Directing Development: Do One-Way Roads Inhibit the Effect of Downtown Investment? A Case Study of Hickory, North Carolina

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Abstract

In cities across the United States, residents and policymakers have passed measures to increase accessibility and walkability as a strategy for revitalizing disinvested downtowns. Alongside some of these measures, one-way roads have been reverted to two-way traffic due to their observed hindrance on walkability and pedestrian safety. In Hickory, North Carolina, long-range planners describe the land along the city's downtown one-ways as less viable for development due to the speed and load of the traffic that they carry. This study aims to measure whether these roads have, in fact, hindered development. To answer this question, I observe the impact of one-way roads on the efficacy of a downtown pedestrian infrastructure plan that the city passed in 2014, aimed at increasing investment and development in the city's downtown. I use a difference-in-differences approach to measure how the indirect effects of this investment package are felt on one-way road property values and vacant land rates relative to two-way road properties, within the central business district.

Keywords: one-way streets; downtown redevelopment; property value appreciation; vacant land reclamation

JEL Classification*:* R12; R58

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1 Introduction

Downtown Hickory, North Carolina is bordered by two one-way road pairs, one north of downtown and one south of downtown. The pairs act as through-roads through the city center, connecting commuter and commercial traffic from regional highway US 321 (west of downtown) to two of the city's main inner-city highways, NC 127 and Lenoir Rhyne Boulevard (east of downtown). Figure 1 shows the full extent of the one-way roads as they connect these arterial routes.

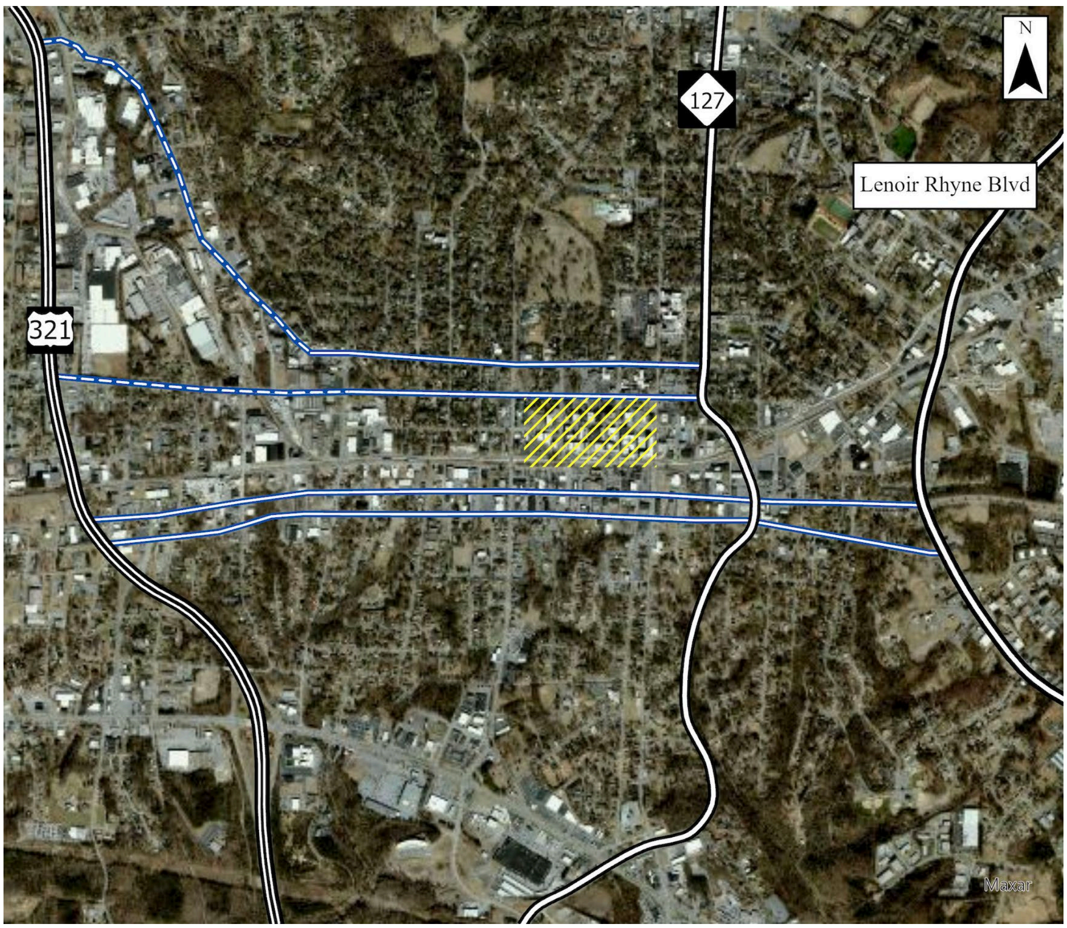

Figure 1: The one-way roads observed in the study area, as they connect to US 321 and two arterial routes, are in blue. The dashed white center line marks where they transition to two or three lane two-way roads. The hatched yellow area is Union Square.

Hickory's central business district is focused within one historic commercial block called Union Square. Commercial and industrial activity extends out from this block and becomes mixed with residential housing within a few blocks. Figure 2 highlights the one-way roads as they border Union Square and are contained within the central-most blocks of downtown. The colored area is the study area for this case study, and all shaded properties were used in the analysis. The properties are shaded by their zoning status in 2013.

