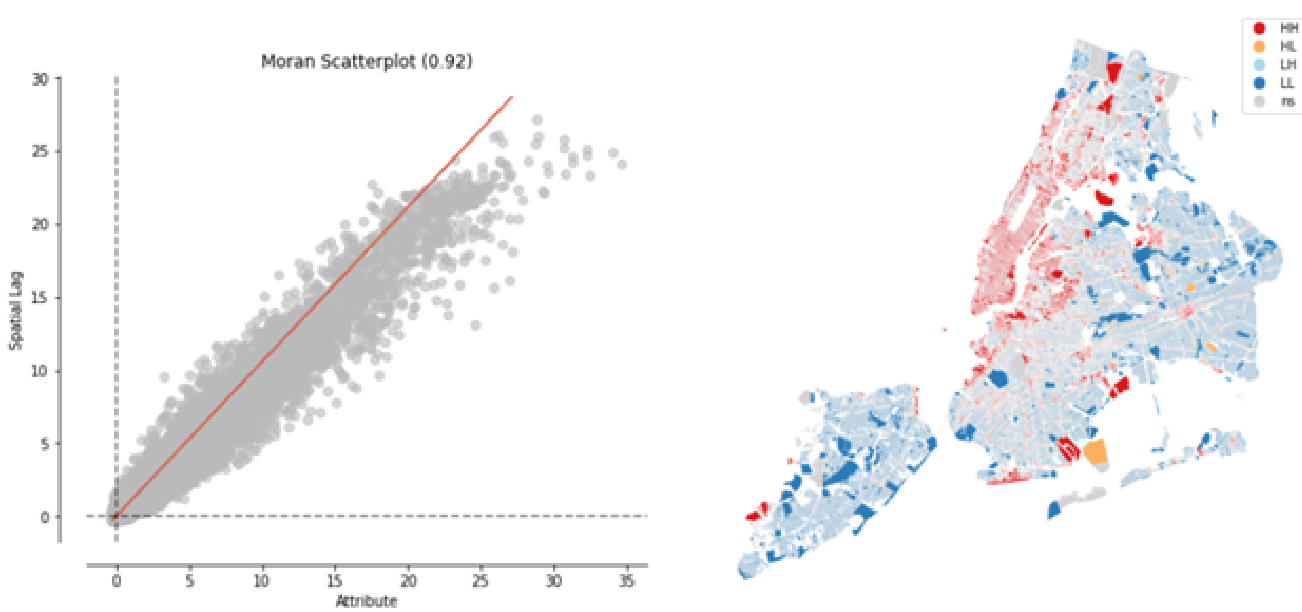


The dataset that we built to estimate the different models is composed of three components. The first uses the data for the selected variables in each one of the used years (2010,2012,2014); the second captures the temporal trend calculating the differences across years, and the last takes into account the spatial pattern.

capture the feature importance across the variables for each borough (*Appendix 6*). For the residential model, the built FAR in the baseline year is very important because most of the lots do not change from the baseline-built area. Land price and total price variables are important spatially for Brooklyn, Manhattan and Queens. Subway access seems to be very important for the Bronx and Brooklyn. For Manhattan it does not appear as a key factor, maybe because within Manhattan there isn't a high variance across subway access relative to other boroughs.

Results show that spatial patterns are very important to understand the underlying trends of neighborhoods leading to an increase in the residential built FAR. For all five boroughs, the variables accounting for the change in neighbors' values become systemically important for each individual model, demonstrating the impact of including temporal and spatial patterns in the model specification. We found that socio-demographic variables such as income and percentage of low education households are relevant for most of the boroughs, showing the social responsibility of city rezoning. Vulnerable communities (poor or low educated) under certain conditions (e.g. good subway access, strong prices) might be subject to an upzone of their neighborhood, starting a process of gentrification.

Figure 5



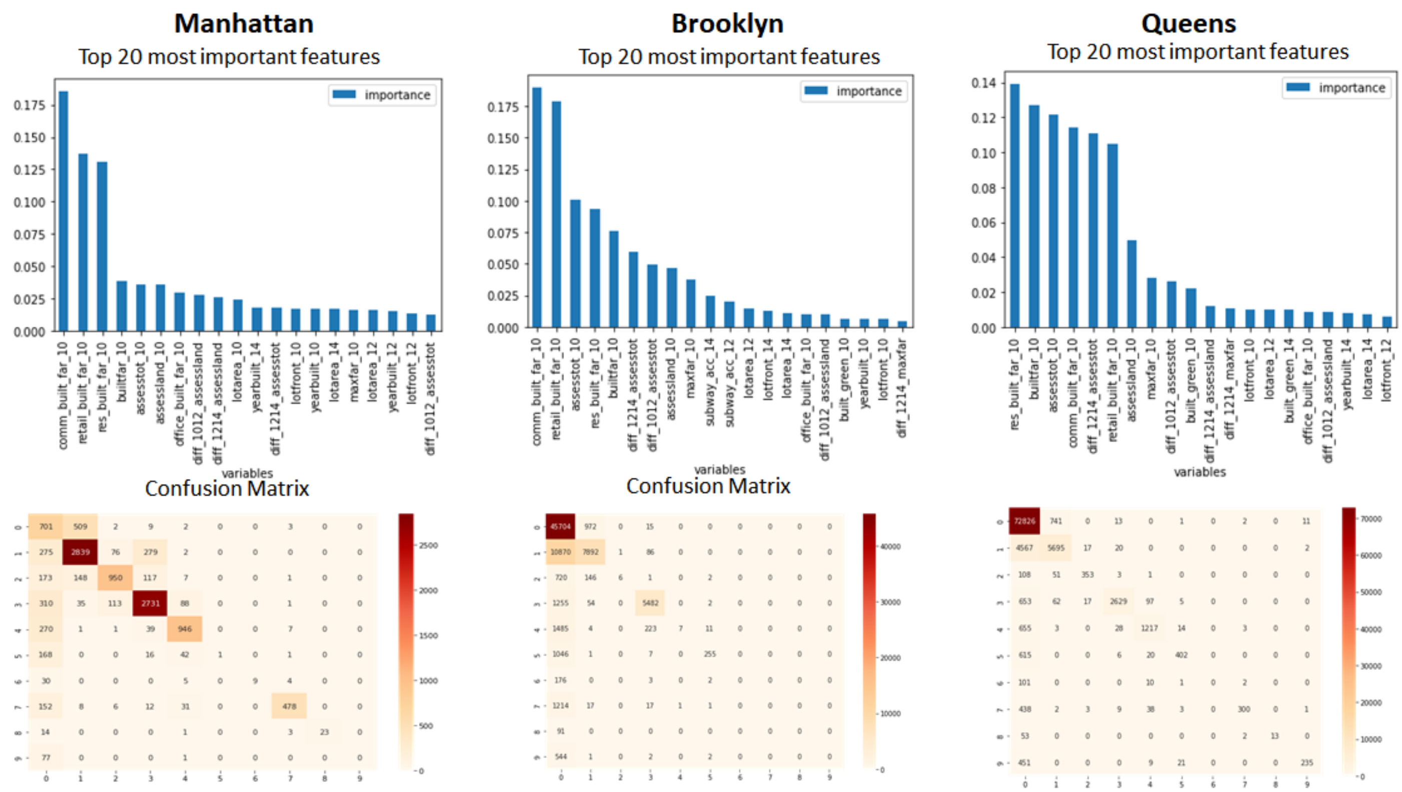
Spatial Autocorrelation

Our training sample accuracy is high, having an average accuracy of 0.96 across the five boroughs. Our test accuracy is slightly lower, but still shows great performance with an average score of 0.92. We have great results; however, this is primarily due to the stationary characteristics of built FAR across years. For most of the lots, the built area did not change between 2010 and 2017, so having a model that predicts the same value would give us a score around 0.81. For that reason we also calculated the accuracy including only the lots that were upzoned in the observed period. Results show that our estimated models have an average score of 0.71, with a maximum of 0.85 in Manhattan and the lowest prediction power in Queens.

