Title
Improving the Distribution of Densities in Southern California

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Improving the Distribution of Densities in Southern California

A Research Report from the University of California Institute of Transportation Studies

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16. Abstract

Many of the biggest transportation challenges in Southern California arise not due to its overall density but due to the lack of concentration of densities. While recent years have witnessed increasing efforts to expand public transit services and encourage compact development in transit areas, there is a dearth of research providing support for improving the distribution of densities in the region. This project adopts a simultaneous equation modeling (SEM) approach to reveal the complexity of parcel-level (residential) land use intensification dynamics in a five-county Southern California metropolitan region with emphasis on the importance of reciprocal interactions between current and planned land use changes and the critical role of public transit accessibility. Results suggest that residential densification and upzoning processes reinforce each other. Urban residential upzoning can promote the probability of parcel-level residential densification significantly, even though it does not always lead to an immediate market response in every location. More importantly, the residential density increases are found to induce further plan/zoning modifications in nearby areas, indicating the presence of feedback loops in this dynamic relationship. There is also evidence of the positive influence of public transit accessibility. Single-family residential land parcels with greater access to high-quality transit services show a higher level of densification and upzoning probabilities, when all other conditions are held constant. Such positive effects are detected not only in existing high-quality transit areas but also in locations where public transit services will be available in the future.

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Disclaimer

Improving the Distribution of Densities in Southern California

UNIVERSITY OF CALIFORNIA INSTITUTE OF TRANSPORTATION STUDIES

January 2020

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Executive Summary

Many of the biggest transportation challenges in Southern California arise not due to its overall density but due to the lack of concentration of densities, but little is known about how to address this critical problem and its adverse consequences. While recent years have witnessed increasing efforts to expand public transit services and encourage compact development in transit areas, there is a dearth of research providing support for improving the distribution of densities in the region. Furthermore, existing studies have tended to focus on the City of Los Angeles, limiting our ability to understand what opportunities (or challenges) exist in the rest of the region to improve the overall density distribution towards more sustainable urbanism.

This project aims to fill these gaps through a spatially-explicit, micro-level investigation of urban densification processes in a five-county Southern California metropolitan region. More specifically, the project adopts a simultaneous equation modeling (SEM) approach to reveal the complexity of parcel-level (residential) land use intensification dynamics with emphasis on the importance of reciprocal interactions between current and planned land use changes and the critical role of public transit accessibility. It also attempts to identify hotspots that deserve attention for more strategic concentration of densities within the region.

Results suggest that residential densification and upzoning processes reinforce each other. Urban residential upzoning (measured using general plan land use as a proxy) can promote the probability of parcel-level residential densification significantly, even though it does not always lead to an immediate market response in every location. More importantly, the resultant residential density increases are found to induce further plan/zoning modifications in nearby areas, indicating the presence of feedback loops in this dynamic relationship.

The SEM results also provide evidence of the positive influence of public transit accessibility. Single-family residential land parcels with greater access to high-quality transit services show a higher level of densification and upzoning probabilities, when all other conditions are held constant. Such positive effects are detected not only in existing high-quality transit areas but also in locations where public transit services will be available in the future. These areas appear to present great potential for accommodating future growth in a way that promotes sustainable urbanism rather than allowing continued sprawl.

Introduction

Decades of urban transportation research has explored ways to create sustainable communities, and it has been suggested that the vision of sustainability, particularly greenhouse gas (GHG) emission reductions, can be achieved not only through sustainable mobility approaches putting emphasis on technological advances (e.g., alternative fuels, higher efficiencies, etc.) but also through sustainable urbanism wherein explicit attention is paid to the importance of systematic linkages between land use and transportation and changes we can make by modifying urban land use and new investment/development patterns (Cervero and Murakami, 2010). While the former approaches have gained growing popularity in recent years, there has been little doubt that transportation and sustainability outcomes are largely shaped by the way we design and develop our cities. In this light, a great deal of attention has been paid to how a certain pattern of land use/development is associated with vehicle miles traveled (VMT), traffic congestion, GHG emissions, and other transportation/sustainability indicators.

Studies concerning the nexus between urban land use/development and transportation have been diversified quite dramatically (in terms of research design, scale/unit of analysis, data sources, etc.), but the literature has long focused on densities. This tradition can be traced back to the Newman and Kenworthy's hyperbola (1989a,b) showing a strong, inverse relationship between urban densities and automobile dependence of the cities (see, e.g., Ewing et al., 2018). The well-known debate between Gordon and Richardson (1997) and Ewing (1997) is another good example illustrating how the scholarly conversations have centered around densities and how important densities are in this domain of research and policy making. While other built-environment variables have been increasingly employed in more recent studies, it has been widely acknowledged that densities are highly associated with many of such sustainable land use or transportation indicators (p. 402, Cervero and Murakami, 2010). In other words, promoting a more efficient use of land through compact development is still placed on top of the priority list.