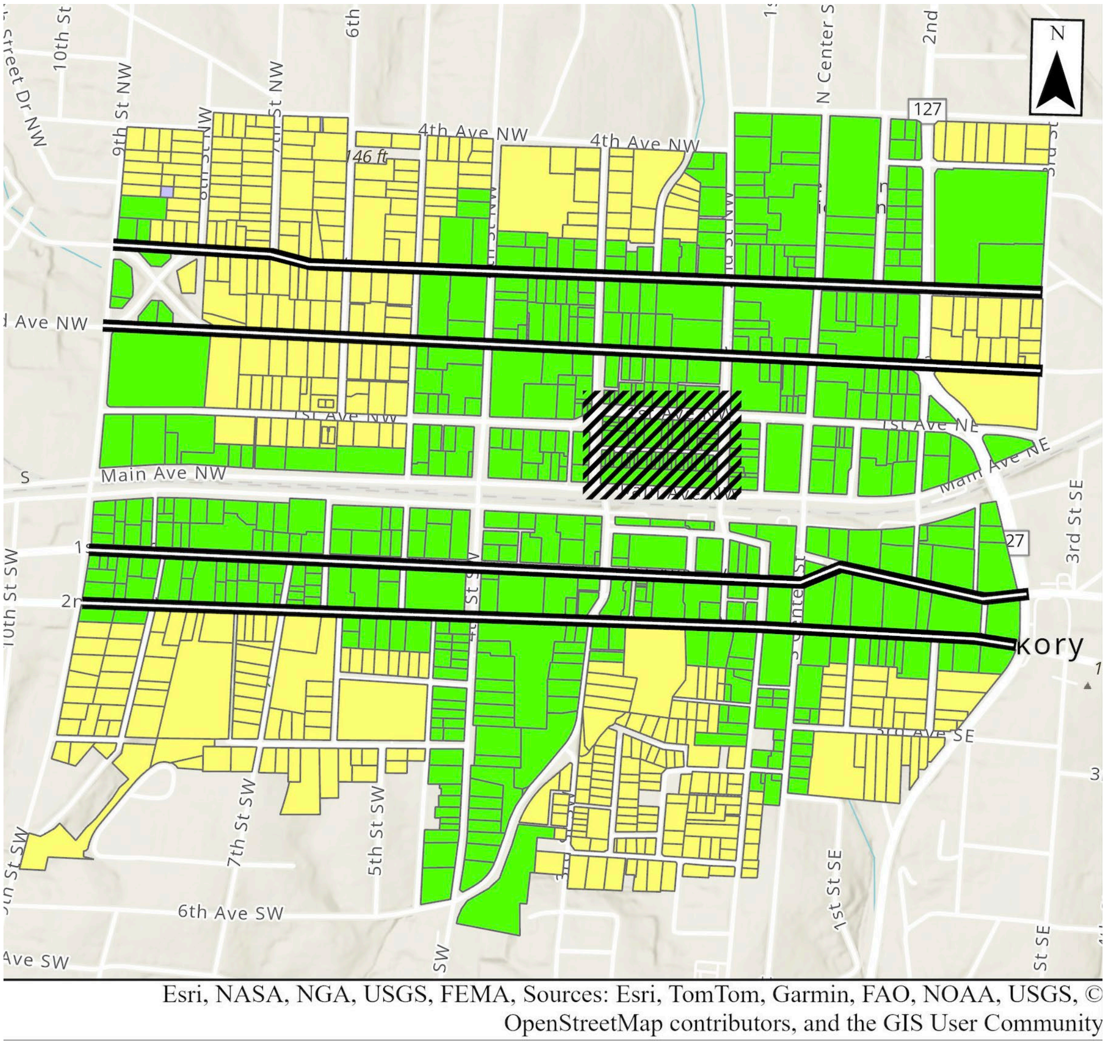

Figure 2: A map of the downtown one-way roads, as they intersect the study area and border Union Square (hatched area). Yellow properties are residential, and green properties are commercial/industrial/office and institutional. The 2013 dataset included very few (hardly visible on this map) "unknown" properties.

This study observes the impact of one-way traffic patterns on relative levels of investment and development throughout downtown Hickory, North Carolina following a revitalization intervention. In 2014, the residents of Hickory, North Carolina passed a $25 million bond referendum aimed at improving walkability and increasing business activity in the city center. The main objectives of this spending were: (a) the rehabilitation of the Union Square promenade and streetscapes, which increased the capacity and aesthetics of the downtown's outdoor dining, event, and walking space, and (b) the construction of a 10-mile multiuse path that begins in downtown and extends outward throughout the city (City of Hickory, n.d.-a). After its passage, the city leveraged the bond to receive an additional $75 million in grant funding for related projects, largely targeting the city walk (City of Hickory, n.d.-a). The first part of the package, the Union Square rehabilitation, was completed in 2019, and the city broke ground on the urban greenway in the same year (City of Hickory, n.d.-b). The spending projects did not change the traffic patterns of the city's downtown one-way roads.

Ample studies have explored the costs and benefits of one-way through-roads in downtowns with respect to pedestrian safety and traffic efficiency (Gayah & Daganzo, 2012; Steuteville, 2019; Walker et al., 2001). Unlike past studies focused on traffic impacts, this case study of Hickory, N.C. will add to the budding body of research that explores potential economic impacts---measured through variables like storefront visibility, property value appreciation or depreciation, and vacant land development---to understand the full effects of unidirectional road design (Riggs & Gilderbloom, 2016, 2017; Walker et al., 2000).

In particular, this study will employ a difference in differences approach to test whether downtown properties on one-way roads and two-way roads see different levels of investment and development, measured by property value appreciation and vacant land activation levels. The study will isolate this difference by measuring the change in these variables before and after an intervention intended to stimulate development, the bond referendum. By observing development patterns in this way, the study seeks to determine whether these one-ways act as a buffer to downtown growth, update the current understanding of the economic impact of one-way roads on downtowns, and guide future traffic decisions associated with downtown revitalization efforts.

The study finds a weakly significant difference (within a 0.10 significance threshold) between one-way properties' property value appreciation following the intervention and that of all other properties. The study does not find significant differences in vacant land activation rates between the control and treatment. The first finding is consistent with, though less significant than, the property value appreciation conclusions from Riggs and Gilderbloom, suggesting that properties on one-way roads may appreciate more slowly than other properties due to lower levels of investment or desirability (2017). The other findings, however, suggest that the traffic pattern does not significantly affect the viability of land for development, as Hickory's long-range plan currently suggests. Further implications of the study and ways it can be improved are detailed in the Discussion section.

2 Theoretical Framework

General background

Small cities in the southeastern United States (particularly those between 10,000 and 50,000 residents) are experiencing faster growth than any other region in the country (Bureau, 2022). As many small cities in the Southeast look to accommodate ever-increasing demand, returning attention to their downtown core will be critical to avoid the inefficiencies of sprawl (Marohn, 2020). Following the wisdom of prominent urbanist Jane Jacobs, rebuilding downtowns efficiently will begin at the street level. Amending traffic patterns is one low-cost initiative municipalities can adopt to calm roads and improve the pedestrian experience of downtown residents, business owners, and visitors.

In Hickory's 2030 Comprehensive Plan, local officials briefly address the potential spillover effects of one-way traffic patterns. The roads were converted to one-way traffic to "expedite traffic flow," a goal the officials say the roads achieve. That said, the plan recognizes the unintended consequences of one-way traffic, noting that the one-way roads "lessen the viability of land alongside (the one-way roads) for commercial or residential development." In suggesting directions for improvement, the plan reports that city officials have considered two-way conversion feasibility studies, but the city has not enacted such studies yet. The plan explains that recent changes, like a general increase in vehicular traffic and the opening of new pedestrian connectivity networks, may have reduced the need for such considerations (Studio Casecade, Inc & City of Hickory, 2022).

To understand the practical differences between one-way and two-way roads, the following literature review explores the current field of knowledge on relevant metrics like road capacity, speed, and pedestrian safety. Examination into these street-level differences occupy the bulk of scholarly research on one-ways. The findings of these studies provide context about how the pedestrian, resident, or storefront experience may be impacted by one-way traffic. Such context is relevant for assessing how the development viability of one-way-abutting properties is in turn impacted, which will be the primary focus of this case study.

Existing research

Studies assessing the capacity, speed, and pedestrian safety differences between one-way and two-way traffic patterns arrive at different conclusions. From the 1940s through the close of the century, traffic engineers lauded the efficiency of one-way streets for serving downtown traffic (Highway Research Board, 1949; US Chamber of Commerce, 1955; Bruce, 1967; Stemley, 1998). Compared to two-ways, one-ways were shown to have higher trip capacity and pose fewer collision risks. Though this favorable impression of one-ways persisted through much of the twentieth century, recent research is less certain that one-ways are safer and more efficient than two-ways.

Capacity

The first variable of interest for assessing a street pattern's efficiency is capacity. A road's "trip-serving capacity" measures the completed vehicle trips on the road when it is saturated but not yet congested (Gayah & Daganzo, 2012). Contrary to what previous traffic recommendations consistently suggested (Bruce, 1967; Stemley, 1998), a modern study by Gayah and Daganzo analyzing the trip-serving capacity between one-way and two-way networks found that one-ways are not ubiquitously more efficient (2012). The researchers found that for *shorter* trip lengths, two-ways can accommodate a higher capacity than one-ways (Gayah & Daganzo, 2012). This finding is relevant to downtown revitalization efforts, for which planners prioritize shorter movements within the center city, rather than long commutes through it.