Land Use Model - Random Forest Classification

With the same variables from the previous model except land use and zoning dummy attributes, we conducted random forest classification to predict 2017 land use and find important variables. We

Figure 6



Max_depth: 10
Max_leaf_nodes: 452
N_estimators: 36
Out of Sample Accuracy: 0.7334

Max_depth: 5
Max_leaf_nodes: 477
N_estimators: 11
Out of Sample Accuracy: 0.749

Max_depth: 7
Max_leaf_nodes: default
N_estimators: 11
Out of Sample Accuracy: 0.897

Feature Outcomes

found the best parameter value by tuning two parameters for each of the three boroughs, calculated the out-of-sample accuracy and plotted the confusion matrix (*Figure 6)*. From the confusion matrix it can be seen that the largest tax lot category, One & Two Family Buildings, has the lowest predictive performance. In the three boroughs, the variables that ranked high in common were the 2010 built FAR, built year, area and front of tax lot, assessment of land, and the change from 2012 to 2014. The top 20 most important features of the Brooklyn model include subway accessibility and built-green area in addition to Map PLUTO data. The results show that future land use may vary and rezoning may occur depending on the size of the tax lot or the width of the front and the extent to which the valuation amount and each built FAR changes.

Results by Variable

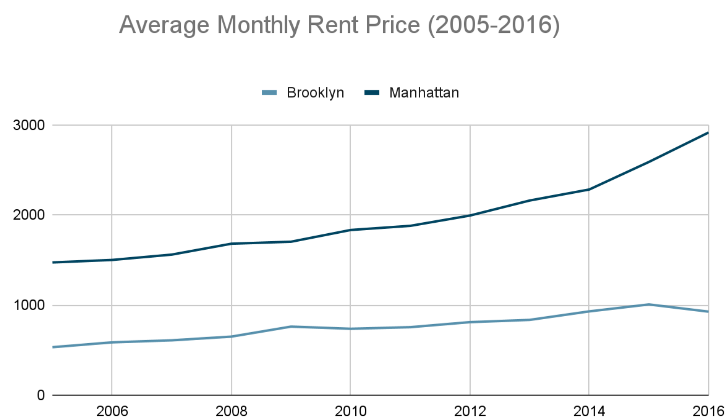
Detailed results for demographics, subway access, built green area, noise, street quality, and crime and their relative correlation in predicting lot-specific land use are included in *Appendix 7*.

Conclusions

Rezonings are implemented to better accommodate communities. However, rezoning outcomes often deviate from their intended goals, which can be destructive for vulnerable populations. The principal components of this analysis support this assertion. We found a positive correlation between built FAR and several factors important to developers. Demographically, we identified current rezonings in which high-income residents are mounting strong opposition. Greater access to transit correlates with more built FAR, implying that communities with good subway access are more likely to benefit from rezoning. The inverse correlation between development and built green space indicates that high density neighborhoods may see greater development from a rezoning. We conclude that rezoning tends to favor development. However, while rezoning is implemented for the good of the community, the social impact may be hampered by stakeholders who have disparate objectives. Planners should not only consider a worst case scenario assuming changes in external factors, but also plan for mitigation should the desired outcomes fail to materialize.

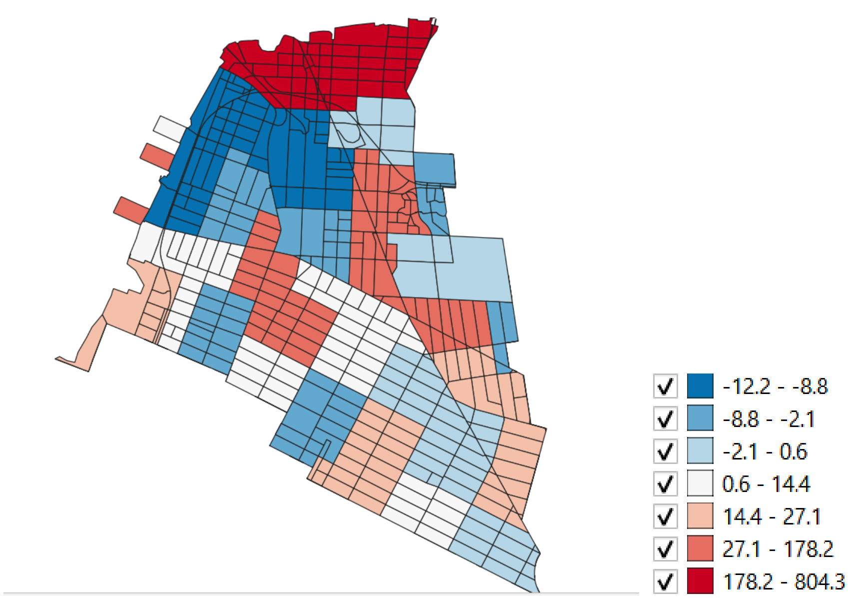
Our results met the expectations of our initial hypotheses. Using Streeteasy data, we confirmed that housing prices at the time of the rezoning were lower in Brooklyn than in Manhattan, which increased residential demand in the rezoned area (*Figure 7*). However, due to the difficulty of obtaining data back to 2004 and earlier, causality (whether the rezoning caused or resulted from the trend) could not be confirmed. Our hypothesis that many of the amenities that attract commercial usage likely also attracted residential customers to the area is supported by *Figure 8*. Moreover, the commercial

Figure 7



Housing Prices Were lower in Brooklyn Than Manhattan (Source: Streeteasy)

Figure 8

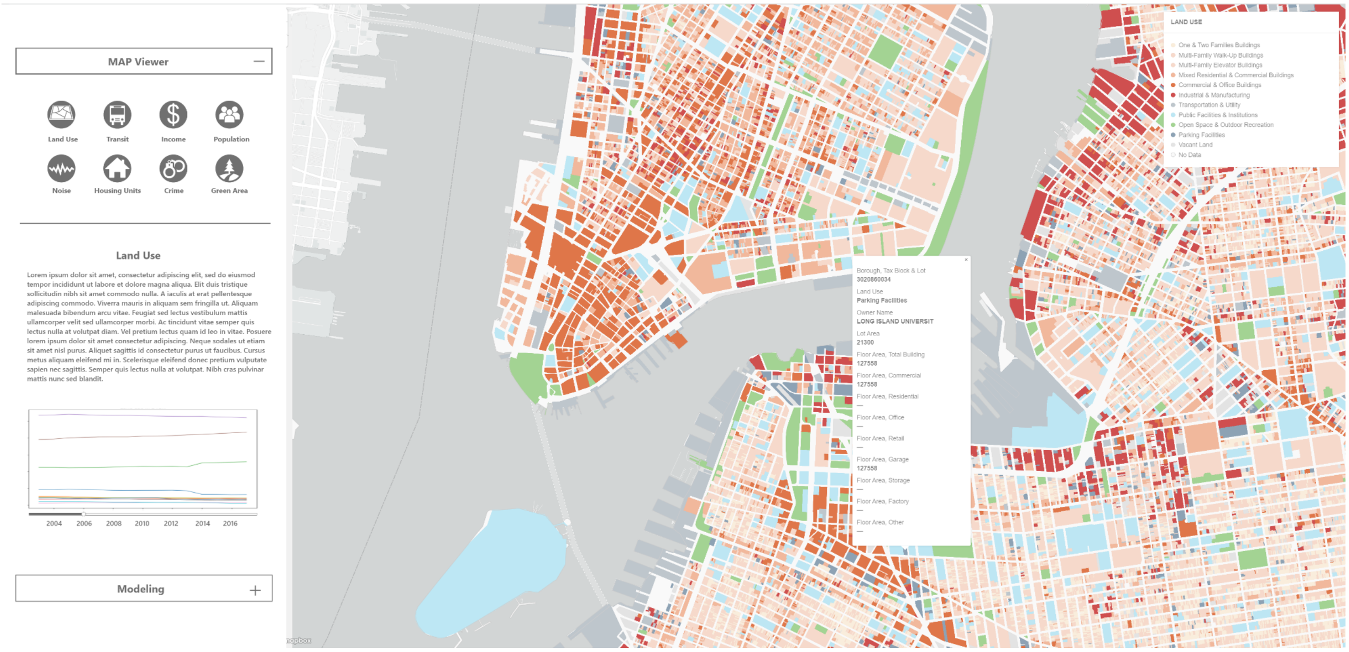


Housing Unit Increase (Source: US Census) and residential real estate developers we interviewed prioritized similar amenities for both land uses. The hypothesis that corporations chose to leave NYC altogether during this period is borne out in the October 8, 2013 *Wall Street Journal*, which describes millions of commercial square feet on the market as large corporations moved workers to lower cost cities.[18]

In summary, each borough has its own land use dynamic. Spatial distribution is important: residents are affected by what is happening in the neighborhood around them and rezoning must consider the entire community.