It is important, however, to note that density changes, if measured only at an aggregate level, do not provide sufficient insights. The overall aggregated density levels measured for metropolitan areas have limited usefulness for policy formulation, even though the variable can explain interregional variation in transportation outcomes to some extent. Eidlin (2010) illustrated this point well in his Access article, "What density doesn't tell us about sprawl," in which he contended that "what matters is the distribution of density, or how evenly or unevenly an area's population is spread out across its geographic area." (p.4). The distribution of densities has also been found to be crucial to regional economic performance. For instance, according to Florida (2012), "economic growth and development is higher in metros that are not just dense, but where density is more concentrated."

Southern California, specifically the Los Angeles urbanized area, has been regarded as a perfect example to illustrate this point – why the distribution of densities does matter. Many of its transportation challenges can be attributed to the so-called dysfunctional densities (coined by Bill Fulton) – a range of density levels "high enough to swamp arterial streets with car traffic, but not high enough to sustain other transportation choices" (p.31, Boarnet, 2008). Eidlin (2010) described this problem by stating "[t]he LA region's combination of high, evenly distributed density puts it in an unfortunate position: it suffers from many of the problems that accompany high population density, including extreme traffic congestion and poor air quality; but lacks many of the benefits that typically accompany more traditional versions of dense urban areas, including fast and effective public transit and a core with vibrant street life. … It is too dense to function like classic suburbia, but also has few areas dense enough to be a 'city' in the manner of central city New York or San Francisco" (p.4).

In order to resolve this problem, we need to find effective ways to induce more concentration of urban activities in a set of carefully chosen locations rather than allowing dense sprawl to continue in the region. For this purpose, in recent years, the Southern California Association of Governments (SCAG) has delineated high-quality transit areas (HQTAs) and made efforts to direct future growth into the areas. However, the HQTAs alone do not provide detailed guidance for the creation of higher-density activity centers/nodes that can contribute to addressing the problematic distribution of densities. In addition, little is known about where these dysfunctional density problems tend to occur, why these problems have persisted, and in what ways planners can make a meaningful step to address this issue and eventually achieve more sustainable land use-transportation outcomes. Furthermore, existing studies have tended to focus on the City of Los Angeles, resulting in lost opportunities for understanding what challenges exist in the rest of the region, particularly in places with great potential for future density concentrations.

To gain a more nuanced understanding of the distribution of densities, its temporal dynamics and broad implications, more attention should be paid to how urban (or metropolitan) spatial structure is constantly reshaped by market forces and planning interventions with a close look at (micro-level) changes that arise in different parts of the city or region, and this project aims to take a step in that direction by examining the process of urban densification in a five-county Southern California metropolitan area. More specifically, the project provides a parcel-level investigation of urban (residential) land use intensification by employing a simultaneous equation modeling (SEM) approach. Emphasis is on the possible bidirectional interactions between current and planned land use changes – that is, how individual localities have changed their land use plans (to spur or not to prevent residential densification), to what extent such land use plan changes have contributed to actual land use intensification, and how the resultant land use changes and density increases can induce further plan modifications in nearby areas. Consideration is also given to the impacts of existing and future (high-quality) transit services, which should be integrated with local/regional land use planning more systematically to promote sustainable urbanism.

Previous Research

Urban densification, especially residential land use intensification, has gained increasing popularity in research and practice alike, as part of the solution to unchecked urban expansion and various challenges associated with continued sprawl (see, e.g., Ewing, 1997; Jabareen, 2006; Daneshpour and Shakibamanesh, 2011). Many studies have reported that concentrated residential densities, combined with public transit, diverse land uses, and complete street networks, are crucial to reducing energy consumption, VMT, GHG emissions, and other causes/indicators of environmental threats (see, e.g., Cervero and Sullivan, 2011; Yigitcanlar and Kamruzzaman, 2014). As briefly mentioned earlier, more and more attention has also been paid not only to the promise higher density development may hold for sustainable urbanism but to the importance of density distributions or concentrations (Eidlin, 2010; Florida, 2012).

In the literature, some scholars have examined the trend of density change patterns at aggregated (regional) levels. Sarzynski (2013), for instance, provided an analysis of 257 metropolitan areas in the U.S. and detected a trend towards both housing and job densification from 1990 to 2010, while the factors behind the trend appeared to vary by regions. A relatively larger number of studies have focused on a range of benefits that could be brought by density increase with regard to population health, public transit usage, and fiscal efficiency (see, e.g., Ewing et al., 2003; Lopez and Hynes, 2003; Ewing and Hamidi, 2015). Other scholars have directed attention to the trade-offs between the benefits and costs involved in densification. In their well-known article, titled “Are compact cities a desirable planning goal?,” Gordon and Richardson (1997), for instance, presented their critical view on compact development by stating that “[h]igh-rise or concentrated settlement is costly and only worthwhile if transport or communications costs are high” (p.100). Westerink et al. (2013) also claimed that “if lower income people are forced into high-density living with few social or economic opportunities, there is potential for a spiral of deprivation, exclusion and anti-social activity” (p.488).