Speed

The next variable necessary to determine the suitability of a road layout is the vehicular speed that the road can accommodate. Modern scholarship tends to support past research findings that one-ways allow cars to drive at increased speeds by reducing conflicts like the "left turn problem;" when drivers must slow down behind vehicles waiting to cross oncoming traffic (Walter et al., 2000; Bruce, 1967). For downtowns looking to better support the businesses within the core, however, lower-speed streets may be preferred to higher-speed streets as they allow for greater walkability and business visibility.

Pedestrian safety

Current research on downtown revitalization lists improving walkability as a top priority for bringing people and businesses back to the city center (Balsas, 2019; Leinberger, 2005). For cities looking to prioritize walkability, planners must assess the tradeoff between vehicular speed and pedestrian safety (both real and perceived). High-speed traffic is dangerous to pedestrians using sidewalks and crossing intersections, and it likewise deters such uses of the street. A report by the American Automobile Association in 2011 found that the average pedestrian faces a ten percent fatality risk if struck by a vehicle driving 23 miles per hour, but that risk rises to fifty percent if the vehicle is driving 42 miles per hour (Tefft, 2011). The risk is higher for children and the elderly, as well as in crashes involving taller and heavier cars (Tefft, 2011; Montfort and Mueller, 2020; Tyndall, 2024). As the speed of cars driving through downtown increases, the safety of pedestrians sharing the space—and thus the perceived walkability—decreases. One-ways, which studies show accommodate and encourage higher driving speeds, may likewise detract from revitalization efforts.

One-ways are not the only type of pedestrian-unfriendly streets, and some argue that other factors like road width may better predict the safety of a street than traffic direction (Brown, 2017; Price, 2016). A statistical analysis to determine the relationship between several street characteristics and injury accidents found that street width was most strongly correlated with vehicular accidents (Swift, et al., 2006). When roads are wider, drivers perceive less risk and exercise less restraint; on narrow roads, the reverse is true (Hamidi & Ewing, 2023). Those who are skeptical of the problem-solving potential of two-way conversions cite similar evidence (Brown, 2017; Price, 2016). They argue that several other determinants—including street width and surface markings—are better indicators of a road's safety than the directional division of traffic. To understand the pedestrian safety impacts of one-way traffic specifically, qualities particular to unidirectional traffic—like intersection configurations—should be considered.

Comparisons of one-way and two-way intersections with regard to pedestrian collisions have produced conflicting results, largely due to inconsistent methodologies. Much of the debate centers around whether one-way intersections or two-way intersections present more "conflict points" (or "conflict sequences"): points within an intersection (or scenarios for crossing an intersection) at which the path of a vehicle collides with the pedestrian path (Stemley, 1998; ITE, 2004; Walker et al., 2000). For example, a possible conflict point at a crosswalk in a two-way network is at the beginning of a crossing voyage, when the car in the parallel lane turns right. A conflict sequence consists instead of all the possible moves a car can make into a pedestrian's path at an intersection. Comparing potential conflict points has proven difficult, however, as inconsistencies exist between researchers' definitions of possible intersection scenarios. A study highlighting the pedestrian safety benefits of one-way streets, for example, compared one-lane one-ways to two-lane two-ways, which had more conflict points simply because more lanes had to be crossed (ITE, 2004). On the other side of the scholarly debate, a study favoring the intersection safety of two-way traffic showed eight possible one-way configurations that included both one- and two-way roads intersecting, resulting in sixteen possible conflict sequences. They compared these sixteen conflict sequences to one two-way by two-way configuration that likewise only had two total conflict sequences (Walker et al., 2000). Such a comparison would only carry predictive weight if pedestrian street-crossing success was determined by the pedestrian's ability to remember all possible traffic patterns, rather than to look both ways.

Likewise, predictive models of pedestrian intersection-use offer poor insight into pedestrian safety. Measurements of real conflicts—quantitative analyses of the number of pedestrian accidents across different traffic configurations—may provide more credible evidence than predictive models. However, recent quantitative studies of this kind have also produced conflicting results (Quistberg et al., 2015; Riggs and Gilderbloom, 2016).

Gaps in knowledge and study contribution

Traffic flow, safety, and pedestrian experience all contribute to the economic function of a street, but few studies have tried to explicitly measure the economic impact of unidirectional traffic on downtowns. The first study to begin addressing this question analyzed the livability impacts of a one-way to two-way conversion project on the edge of downtown Louisville, Kentucky, observing three metrics: collision frequency, crime, and property value (Riggs & Gilderbloom, 2015). This study took advantage of a natural experiment in which a one-way pair was converted back to its original two-way configuration. Building a difference-in-differences model between the converted one-way pair and an adjacent one-way pair that was not converted, researchers found improvement across all three variables of interest after the conversion. Traffic collisions on the new two-way road decreased significantly from before the conversion (despite an increase in traffic flow). Additionally, crime on that street fell significantly, and property values underwent a significant rise (Riggs & Gilderbloom, 2015).

Given the absence of such conversion projects in many cities, this study will test the efficacy of a difference in difference model where the intervention affects the variable of interest and is separate from the treatment. If the model is effective, it will inform the cost-benefit analysis of one-way to two-way conversions, as well as offer insight into how the effects of unidirectional traffic flow, a legacy mid-century policy, do or do not persist in downtowns decades after their implementation.

3 Data

Data Sources

Data for this study were gathered from three primary sources: The GIS office at Catawba County, NC State University Libraries' Data & Visualization Services department, and NC OneMap. The county performs property tax assessments every four years, so this analysis was conducted using data from one year (usually the first year) within each four-year interval (1999-2002, 2003-2006, 2007-2010, 2011-2014, 2019-2022, 2023-2026).[2] Data within each time period changed minimally with slight adjustments to some properties when requested. For example, almost all the property data in the 2002 dataset was recorded in 1999, and these could likewise be labeled as 1999 values.

Catawba County provided county-wide parcel information (land value, improvement value, total value and zoning) for every year between 2002 and 2011. Changes from this dataset across the 2002, 2003, 2007 and 2011 datasets were used to build the variables of interest for the time periods 1999-2003, 2003-2007, and 2007-2011. NC State provided the dataset for 2013 (which includes 2011-assessments). Unlike the Catawba County dataset, this dataset was shared as a GIS shapefile and included spatial information, which was helpful for determining whether properties dropped from or added to the dataset in the next tax period might have been the result of a property split or merge (further explanation below). Because the NC State dataset provided more information than the county dataset, it was matched to the 2011 data and used to build the variables of interest for the 2007-2011 and 2011-2019 time periods. NC OneMap provided the dataset for 2022 (which includes 2019-assessements) and 2023, and both datasets also included spatial information. They were used to build the variables of interest for the 2011-2019 and 2019-2023 time periods.

Study Area

All raw datasets contained information for the whole county. The study-area for this project is the city of Hickory's central business district, which extends out from Union Square (refer to Figure 2). The area runs west to east between 9th Street NW/SW and 3rd Street NW (which becomes NC 127), and north to south between 4th Avenue NW/NE (which becomes 5th

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[2] Data for 2015-2018 could not be sourced, so the period from 2011-2019 is observed in its place

Avenue NE) and 4th Avenue SW (among other parallel roads). The west/east bounds sit about five blocks to the west and three blocks to the east of Union Square, and the north/south bounds are one street past the further-most one-way road. To shrink the county-wide data to the size of the study area, the property identification numbers (PINs) of the properties within the study area were extracted from the 2013 GIS dataset and the matched to the PINs in the 2011 dataset. The short-list of 2011 PINs was then extracted from the 2007 dataset, which was then used to gather the study-area PINs from the 2003 dataset, and so on.