Website

Link to [website]



Map Viewer For Visualizing Input Variables Used to Predict Land Use Included in Website

Appendices

Appendix 1. Environmental Impact Statement: 19 Impact Areas

1. Land use, zoning, and public policy
2. Socioeconomic conditions
3. Community facilities
4. Open space and recreational facilities
5. Shadows
6. Historic resources
7. Urban design and neighborhood resources
8. Neighborhood character
9. Hazardous materials
10. Infrastructure
11. Solid waste and sanitation services
12. Energy
13. Traffic and parking
14. Transit and pedestrians
15. Air quality
16. Noise
17. Construction impacts
18. Public health
19. Mitigation

Appendix 2. Five Whys: Identifying the Roots of the Problem

The leading causes of the problem of deviations to rezoning goals (the "5 Whys") and some examples of why they occur are as follows:

1. **Failure to adequately develop mitigation plans, and failure to monitor results over the course of the build years**

Because a rezoning takes a prescriptive view of the intended outcome, it may not mitigate effects caused by an alternative scenario. When residential development replaced the intended commercial development in Long Island City and Downtown Brooklyn, for example, the plans did not address infrastructure issues in the new residential districts. MAS advocates for plans to have a reversed proposed land use alternative, should the planned development not materialize; they also favor using Generic EIS's for large-scale rezoning to address possible mitigation with greater flexibility.[7] MAS points to serious flaws in the CEQR process, which is supposed to mitigate adverse impacts. The study notes that better scenario planning and periodic monitoring could enhance future city rezoning.[7]

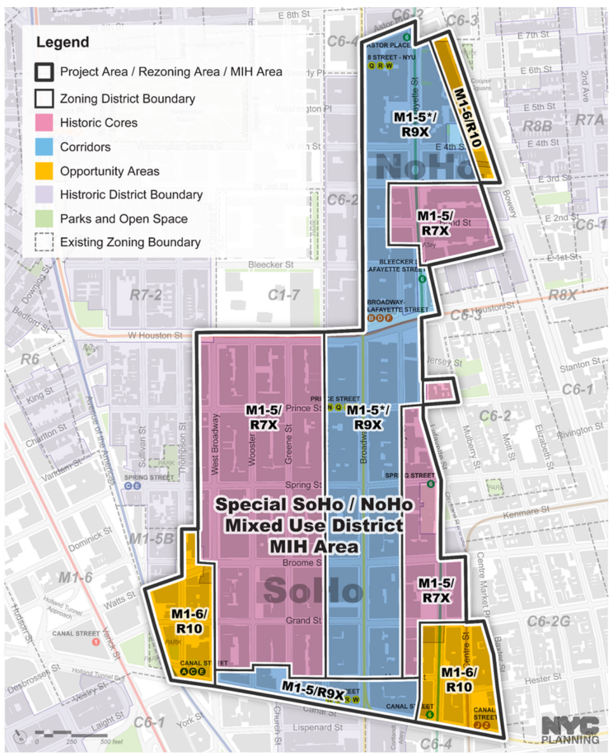
2. **Failure to recalculate incentives for developers and members of the commercial and residential community necessitated by changes in outside forces such as the economy, technology, or income tax structure**

Changes occurring during the build years may reduce incentives to achieve the intended goals. For instance, during the Downtown Brooklyn build years, 2004-2013, the 2008 financial crisis caused a tightening of the mortgage market, making it more difficult for builders to borrow. In addition, as technology became more efficient during this decade, businesses such as banks opted to move their back offices out of NYC to less costly areas of the country.[18]

3. **Narrow focus by planners: policies of the rezoning may conflict with desires of the communities surrounding the rezoned area**

Community members must buy into a rezoning to make it successful. Mayor de Blasio has proposed a series of citywide zoning alterations to improve affordable housing. While admirable in its intent, a one-size fits all approach will not work across neighborhoods. Factors such as a community's population density, resident income levels, and demographics of the surrounding neighborhoods will drive the desired amount of affordable housing. Some communities want to be upzoned, others downzoned. And many residents do not want change at all, making engagement with them is critical to understand what they do want. For instance, the proposed Soho-Noho rezoning (*Figure 9*) was initially about retail encroaching upon an area originally intended for artists and industry. With de Blasio's emphasis on affordable housing, the proposal has grown to include potentially 900 affordable housing units, depending on development, and is a contentious issue in the community.[19, 20]

Figure 9



Soho/Noho Subdistricts Are in Contention For Type of Land Use (Source: NYC Dept. of City Planning)[20]

In the Vancouver example, the city tried to enhance housing affordability by rezoning almost all houses city-wide to duplexes.[11] The issue is one of tradeoff between highest and best use vs. what is optimal for the existing neighborhoods.

4. **Failure to account for zoning loopholes (such as lot mergers allowing the transfer of air rights), which are not subject to CEQR review**

All possibilities for development should be considered, even when not subject to CEQR review. For instance, contiguous buildings can pool air rights, resulting in allowable increased building height, benefiting the granting site and deviating from the planned outcome. However, other rezonings such as the Theater District and the High Line have monetized the loophole by mandating that a portion of the proceeds from air rights transfers go into a public trust for improvements to the area[21].

5. Inadequate theoretical and/or social value associated with the project

If neighborhoods are not supportive of the proposed theoretical and social value of the rezoning, the outcomes are more likely to fail. While rezoning is predicated on theoretical value, social impact can boost or derail a project. The bitter Soho/Noho debate is pitting those committed to historic preservation (and some NIMBYists) with those advocating for more affordable housing which would result in this affluent neighborhood's opening to a wider cross-section of New Yorkers.

Appendix 3. The ULURP Process and Target Audience for the Project

Applications for changes to land use in the city are publicly reviewed through the Uniform Land Use Review Procedure (ULURP).[22] The procedure includes discussions with community stakeholders, consultations with borough administrators, with final decisions made by the Mayor and City Council. An application must first be certified as complete by the NYC DCP. A Draft EIS is required for certification. Certified applications are sent to the relevant Community Board(s), Borough President, and City Council. The Community Board and the Borough President review the proposal and deliver an advisory decision to the City Planning Commission (CPC). The CPC then has 60 days to hold a public hearing and approve or disapprove the application; approved applications move on to the City Council for approval. Finally, while Mayoral approval is not required, the Mayor may veto the City Council approval. The Council, with a 2/3 supermajority, may override the Mayor's veto.

Given the ULURP process, the target audience for this analysis includes not only rezoning planners, but also those tasked with reviewing and approving zoning projects, including Community Board members, the Borough President, City Council members and the Mayor's office. According to Thomas Devaney, Senior Director of Land Use and Planning at MAS, under the current process the city often fails to explore all of the alternatives, and also does not adequately monitor the rezoning after approval.[23] Irene Janner, Brooklyn CB2 member since 1988, was actively involved in the Downtown Brooklyn rezoning and subsequent residential building in the area. She noted that "developers rule", and that there is enough flexibility in the FAR regulations that developers usually get their way in building for a particular land use.[24]

Appendix 4. PLUTO Variables Collected by Year

Variables collected in PLUTO have changed over time. Each row shows the year in which years data was collected for a particular variable. (Source: PLUTO)

Appendix 5. Project Risks and Mitigation Strategies

The main risk to the project involved the availability of data required to assess neighborhood changes pre- and post-zoning. For Downtown Brooklyn, data was needed dating back to 2004. PLUTO data collected in 2004 is different from what is collected today, so time series cannot be directly compared. We mitigated this by cross-referencing the columns to select the data required; and in some cases we used different years, but maintained the 10-year trend. Another issue was that the available data was not always specific enough for what we require. For instance, FAR regulations are readily available by building. However, data regarding setbacks and increased height, which may be allowed in return for space allotted for public amenities such as affordable housing or schools, are not tracked.