Detailed mechanisms of densification dynamics, however, have not been examined extensively at more disaggregated levels, mainly due to the limited availability of data required for such investigations. In urban planning literature, there are only a handful of studies employing spatially explicit (micro-level) data for systematic analysis of the densification processes in a city or region. Some of these studies have used lot size and/or housing composition statistics to understand the nature of urban densification processes (see, e.g., Song and Knapp, 2004; Kopits et al., 2012; Delmelle et al., 2014), while others have focused on floor-to-area ratios and dwelling units per acre to determine the scale or type of redevelopment or other forms of densification projects in urban areas (see, e.g., Belzer and Autler, 2002; Schuetz et al., 2018). More recent studies have utilized parcel-level (or equivalent) land use data layers to reveal some important features of urban densification dynamics and their major determinants (see, e.g., Gabbe, 2018; Kim et al., 2018).

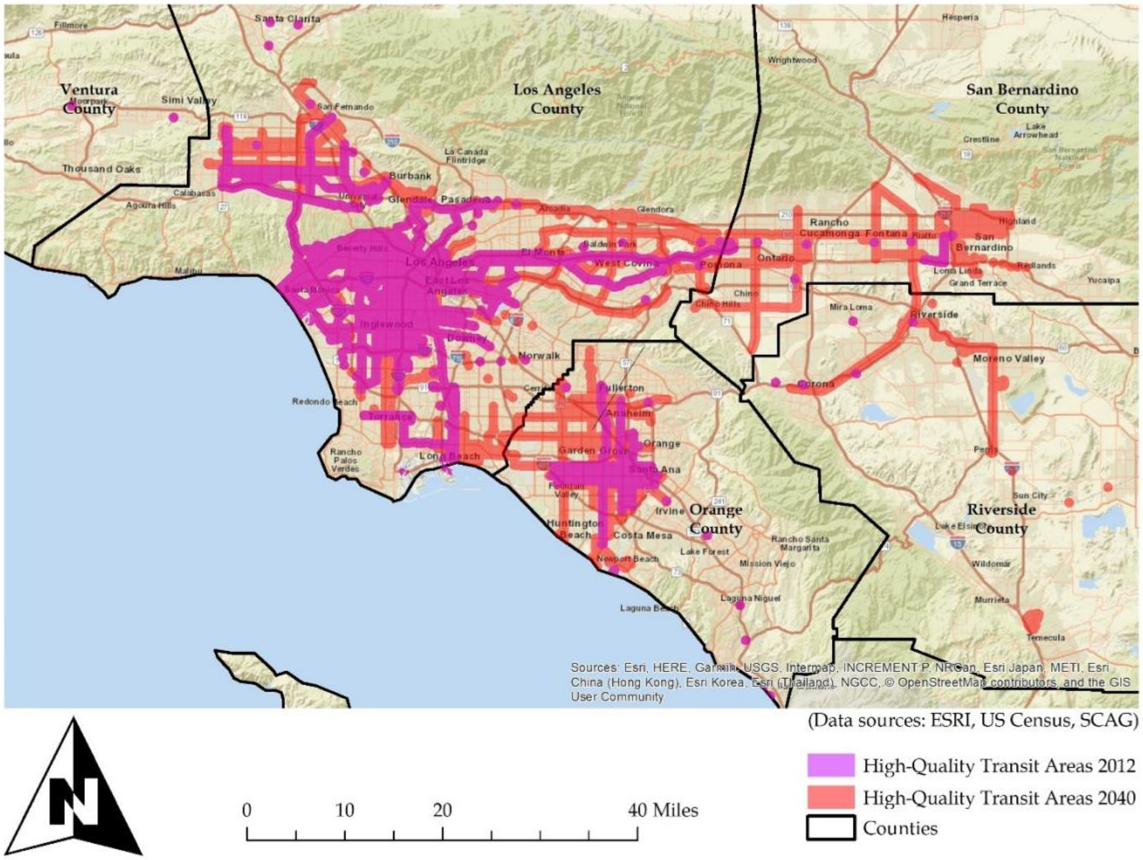
Although these studies have provided empirical evidence highlighting the importance of a wide range of factors (including detailed locational characteristics, neighborhood environments, and planning/policy contexts and interventions), the findings are not always consistent across studies. For instance, one study from the Netherlands reported that "land use densities increase[d] within designated urban development zones and areas that rich in amenities" (Broitman and Koomen, 2015, p.32). However, in his micro-level analysis of Los Angeles, Gabbe (2018) found that "[p]arcels nearer to the beach and [other amenities] … [we]re generally associated with lower odds of upzoning" (p.295). Even if such areas have the relaxation of density restrictions, other regulatory barriers could still impede substantial densification through a variety of mechanisms, including "bans on … compatible land uses … or procedural rules that add to 'soft' development costs" (Schuetz et al., 2018, p.1673).