Accounting for added/removed properties

Because PINs can change between assessment periods as properties are partitioned, combined, or otherwise added/removed, care was taken to reduce the effect of endogenous property value changes (changes that occurred between assessment periods due to a change in the size of the property and not from the property's appreciation or depreciation). For the 1999-2003, 2003-2007, and 2007-2011 datasets, it was not possible to check whether value from PINs that were removed may still exist in other properties, because there was no spatial information for these properties. For the 2013-2019 and the 2019-2023 datasets, it was possible to check the properties around each added or removed property and determine where a split or merge occurred. Then, the relevant properties were re-combined so that the change in value could be recorded as though the property had not changed size.

That this check could not occur in the first three datasets is not of great concern, as property changes across the county were relatively rare and even more rare in the central business district (as opposed to the suburbs and exurbs, where property subdivisions are more common). Appendix A shows the number of properties that were merged or split in the cleaning process, as well as the total change in the number of properties between datasets as a percentage of the total number of properties in the county.

4 Methods

Variables of interest

This study measures the across-time trend in new investment in each property using two methods. Method 1 measures total property value appreciation, controlling for inflation, across the five time periods in the study. Total property value is the sum of the land value and the improvement (building) value of each property. The appreciation value was a simple change over time calculation, using a countywide price index to adjust for inflation in year *t*.

$$\frac{\frac{Total\ Prop\ Value_t}{P\ Index} - Total\ Prop\ Value_{base}}{Total\ Prop\ Value_{base}} \tag{1}$$

The price index was calculated using the average countywide change in property values across each time period: [3]

$$1 + \frac{Mean\ Countywide\ Value_t - Mean\ Countywide\ Value_{base}}{Mean\ Countywide\ Value_{base}} \tag{2}$$

The price index and the property appreciation values were calculated over the same time periods, which were the four year stretches within each tax assessment period: 1999-2003; 2003-2007; 2007-2011; 2011-2019; 2019-2023. For example, in the 2003-2007 assessment period, total value appreciation was measured as:

$$\frac{\frac{Total\ Prop\ Value_{2007}}{P\ Index_{2003-2007}} - Total\ Prop\ Value_{2003}}{Total\ Prop\ Value_{2003}} \tag{3}$$

Method 2 measured levels of property activation on properties that were vacant in the base year. Because these analyses were restricted to only include once-vacant properties, only 700 observations were included in the Method 2 analysis. Appendix B offers a comparison of the treated/control makeup of the total dataset and the Method 2 sample dataset. The difference between the percentage of treated properties in each dataset is not great and the slightly smaller percentage of treated members in the sample dataset should not reduce the strength of the results.

[3] The bundle of county properties used to build each average was shrunken using Tukey's Rule to remove outliers.

The “Property Activation” variable was measured three ways: new land value (land value was zero in the period’s base year, then became positive); new building value (building value was also zero in the period’s base year, then became positive); and total activation (new land value plus new building value, or the combination of the two other measurements). The last measurement was intended to capture the full potential effects of the treatment and intervention on vacant land recovery by looking at both new land generation and new building.

Each “Property Activation” metric is a dummy variable that has a value of one if a vacant property (one whose base-year land and improvement value was zero) became positive. A change from zero in the building value signifies new construction. This type of change was more common than a change from zero in the land value. The potential causes of a change from zero in the land value are less certain, but it is similarly a sign of new investment. A change from zero in a property’s land value may signify the selling or development of government-owned properties, or the rehabilitation of previously contaminated or otherwise unusable, and likewise value-less, land.

Treatment and intervention variables

To understand the impact of one-way roads on property appreciation, each property in the study area that sits on a one-way road was considered a member of the treatment group and given a Treatment dummy variable value of one. Any property not on one of the four one-way roads in the study area was given a Treatment dummy value of zero. Observations in time periods 4 and 5 were considered post-intervention and given an Intervention dummy variable value of one. The values gathered in these two time periods reflect the initial response to the knowledge of the investment package and the initial ground-breaking on the improvements. Observations in time periods 1, 2, and 3 were given an Intervention dummy value of zero.

Control variables

The model employs panel data to control for property-level fixed effects and the fixed effects of general time trends. The regression further controlled for the effect of property type on the variable of interest, using zoning information as a proxy for property use. Property type was included in the regression as a factor variable, and all properties in the study area fell into one of three zoning categories:[4]

1. Residential
2. Non-residential
3. Unknown

Omitted Controls

Some properties changed use category over the course of one time period. These changes have the potential to sway the response variable, as a rezoning may allow for an owner to increase the property's use and appreciate its value, independent of the intervention. I determined that this use change should not be used as a confounding variable, however. The change is a side effect of the intervention, because zoning changes are a step in the process to redevelop a property. The decision to convert a property to a higher and better use is made before the decision to rezone. Therefore, the value appreciation seen on these properties is not a result of the zoning change and may be a result of the intervention.

An additional interaction term between the treatment and property use variables was tested in the panel regression, but the effects of this interaction term were negligible (the significance of the coefficients did not change, and the coefficient of the interaction term was not significant). This term might be useful with more specific use categories, because industrial properties appear more likely to be situated on one-way roads, but such use categories are not included in this analysis.

Model Design

Rationale

I estimate a difference in differences (DiD) model using panel data and including unit (property), use (property type), and time fixed effects to account for unobserved heterogeneity. The 4,780 observations were sorted into 991 clusters (individual downtown properties) observed over five consecutive time periods. The DiD model measures the effect of the treatment (one-way design) on the variables of interest (two proxies for downtown development), before and

[4] Non-residential includes: Commercial (all levels); Industrial; Office and Institutional; and other. Data from the Catawba County dataset listed only two use types---C (non-residential) and R (residential)—so properties that later fell into more specific categories were grouped into either of these two. "Other" properties include the hospital, art museum, and public parks.

after an intervention (the infrastructure bond).[5] By observing development trends on both road types before and after the intervention, rather than across time only, the model will capture any difference in the treatment group's response to the intervention. In the case of this model, that response is equal to each property's ability to secure investment following an intervention intended to stimulate it—the targeted infrastructure improvement bond.

Variables and Regression Equations

Equation (4) details the regression equation for the Method 1 DiD with unit (embedded in the panel data), time, and property type ("Use") fixed effects.[6] The regression controls for the latter two fixed effects by using dummy controls for time and use.

$$Total\ Appr_{it} = \beta_0 + \beta_1 Treatment_i + \beta_2 Intervention_t + \beta_3 (Treat * Int)_{it} + \beta_4 Use_i + \beta_5 Time_t + \varepsilon_{it} \quad (4)$$

This regression equation is repeated for only non-residential properties to observe the effects on commercial properties concentrated in downtown (and the use dummy was removed). The rationale for doing so was two-fold: (a) non-residential properties are the targets of the investment package, and the effects on non-residential properties are likewise extra relevant; and (b) I speculate that removing residential properties from the analysis could reduce lingering inflation-related effects. Residential properties experience higher rates of appreciation, and the price index used to deflate the data was calculated using combined residential and non-residential properties in the county. It is likewise possible that the index did not fully adjust for the residential property inflation levels, especially during the period of high home value inflation between 2019 and 2023.