Another data risk involved where adequate tools did not exist for the desired visualizations. For instance, air rights may be transferred to neighboring buildings, resulting in a merged lot with greater height allowance. Data on unused air rights is readily available by building; however, the data can only be viewed for one building at a time and is not aggregated in a dataset. Moreover, merged lots are not tracked. According to Amanda Doyle, Assistant Director of Enterprise Data Management at NYC DCP, no merged lot data exists; a significant increase in the lot area could be used to estimate lot mergers, but there is no way to find out whether additional development rights were obtained as part of the merger.[25] A mitigation strategy to understand where zoning lot mergers occurred might be to look at pre- and post-zoning air right availability, and create a visualization of clusters of buildings whose air rights have been exhausted. Finally, data obtained from different databases, such as PLUTO and US Census data, could not be merged. Mitigation included manually creating an overlay of the two datasets.

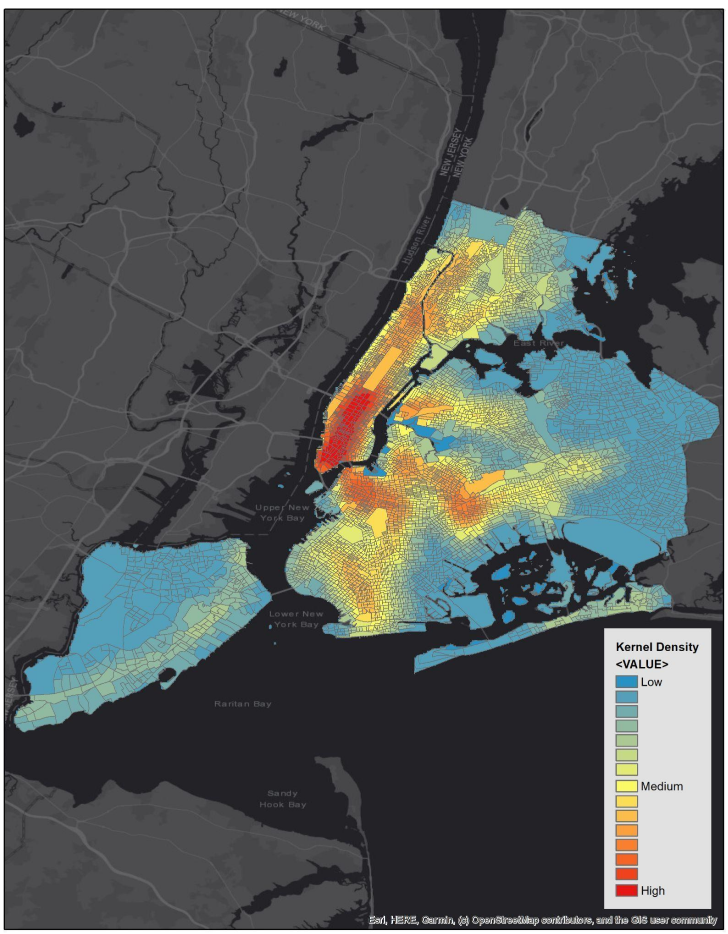
Appendix 6. Top 10 Most Important Features by Borough

Bronx	Brooklyn	Manhattan	Queens	Staten Island
res_built_far_10	res_built_far_10	res_built_far_10	res_built_far_10	res_built_far_10
diff_1012_assessland	maxfar_10	diff_1214_res_built_far	assesstot_10	diff_1012_res_builtfar
diff_1012_builtfar	subways_access	diff_1012_assesstot	diff_1214_res_built_far	lot_area12
diff_1214_assesstot	diff_1214_res_built_far	retail_built_far_10	garage_built_far	lot_area14
subway_access	assesstot_10	comm_built_far_10	yearbuilt_10	year_built_10
retail_built_far_10	diff_1214_assessland	assessland_10	maxfat_10	lot_front_14
comm_built_far_10	diff_1012_assessland	diff_1214_assesstot	lotfront_10	year_built_14
income_14	lot_area_10	diff_1214_assesstot	diff_1214_assesstot	low_educ_14
assesstot_10	assessland_10	lotfront_10	lot_area_14	office_built_far_10
diff_1214_assessland	low_educ_14	maxfar_10	low_educ_14	diff_1214_res_builtfar

Appendix 7. Detailed Results by Variable

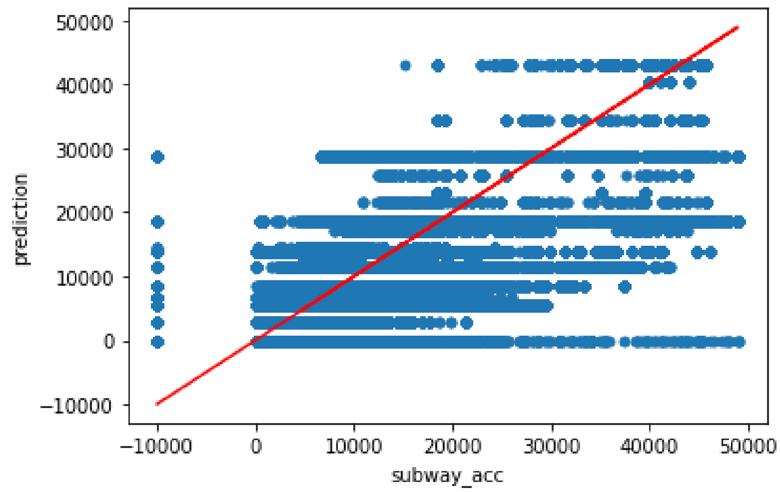
Subway Access: A kernel density was plotted for subway access, based on the location of subway stations across the city (*Figure 10*). In deciding where to build, all three developers listed subway access as their top priority. This is reflected in Downtown Brooklyn, a neighborhood that aside from Manhattan, has one of the highest subway densities in the city. *Figures 11 and 12* show the results of linear regression subway and facility FAR which has high (0.44) r-square score and positive strong correlation with other FARs (facility, residential, commercial).

Figure 10



Kernel Density for Subway Access (Source: MTA)

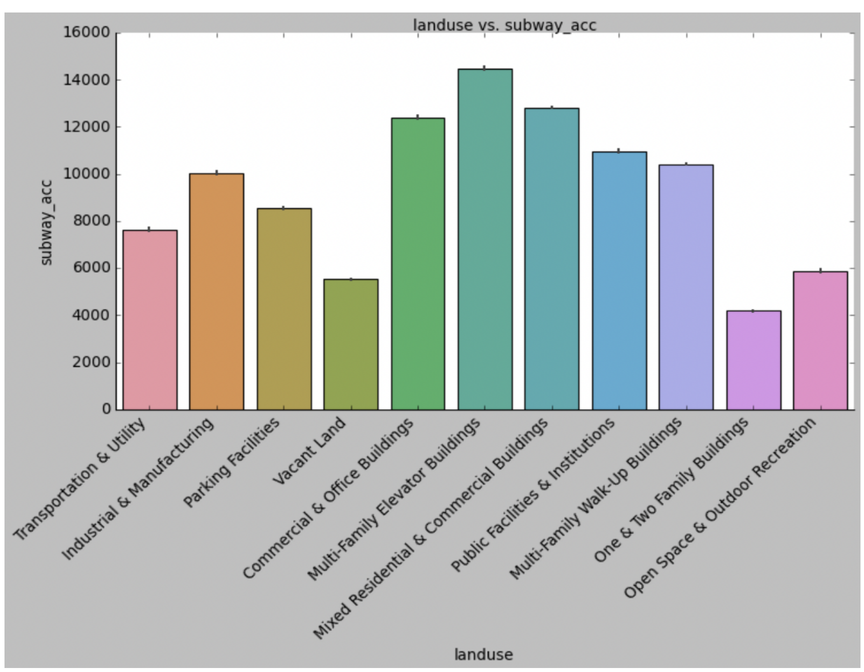
Figure 11



	Slope	Intercept	R2
facilfar	2880.823102	-107.676979	0.439551
residfar	3302.674700	1823.204424	0.380772
commfar	2913.974388	5721.744476	0.188904

Linear regression Subway Access vs. Facility FAR (Source: MTA)

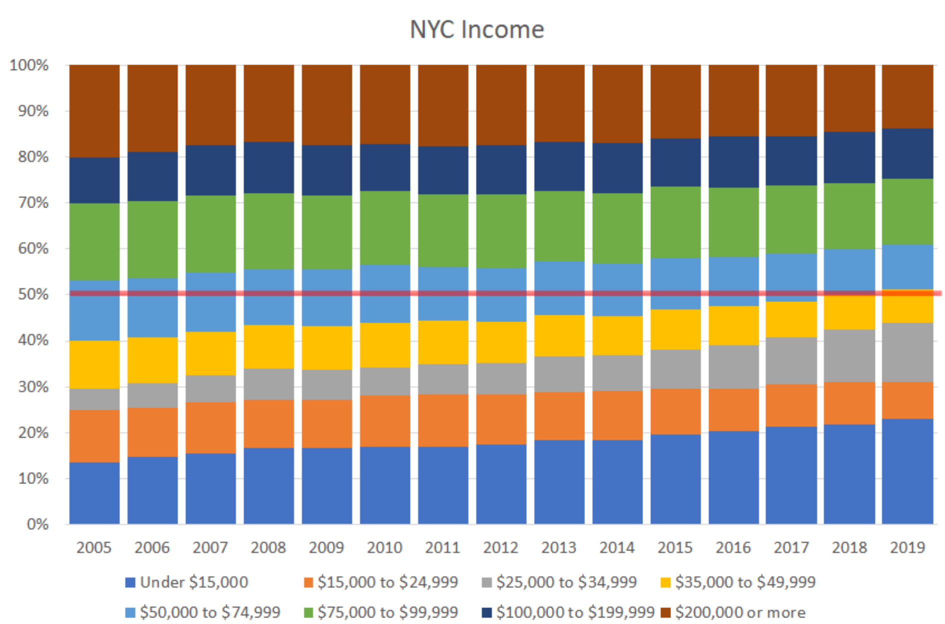
Figure 12

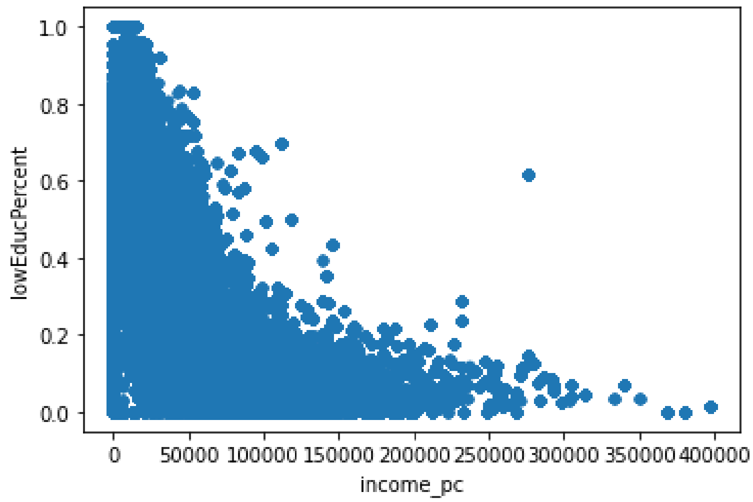


Land Use vs. Subway Access (Source: PLUTO and MTA)

Demographics: Using US Census data, the change in resident income, population, and education were mapped for Downtown Brooklyn vs. NYC overall. As shown in *Figure 13*, income increased by more in Downtown Brooklyn than in NYC over the period. We plotted income vs. education, conducted a linear regression, and found higher income to be negatively correlated (-0.55) with lower education with 0.302 R-square. We were unable to obtain income data from before the rezoning, hence cannot prove that the rezoning caused the change in demographics, but can confirm it is correlated. As evidenced by the current Soho/Noho rezoning, residents in areas of higher income and education have more resources to fight development[18], potentially leading to rezoning inequities for vulnerable populations. We deduced that in Downtown Brooklyn, the rezoning's outcome of overcrowded public schools has likely further exacerbated education inequity.

Figure 13



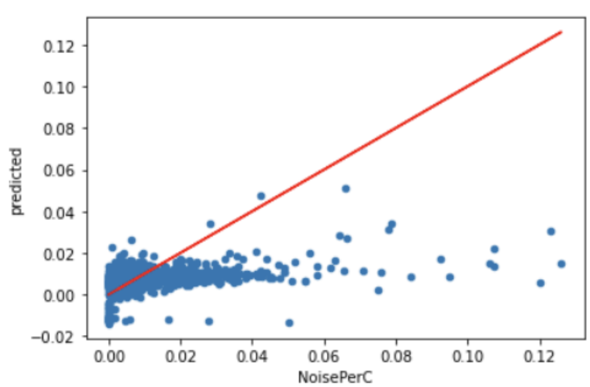


Linear Regression Income vs. Education (Source: US Census)

Noise: Noise complaints per capita were plotted against population, showing positive correlation, indicating that as activity in an area increases due to increased density, so does noise (*Figures 14, 15*). While per capita noise complaints increased for both Downtown Brooklyn and NYC over the period from 2010-2018, the rise in Downtown Brooklyn was greater.

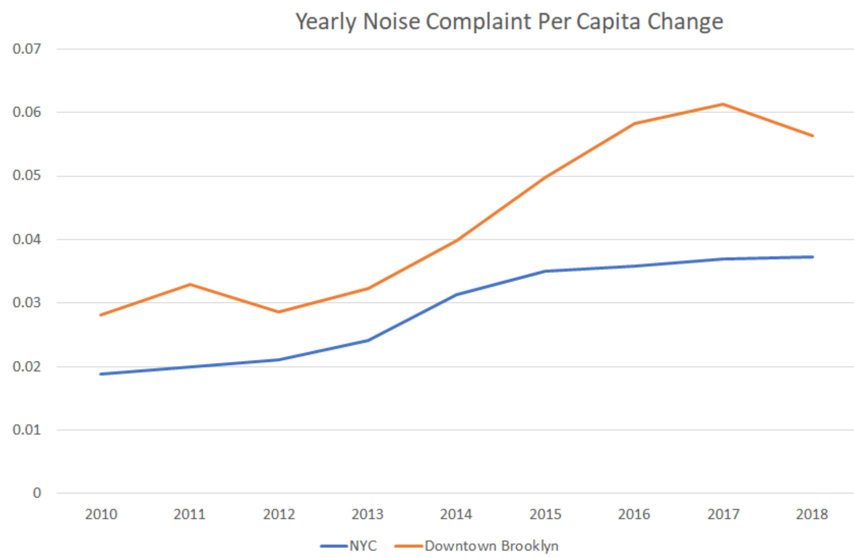
Figure 14

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.0024	0.001	-2.228	0.026	-0.005	-0.000
HousingPerC	0.2811	0.017	16.614	0.000	0.248	0.314
Population	9.967e-07	1.17e-07	8.491	0.000	7.67e-07	1.23e-06
BuiltMean	-0.0148	0.002	-7.800	0.000	-0.018	-0.011



Linear Regression Noise Complaint Per Capita vs. Housing Units, Population and Built Mean (Source: US Census)