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[5] Because property value data for the 2015-2019 assessment period, during which the intervention occurred, was unavailable, the intervention was observed over the 2011-2019 period. Changes within the 1999-2003, 2003-2007, and 2007-2011 periods were considered pre-intervention, and changes within the 2011-2019 and 2019-2023 periods were considered post-intervention.

[6] Where: *Total Appr*$_{it}$ is the total four-year appreciation value of property i in assessment period t, adjusted for inflation; β_1*Treatment*$_i$ measures the effect of treatment on property value appreciation; β_2*Intervention*$_t$ measures the effect of the intervention on property value appreciation; β_3*(Treat∗Int)*$_{it}$ measures the effect of the interaction between the treatment variable and the intervention variable; β_4*Use*$_i$ measures the fixed effects from a property's use; β_5*Time*$_t$ measures the fixed effects from changes in time; and β_6*(Use∗Treat)*$_t$ measures the effect of the treatment on the property type.

Equation (5) details the regression equations for Method 2. The regression was run three times for each of the three land activation types: new land, new building, and total activation.

$$Activation_{it} = \beta_0 + \beta_1 Treatment_i + \beta_2 Intervention_t + \beta_3 (Treat * Int)_i + \beta_4 Use_i + \beta_5 Time_t + \varepsilon_{it} \quad (5)$$

5 Results

Preliminary observations

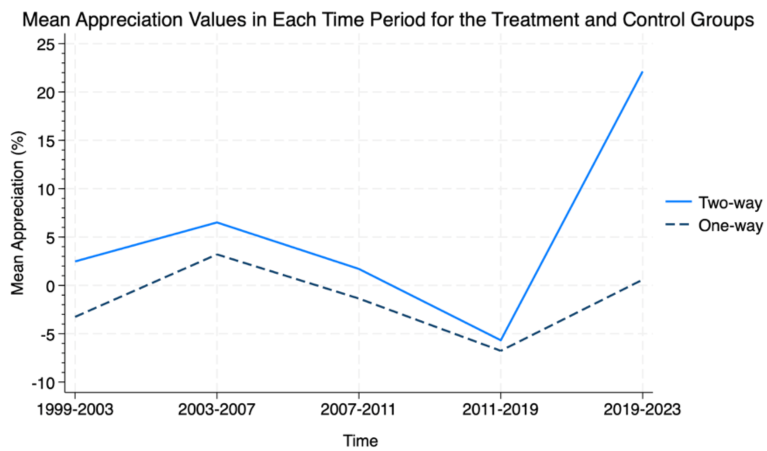
Delineating Pre- and Post-Intervention Effects

Figures 3 and 4 below show the mean and median inflation-adjusted appreciation values across all properties in the study area within each of the time periods. Charts for both the median and mean values appear to follow parallel trends prior to the intervention period. The intervention occurred during the 2011-2019 period, so the value for that period includes whatever immediate results did or did not occur post-intervention. The five-year-out results of the intervention (if one uses the 2018 groundbreaking) on improvements as the intervention, not the 2014 passage of the bond), are likely more explanatory than the immediate results (especially because the build out of the improvements continue into 2025).

Mean and Median trends

The mean appreciation values are more variable than the median appreciation values because they are more sensitive to outliers. This skewing is not wholly undesirable within the results, however, because outliers are a sign of major development (e.g. new construction).[7] The mean appreciation values (top) are higher on the two-way roads than the one-way roads in every period. The median appreciation values (bottom) are nearly equal between the control and treatment groups prior to the intervention. The effects of the 2008 financial crisis are visible in the 2007-2011 drop in appreciation values. In the 2011 to 2019 period, during which the spending bill passed (2014) and construction on downtown improvements began (2018), the graph breaks slightly from the pre-intervention trend. There is an apparently drastic difference in the mean two-way appreciation levels between the control and treatment groups, but these graphs do not provide causal evidence or results. Most importantly, they do not control for unit-level fixed effects.

[7] The Method 1 dataset---which uses property appreciation values---excludes properties that had a value of zero in the base year and a positive value at the end of the time period (i.e. new construction on a previously vacant lot). High appreciation values may still be a sign of new construction, however, because construction can occur on previously developed lots, as is the case with tear-down developments or building expansions.



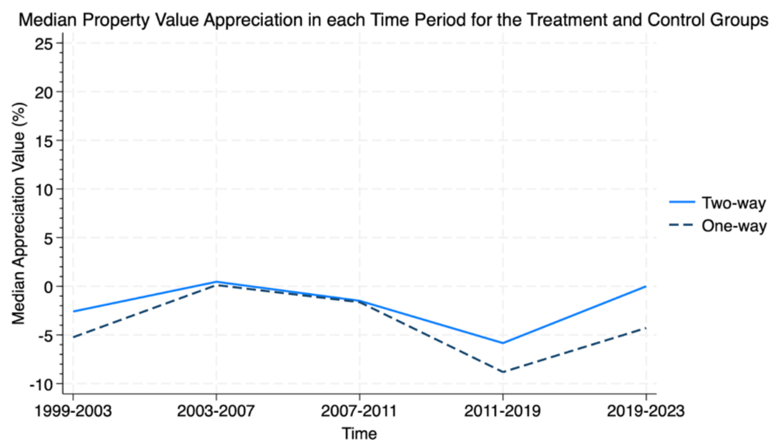
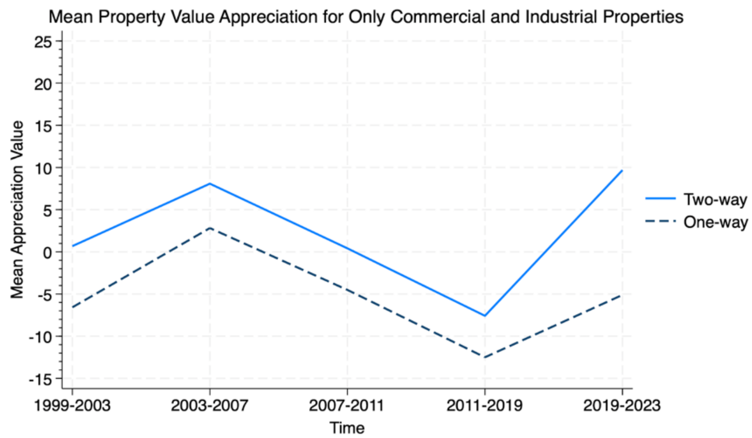


Figure 3: The mean (top chart) and median (bottom chart) property appreciation values across the five time periods for the treatment and control groups. The intervention affects the 2011-2019 and 2019-2023 period.

The same graphs were created with residential properties excluded from the observation pool to observe the mean and median trends of only non-residential properties. This step was largely a precautionary measure, as the properties were already inflation-adjusted. Because the variable tested was total property appreciation (which includes the tax-assessed value of the building (or home) on that property), and because homes tend to appreciate faster than other buildings, an analysis of only non-residential properties was included in the final analysis. The means graph that includes residential properties (particularly the two-way line) does follow a similar trend to that of national nominal home price values over that period. That this is truer on the two-way roads than on the one-way roads is reasonable, because a higher percentage of the roads on the two-way roads are residential.

The control group also includes the properties presumably most-effected by the investment package—those in and immediately surrounding union square. Observing the trends for non-residential properties by themselves makes it possible to more closely see the effects of the investment package following its passage. For just non-residential properties, the trends between the treatment and control are much more similar.