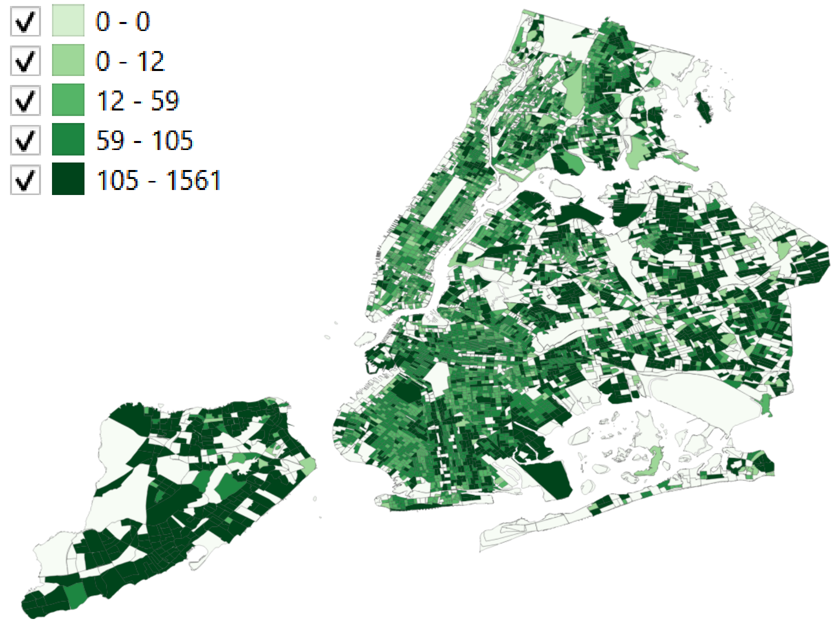
Figure 15



NYC vs. Downtown Brooklyn Yearly Noise Complaints Per Capita Change (Source: 311 data)

Street Quality: Both residential developers interviewed specified street quality as an important factor in deciding whether to develop a parcel for residential use. (In comparison, the commercial developer noted that co-location of companies within a particular industry, usually for the reason of attracting top talent, was an important factor for commercial space). We mapped 2015 NYC Open Data street tree counts *(Figure 16*); however, the collected data is aggregated at the census group level only for 2015, which is not specific enough to understand the trend.

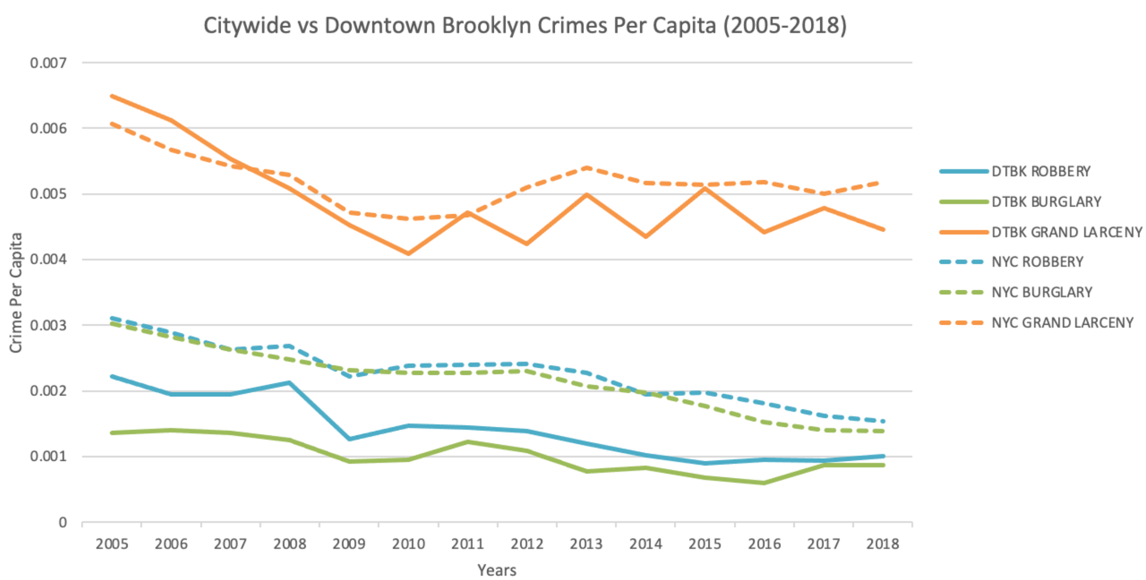
Figure 16



Street Tree Counts by Census Group Level (Source: 2015 NYC Street Tree Census)

Crime: Per capita crime in both Downtown Brooklyn and in NYC overall declined over the build years. Three types of crime were plotted from 2005-2018; the decline in Brooklyn crime was consistent with the decline city wide (*Figure 17*).

Figure 17

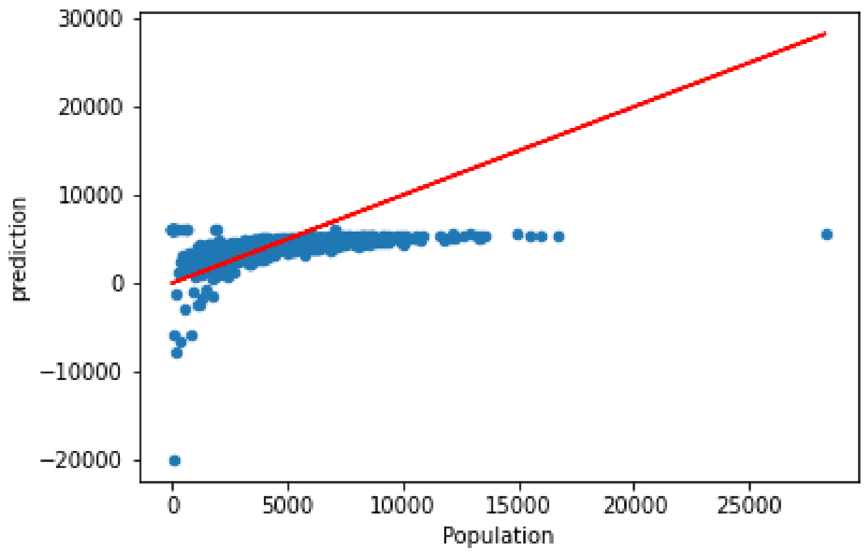


Historical Crime Data - Citywide vs. Downtown Brooklyn (Source: NYC Police Department)

Housing Units: Housing units per capita were plotted against population, showing negative correlation by conducting linear regression with 0.279 r-square score (*Figure 18*).

Figure 18

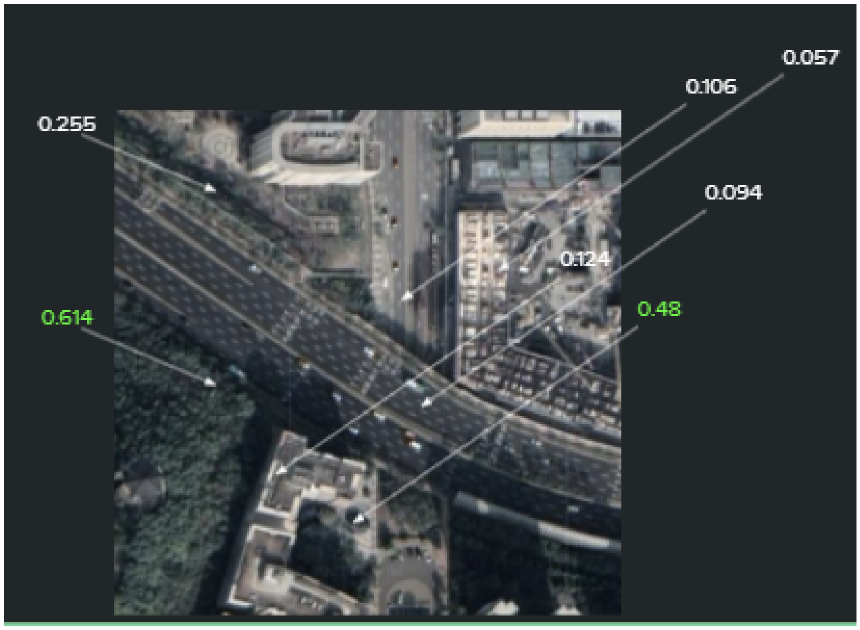
	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	6065.7172	83.410	72.721	0.000	5902.142	6229.292
HousingPerC	-6.509e+04	2271.260	-28.660	0.000	-6.95e+04	-6.06e+04



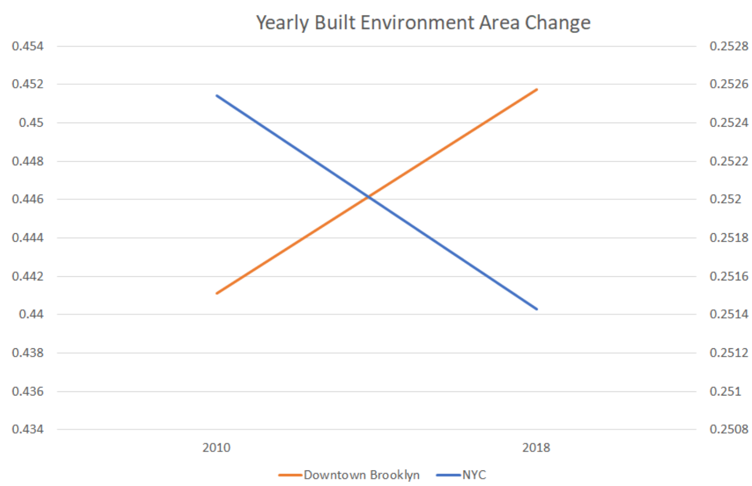
Linear regression housing units per capita vs population (Source: US census)

Built-Green Area: City surface characterization is conducted by remote sensing which detects surface color and converts it to a value between 0 and 1 . *Figure 19* indicates that if values are large, such as 0.614 and 0.48, it can be interpreted that a dense green area has been formed. By comparing Downtown Brooklyn and NYC (2010 and 2018), there are relatively more green areas in Downtown Brooklyn.

Figure 19



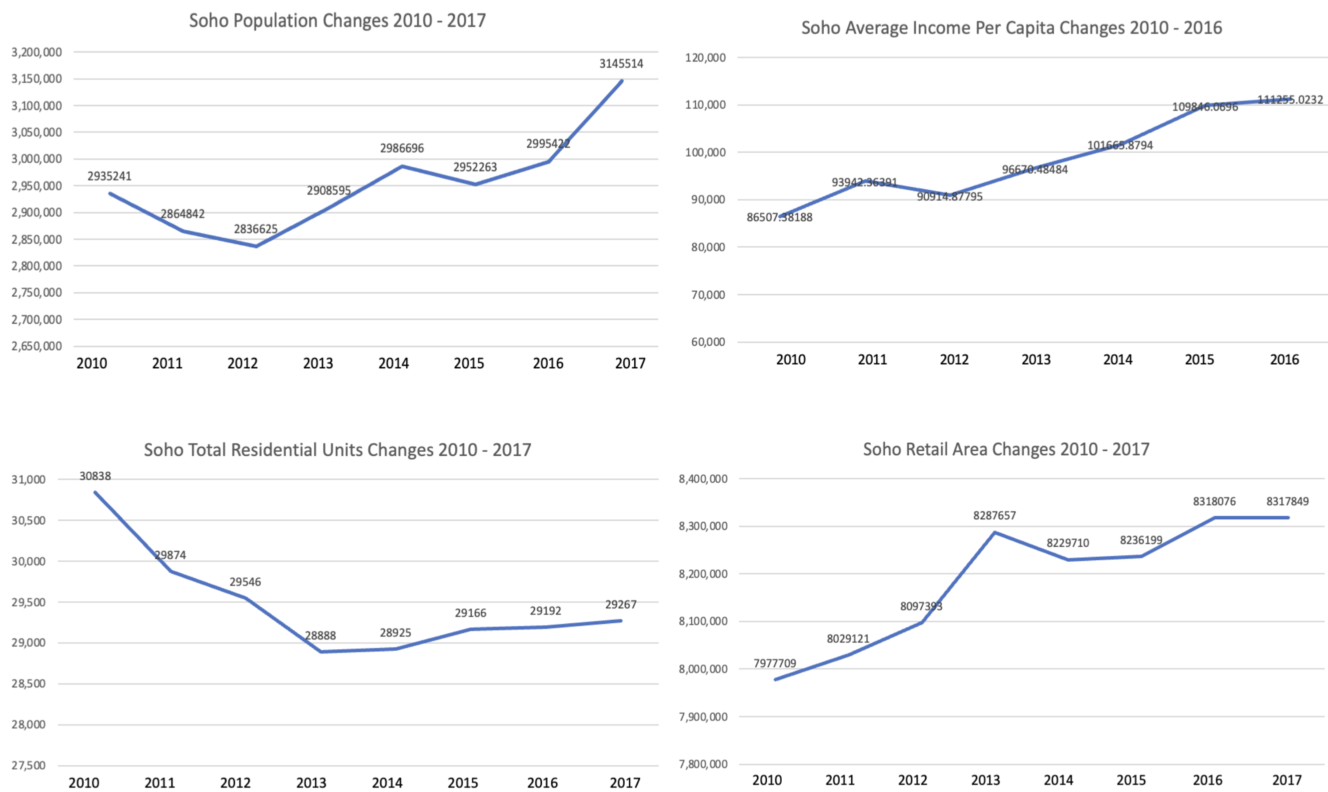
Supervised classification (Source: Google Earth Engine)



Downtown Brooklyn vs NYC Built-green area change from 2010 to 2018 (Source: Google Earth Engine)

Case Study - Soho and Gowanus pre-rezoning: Between 2010 and 2017, the Soho area population grew 7%, from 2.9 million to 3.1 million. More people with higher average income moved into Soho during the period, while the number of total residential units decreased from 30,838 to 29,267 and total retail area increased by nearly 5% (*Figure 20*), leading to an imbalance between housing demand and supply. More housing units were required while the mixed-use commercial district of Soho/Noho still needed to be supported and enhanced.

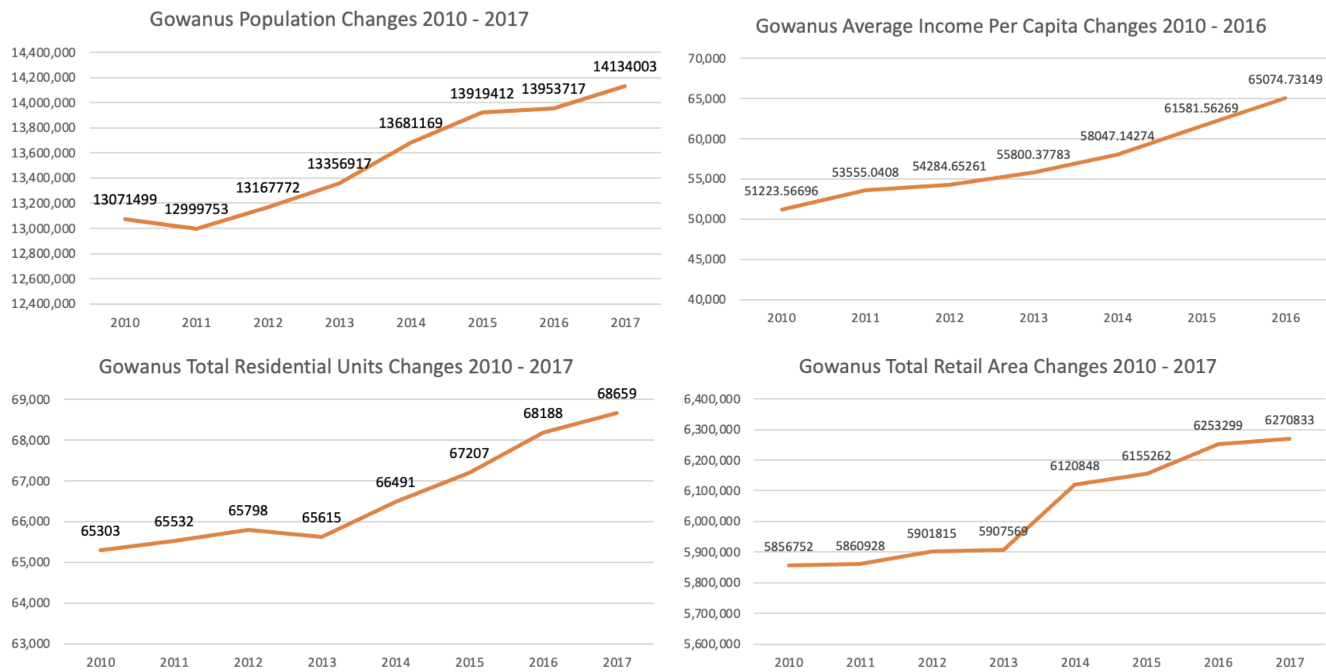
Figure 20



Soho Pre-rezoning Changes from 2010 to 2017 (Source: US Census and PLUTO)

In Gowanus, between 2010 and 2017 the population saw steady growth and residential units increased correspondingly (*Figure 21*). Although both rezonings have been contentious among stakeholders, the Gowanus pre-rezoning situation is less fraught than Soho in terms of ability to build more affordable housing for growing demand.