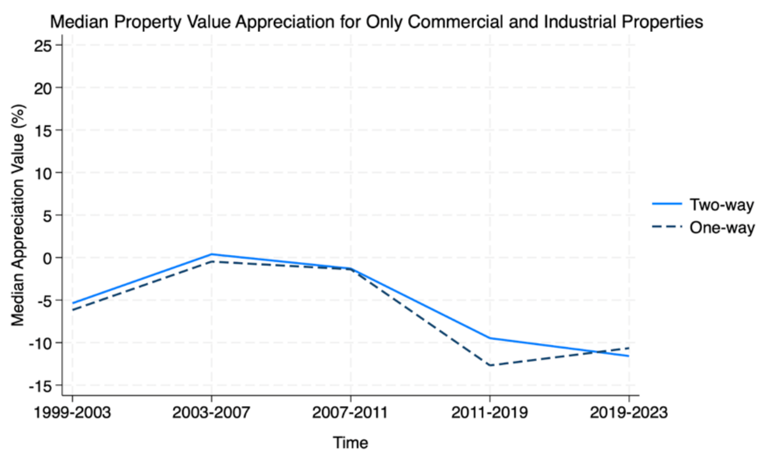


Figure 4: The mean (top chart) and median (bottom chart) appreciation values of only *non-residential properties across the five time periods for the treatment and control groups. The intervention affects the 2011-2019 and 2019-2023 period.*

The trends in the median values are also worth noting. The median appreciation values, less influenced by outliers, tracked closely between the treatment and control groups. The difference between the control and treatment groups' responses to the intervention appears markedly different in the median value chart for non-residential properties. The median value of non-residential properties on two-way roads *depreciated* five years out from the intervention, and they did so at a slightly faster rate than the properties on the one-way roads. Still, these charts are not adjusted for unit fixed effects and only provide preliminary insight into group-wide trends.

Panel Trends

Figures 3 and 4 show mean and median appreciation values across time for all properties in the study area. Though the mean and median values tend to be lower in the treatment group, the effects are not clustered to understand how singular properties, tracked across time, differ between singular properties in the control group. Figure 5 shows predicted property appreciation values over time when the data has been clustered by property to account for within property fixed-effects. In this model, the properties in the treatment group have a higher predicted appreciation value in all time periods, but the confidence intervals of the treatment and control groups overlap. The properties in the control group do experience a bump following the intervention, and the main regression equations measure the significance of that bump.

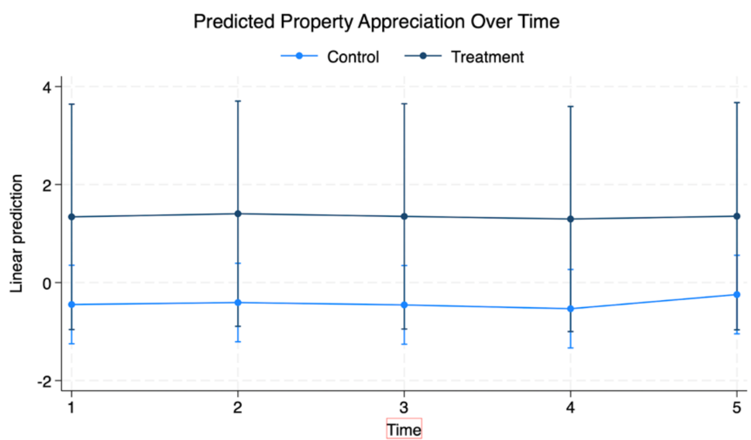


Figure 5: The trend in property appreciation values controlling for within property fixed effects

The results of a single-variate panel regression using the treatment only, like the one represented in Figure 5, are in Table 1. As evidenced by Figure 5, the effect of the treatment on property appreciation values is not significant.

Table 1

The Effect of the Treatment on the Change in Property Appreciation Values

Prop. Appreciation	β	Std. Err.	p-value	Sig.
$Treatment_i$	1.704	1.609	.290	

Regression Results

The results of the panel regression for Method 1 are in Table 2. The treatment alone is not significantly different from zero, as Figure 5 suggested. The Intervention coefficient is positive and significant within the 0.05 threshold. The coefficient suggests that the four-year property appreciation rate was about seventeen basis points higher following the intervention. The interaction variable is negative and significant within a 0.10 significance threshold. The interaction variable, though not significant within a 0.05 significance test, suggests that properties in the treatment group felt the effect of the intervention at lower levels than properties in the control group. The appreciation rate for treatment properties following the intervention was about eight basis points lower than the post-intervention rate for control properties.

Table 2

Panel Regression of the Change in Property Appreciation Values before and after the Intervention

Prop. Appreciation	β	Std. Err.	p-value	Sig.
Treatment_i	1.729	1.538	.261	
Intervention_t	.178	.077	.021	**
$(\text{Treat x Int})_{it}$	-.087	.051	.088	*
Use in base year				
Non-residential	.120	0.104	.248	
Unknown	(empty)			
Time				
Period 2	.046	.027	.092	*
Period 3	-.004	.025	.870	
Period 4	-.229	.065	.000	***
Period 5	(omitted)	.	.	

The panel regression for Method 1 was repeated for only non-residential properties. No results from this analysis were significant. Appendix C includes the results of this regression.

The results of the panel regression for Method 2 provide further information on the investment response between the treatment and control groups following the investment intervention. Observing the response in total activation levels, the response to the treatment alone was not significant, and the response to the intervention was again positive and significant (Table 3). Following the intervention, the property activation rate was about nine basis points higher than the pre-intervention rate. The variable of interest, the interaction variable, was not significantly different from zero.

Table 3

Panel Regression of the Change in Total Activation Levels before and after the Intervention

Total Activation	β	Std. Err.	p-value	Sig
$Treatment_i$	.426	.344	.217	
$Intervention_t$	.091	.034	.007	***
$(Treat \times Int)_{it}$	-.006	.044	.894	
Time (base is Period 1)		.	.	
Period 2	.055	.023	.017	**
Period 3	.040	.017	.022	**
Period 4	.024	.037	.515	
Period 5	(omitted)	.	.	
Mean dependent var	0.109	SD dependent var	0.312	
R-squared	0.041	Number of obs	699	
F-test	4.145	Prob > F	0.001	

**** p<.01, ** p<.05, * p<.1*

Separating the total activation measurement into new land and new building measurements helps to explain what type of land activation accounted for most of the observed intervention response. Tables 3 and 4 show the effects of the intervention and treatment on new building and new land levels, respectively. The response to the treatment was again insignificant for both metrics, and the response to the intervention for both metrics was again significant within a 0.01 significance threshold. These results show that the rise in activation levels following the intervention was driven by new building on vacant properties, not new land creation. The interaction variable was not significant for the new land nor the new building metric.

Table 4

Panel Regression of the Change in New Building Levels before and after the Intervention

New Building	β	Std. Err.	p-value	Sig.
$Treatment_i$	.423	.289	.145	
$Intervention_t$	.139	.032	0	***
$(Treat \times Int)_{it}$	-.001	.044	.982	
Time (base is Period 1)				

Period 2	.055	.023	.018	**
Period 3	.04	.017	.023	**
Period 4	-.071	.028	.012	**
Period 5	(omitted)	.	.	