Figure 21



Gowanus Pre-rezoning Changes from 2010 to 2017 (Source: US Census and PLUTO)

Notes

Interviews

- Thomas Devaney, Senior Director of Land Use & Planning, Municipal Art Society of New York, July 22, 2021
- Amanda Doyle, Assistant Director of Data Enterprise Management, NYC Department of City Planning, August 3, 2021
- Irene Janner, Vice Chair, Land Use Committee, Brooklyn Community Board 2, August 18, 2021
- Barry Hersh, Clinical Associate Professor, NYU Schack Institute of Real Estate, and Real Estate Developer, September 28, 2021
- Ethan Bregman, Brooklyn Real Estate Developer, October 4, 2021
- Ryan LeVasseur, Managing Director - Direct Real Estate, Rice Management Company, October 8, 2021

Data Sources

- PLUTO: https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-pluto-mappluto.page
- Subway station location: http://web.mta.info/developers/developer-data-terms.html#data
- Street Tree location 2015: https://data.cityofnewyork.us/Environment/2015-Street-Tree-Census-Tree-Data/pi5s-9p35
- Noise Complaint 311: https://portal.311.nyc.gov/article/?kanumber=KA-01017
- Income: https://www.census.gov/programs-surveys/acs
- Education: https://www.census.gov/programs-surveys/acs
- Population: https://www.census.gov/programs-surveys/acs
- Green-built area: https://earthengine.google.com/
- Crime: https://www1.nyc.gov/site/nypd/stats/crime-statistics/historical.page
- Remote sensing NAIP website: https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/

References

1. NYC Department of City Planning, Initiatives by Borough.
   https://www1.nyc.gov/site/planning/plans/borough.page

2. Florida, Richard, "Dan Doctoroff on Rebuilding New York After 9/11," Bloomberg City Lab. Sept. 19, 2017.
   https://www.bloomberg.com/news/articles/2017-09-19/dan-doctoroff-on-the-dramatic-growth-of-nyc-under-bloomberg

3. NYC Mayor's Office, "NYC Rezoning Commitments Tracker."
   https://www1.nyc.gov/site/operations/performance/neighborhood-rezoning-commitments-tracker.page

4. NYC Office of Environmental Coordination, "CEQR Basics - What Triggers a CEQR?",
   https://www1.nyc.gov/site/oec/environmental-quality-review/ceqr-basics.page

5. Office of the Deputy Mayor for Economic Development and Rebuilding, Downtown Brooklyn Development, *Final Environmental Impact Statement,* CEQR #03DME016K, April 2004. pp.1-852.

6. Rothwell, Jonathan and Massey, Douglas, "Density Zoning and Class Segregation in US Metropolitan Areas," US National Library of Medicine, National Institutes of Health, April 22, 2013
   https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3632084/

7. Municipal Art Society of NY, "Taking a Harder Look at CEQR."
   https://www.mas.org/news/a-tale-of-two-rezonings-ceqr/

8. Churches United for Fair Housing, "Zoning and Racialized Displacement in NYC," Dec. 2019.
   https://static1.squarespace.com/static/5dc0429de5717c7ff1caead0/t/5de6c0e683bec649d37ab0cc/1575403753814/Zoning+and+Racialized+Displacement+in+NYC.pdf

9. Office of Eric Adams, Brooklyn Borough President, "A Decade Later in Downtown Brooklyn: A Review of the 2004 Rezoning", February 2016.
   https://brooklyn-usa.org/wp-content/uploads/2016/02/Downtown-Brooklyn-2004-Rezoning_Final.pd

10. Flanagan, Neil, "This Map Illustrates DC's New Zoning Rules", *Greater Greater Washington*, Oct. 25, 2016. https://ggwash.org/view/43304/this-map-illustrates-dcs-new-zoning-rules

11. Gold, Kerry, Vancouver coping with the unintended consequences of the previous council's rezoning decision," Vancouver Globe and Mail, November 30, 2018.
    https://www.theglobeandmail.com/real-estate/vancouver/article-vancouver-coping-with-the-unintended-consequences-of-the-previous/

12. NYC Department of City Planning, "Downtown Brooklyn Rezoning Proposal", June 28, 2004.
    https://www1.nyc.gov/assets/planning/download/pdf/plans/downtown-brooklyn2/dwnbklyn2.pdf

13. PLUTO and MapPLUTO, NYC Department of City Planning
    https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-pluto-mappluto.page

14. C.J. Gabbe, Local regulatory responses during a regional housing shortage: An analysis of rezonings in Silicon Valley, Land Use Policy, Volume 80, 2019, Pages 79-87, ISSN 0264-8377. https://doi.org/10.1016/j.landusepol.2018.09.035

15. Yang, Q., Li, X., & Shi, X., Cellular automata for simulating land-use changes based on support vector machines, 2008. *Computers & Geosciences, 34*(6), 592–602. https://www.sciencedirect.com/science/article/pii/S0098300407002087

16. Gerberer, Ranaan, "Opponents of Gowanus Rezoning Plan Hire Heavy-Hitter Environmental Lawyer," *Brooklyn Daily Eagle*, October 13, 2021 https://brooklyneagle.com/articles/2021/10/13/opponents-of-gowanus-rezoning-plan-hire-heavy-hitter-environmental-lawyer/

17. Hoffman, Meredith, "Advocates Demand Inclusionary Housing Provision at Broadway Triangle," *dnaInfo,* October 11, 2012. https://www.dnainfo.com/new-york/20121011/williamsburg/advocates-demand-inclusionary-housing-provision-at-broadway-triangle

18. Brown, Eliot, "New York Banks Cut and Run: JP Morgan and Others Leave Millions of Square Feet on the Market", *Wall Street Journal*, October 8, 2013. https://www.wsj.com/articles/SB10001424052702304441404579123690642256618

19. Scheurman, Matthew, "7 Things You Ought to Know About the Soho/Noho Rezoning," *Gothamist*, April 4, 2021. https://gothamist.com/news/7-things-you-ought-know-about-sohonoho-rezoning

20. Hogan, Gwynne, "Controversial Soho/Noho Rezoning Clears Latest Hurdle," *Gothamist,* October 21, 2021 https://champ.gothamist.com/champ/gothamist/news/controversial-sohonoho-rezoning-clears-latest-hurdle

21. Milrose Consultants, "You Ask, We Answer: Milrose Breaks Down the Fundamentals of Air Rights," September 26, 2018. https://www.milrose.com/insights/you-ask-we-answer-milrose-breaks-down-the-fundamentals-of-air-rights

22. "Uniform Land Use Review Procedure," NYC Department of City Planning. https://www1.nyc.gov/site/planning/applicants/applicant-portal/step5-ulurp-process.page

23. Capstone Team Interview with Thomas Devaney, Senior Director of Land Use & Planning, Municipal Art Society of New York, July 22, 2021.

24. Capstone Team Interview with Irene Janner, Vice Chair of Land Use Committee, Brooklyn Community Board 2, August 18, 2021.

25. Capstone Team Interview of Amanda Doyle, Assistant Director of Data Enterprise Management, NYC Department of City Planning, August 3, 2021.