Mean dependent var	0.089	SD dependent var	0.285
R-squared	0.069	Number of obs	699
F-test	3.925	Prob > F	0.002

*** *p<.01, ** p<.05, * p<.1*

Table 5

Panel Regression of the Change in New Land Levels before and after the Intervention

New Land	β.	Std. Err.	p-value	Sig
$Treatment_1$	.002	.055	.965	
	0	.	.	
$Intervention_t$	-.049	.012	0	***
$(Treat\ x\ Int)_{it}$	-.005	.004	.223	
Time (base is Period 1)				
Period 2	0	0	.598	
Period 3	0	0	.435	
Period 4	.095	.024	0	
Period 5	(omitted)	.	.	

Mean dependent var	0.027	SD dependent var	0.163
R-squared	0.095	Number of obs	699
F-test	2.557	Prob > F	0.029

*** *p<.01, ** p<.05, * p<.1*

Mapped Results

Appendix D shows every property in the study area and whether it appreciated significantly, depreciated significantly, or did not experience a significant change in property value during time periods three (immediately pre-intervention), four, and five. Appendix E shows every property vacant in the base year and activated by the time period's closing. As predicted by the regressions, there is no discernable trend in activation from these maps.

6 Discussion

The goal of this study is to test whether downtown properties on one-way roads and two-way roads see different levels of investment and development. The study seeks to isolate this difference by measuring the change in two development proxies—property value appreciation and vacant land activation—before and after an intervention that was intended to stimulate development. The results show a statistically significant response to the intervention across all properties for all development measurements. The tests did not find any significant effect on development levels over time by the treatment alone. One treatment result was significant: the interaction effect of the treatment and intervention on property value appreciation levels. This test found a slight negative response in the treatment when interacted with the intervention that was significant within a 0.10 significance threshold. This finding suggests that, following the intervention, one-way road properties appreciated at slightly lower rates than two-way road properties. None of these results confirm that one-way roads have an outsized effect on the likelihood that a property will experience new development or investment. Potential ways that this study falls short in capturing the full effects of the variables at play within this analysis are discussed below.

Because the study measures the indirect effects of the intervention, it does not fully account for the direct effects of the investment package. It is possible that some properties on Union Square received direct investment from the spending package, and these properties were necessarily in the control group. It was not possible, however, to pinpoint what properties might have received direct effects. Where the study produced significant responses to the intervention, it is possible the results were inflated by direct effects.

In a similar vein, it is possible that additional indirect effects from the spending package were felt more immediately on properties closer to the intervention, and these properties were also more often in the control group. Indirect effects from the spending package may take time to ripple out from the downtown core, so it makes sense that the treatment group, which does not immediately abut downtown, would experience weaker changes than the control group, which includes the properties closest to the core. It would be worthwhile to run this study again in later years to see if the effects have spread to more properties, or to include a control for the distance of each property from the downtown core.

Because the zoning information in some of the datasets only grouped properties based on residential or non-residential use, it was not possible to observe the effect of more specific uses, including industrial or historically higher intensity properties. The southern one-way roads included a higher percentage of these industrial/higher-intensity properties than the rest of the study area. To better control for this difference, future research should separate the properties by more specific uses. In doing so, the research must also account for the possibility that these, and not other roads, were converted to one-ways *because* of their industrial property base.

The effects of the intervention on new building and appreciation levels may also be confounded by the market's response to increased demand. The observed response to the intervention may likewise be the result of population growth that coincided with the time of the intervention and not a response to the intervention itself. Population growth does not affect the treatment variable.

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Appendix A

Property Changes Within Each Time Period			
Property (PIN) appears:	Issue	Number of Properties (% total)	Resolution
In 2019 but not 2023	Property merge	9 (.92)	Combine 2019 values to create 3 merged 2019 properties analogous to 2023 properties
In 2023 but not 2019	Property split	8 (.82)	Combine 2023 values to create 8 merged 2023 properties analogous to original 2019 properties
In 2013 but not 2019	Property merge	15 (1.54)	Combine 2013 values to create merged 2013 property resembling 2019 property
In 2019 but not 2013	Property split	26 (2.66)	Combine 2019 values to create merged 2019 property resembling original 2013 property
In 2019 but not 2013	Property added	7 (0.72)	Create 2013 property with 2019 PIN and values 0
In 2013 but not in 2007	Net property addition	19	Could not join with spatial information, because 2013 PINs were used to determine the 2007 study area. These new properties were removed from the 2007-2013 dataset
In 2007 but not 2003	Net property addition	3	Could not join with spatial information, because 2007 PINs (based on 2013 PINs) were used to determine the 2003 study area. These new 2007 properties were removed from the 2003-2007 dataset
In 2003 but not 1999	Net property addition	0	n/a

Appendix A: The changes in the number of properties between the base and later year of each time period, and what action was taken to remedy the changes. For the three time periods before 2019-2013, spatial information to locate nearby properties to confirm when a split or merge might have occurred was unavailable and extra properties were removed from these datasets.

Appendix B

	STUDY AREA	VACANT IN BASE YEAR
#TREATMNT	1229	101
#CONTROL	3552	598
#TOTAL	4781	699
%TRTMNT/TOTAL	25.71	14.45

Appendix B: Comparison of the number of treated and controlled observations between the total study area and the sample of properties that were vacant in the base year.

Appendix C

Panel Regression of Property Value Appreciation Levels before and after the Intervention, for only *Non-residential properties*

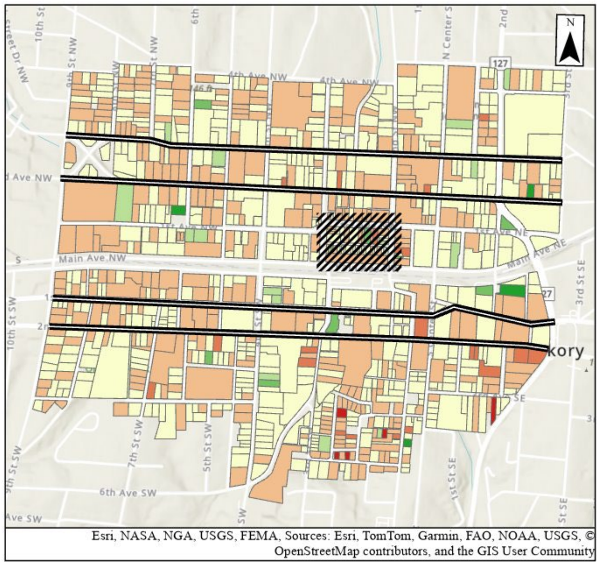
appr_comm	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
ow : base 0	0	.	.	.	.	.	
1	-.104	.229	-0.45	.649	-.554	.346	
post_int : base 0	0	.	.	.	.	.	
1	.056	.084	0.67	.502	-.109	.221	
ow#0b : base 0	0	.	.	.	.	.	
ow#1o : base 0	0	.	.	.	.	.	
1o	0	.	.	.	.	.	
1	-.049	.053	-0.93	.353	-.154	.055	
time : base 1	0	.	.	.	.	.	
2	.081	.033	2.41	.016	.015	.147	**
3	.022	.038	0.60	.549	-.051	.096	
4	-.111	.061	-1.82	.069	-.23	.009	*
5o	0	.	.	.	.	.	
Constant	.014	.084	0.17	.867	-.151	.179	

Mean dependent var	-0.006	SD dependent var	0.774
R-squared	0.006	Number of obs	2694
F-test	10.188	Prob > F	0.000
Akaike crit. (AIC)	5465.982	Bayesian crit. (BIC)	5501.374

**** p<.01, ** p<.05, * p<.1*

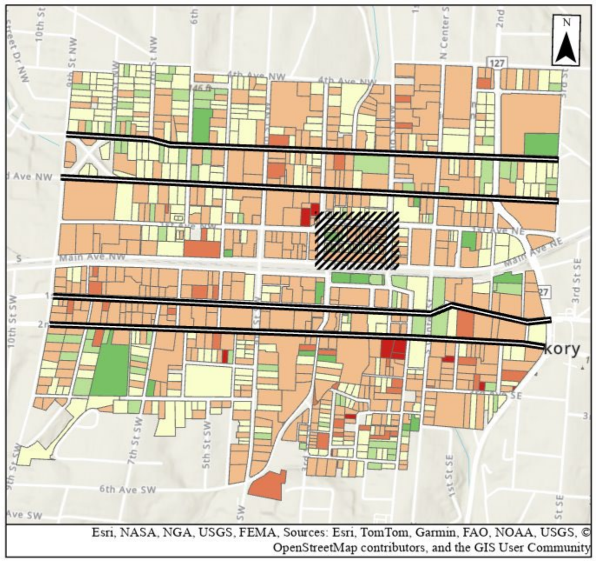
Appendix D[8]

Appendix D: Maps of the study area showing property-level appreciation values for three time periods. Green patches represent appreciation and red patches represent depreciation, while darker properties signify positive or negative outliers. The black lines trace the one-ways, and all properties that face these one-ways are in the treatment group. The black hatched area is Union Square.

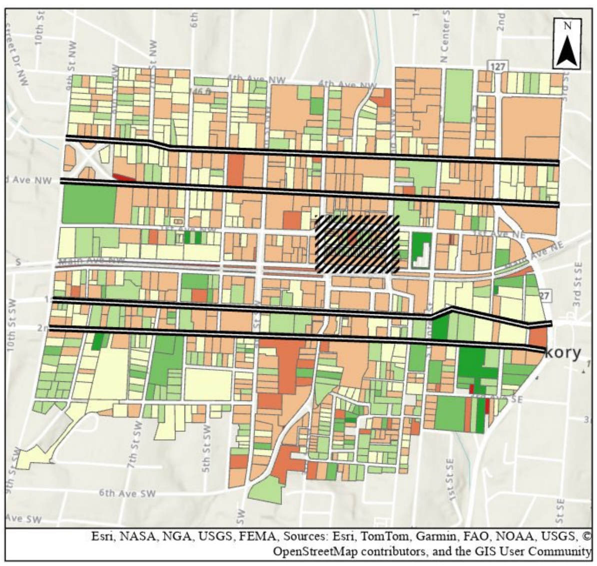


2007-2011: Pre-intervention

[8] The maps were created to visualize where the most significant changes occurred, and they likewise do not mathematically represent the regression findings from the study. Darker green and dark green properties are properties that experienced "significant appreciation." Significant appreciation values were determined by taking the ninety-fifth and ninety-ninth percentile of all positive appreciation values (four-year percentage changes that were greater than zero) that occurred across the five periods of the study (1,977 of the 4,753 observations). Red properties are properties that experienced "significant depreciation." Again, these values were determined by taking the ninety-fifth percentile of all negative appreciation values that occurred in the five periods of the study. This method allowed the same symbolization to be used for each map, but each map likewise does not illustrate within-period significance. Light red, yellow, and light green properties experienced insignificant levels of appreciation or depreciation.



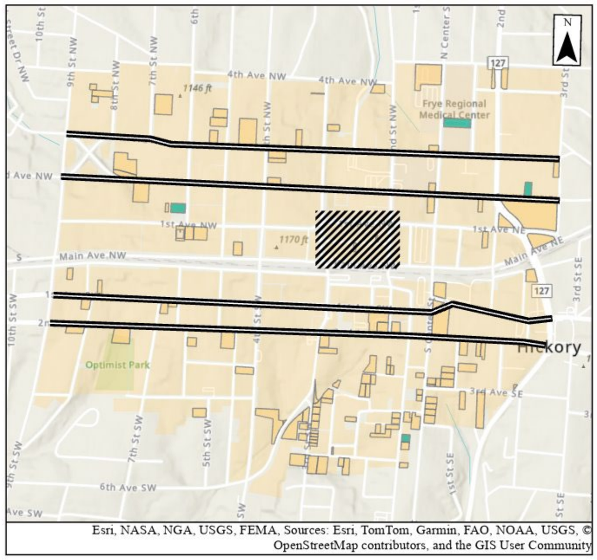
2011-2019: Pre- to immediate post-intervention



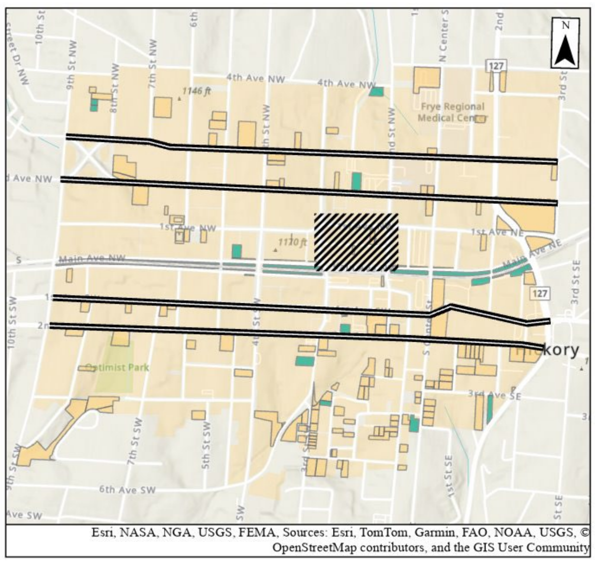
2019-2023: 5-year post-intervention

Appendix E

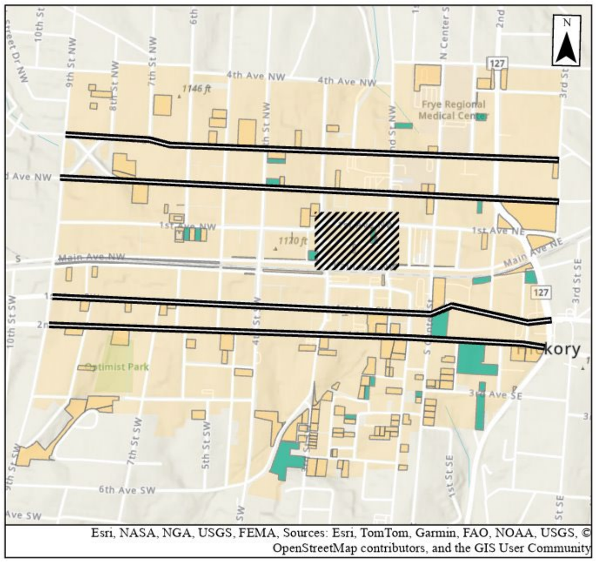
Appendix E: Maps of the study area showing vacant properties (outlined) and activated properties (blue) for three time periods. Properties are outlined if they were vacant in the base year of the stated time period and filled blue if they are no longer vacant (or newly created) in the period's closing year.



2007-2011: Pre-intervention



2011-2019: Pre- to immediate post-intervention



2019-2023: 5-year post-intervention