Furthermore, the existing research is equivocal regarding the spatial distribution of densification within a region. On the one hand, it has been suggested that urban densification is more likely to occur in central locations and places associated with higher home prices, proximity to transportation corridors, and rail transit investments (see, e.g., Delmelle et al., 2014; Broitman and Koomen, 2015). On the other hand, other studies have shown that densification can take place in ex-urban areas and suburban frontiers (see, e.g., Kopits et al., 2012). It has also been reported that urban land use densification processes have been decentralized and diversified, as "densification no longer equates to urban infill, but takes many forms and occurs all over the metropolitan region, especially the urban fringe where 'new suburbanism' may be emerging" (Atkinson-Palombo, 2010, p.77). These interesting, but mixed, pieces of evidence in the literature may suggest that urban densification is highly context-dependent and that a closer look into the context-specific urban densification dynamics (and their systematic interactions with evolving zoning or planning environments) is needed to better understand this important process.

Study Area, Data, and Methodology

Study region

This project provides an empirical investigation of parcel-level land use intensification dynamics in Southern California. The study region is a large metropolitan area, including Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties, "where a broad spectrum of human settlements, ranging from urban cores to less-urbanized edges, coexist" (p.37, Kim, 2015). As briefly mentioned above, over the last several decades, the region has made efforts to promote a more compact pattern of development, while expanding its public transit system in order to achieve the sustainability goals it established (Kim and Houston, 2016). Figure 1 shows the study region with its high-quality transit areas (HQTAs) which are defined by the Southern California Association of Governments (SCAG) as "areas within one-half mile of a fixed guideway transit stop or a bus transit corridor where buses pick up passengers at a frequency of every 15 minutes or less during peak commuting hours" (p.8, SCAG, 2016).



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

(Data sources: ESRI, US Census, SCAG)

Figure 1. Study Region

As shown in the figure, the planned expansion of HQTAs will mainly take place outside of the City of Los Angeles. Table 1 provides a list of the top 30 cities in terms of the proportion of their land areas that will have great access to public transit services by 2040 (i.e., percentage of the areas included in the SCAG's HQTA 2040 boundaries). Eighteen out of the thirty cities had over 50% of their land areas identified as HQTAs in 2012, providing a great opportunity to understand how actual and planned land use patterns have changed under the influence of existing transit services. The remaining twelve cities, such as Stanton and Hawaiian Gardens, currently have limited access to high-quality public transit services, but they are expected to have a large expansion of HQTAs in the future (see table 1 for more detailed information about the HQTA coverage in 2012 and 2040).

Table 1. Top 30 Municipalities (in terms of HQTA% in 2040)

Name	Year Incorporated	HQTA% in 2040 [a]	HQTA% in 2012 [a]	HQTA% Increase, 2012-40 [a]	Population in 2010 [b]	Population in 2000 [b]	Pop. Growth%, 2000-10 [b]	Elasticity Index [c]
Lawndale	1959	100.0%	98.2%	1.8%	32,769	31,711	3.3%	0.018
West Hollywood	1984	100.0%	100.0%	0.0%	34,399	35,716	-3.7%	0.003
Gardena	1930	99.6%	32.0%	67.6%	58,829	57,746	1.9%	0.054
Maywood	1924	98.9%	98.9%	0.0%	27,395	28,083	-2.4%	0.001
Huntington Park	1906	95.5%	95.5%	0.0%	58,114	61,348	-5.3%	0.059
Santa Ana	1886	94.4%	81.7%	12.8%	324,528	337,977	-4.0%	0.005
Stanton	1956	92.7%	0.0%	92.7%	38,186	37,403	2.1%	0.014
Montebello	1920	92.0%	83.9%	8.1%	62,500	62,150	0.6%	0.051
Hawaiian Gardens	1964	91.5%	0.0%	91.5%	14,254	14,779	-3.6%	0.002
Culver City	1917	91.4%	81.1%	10.3%	38,883	38,816	0.2%	0.055
Signal Hill	1924	90.8%	20.3%	70.4%	11,016	93,33	18.0%	0.003
Inglewood	1908	90.2%	87.9%	2.3%	109,673	112,580	-2.6%	0.031
Bell	1927	87.7%	86.7%	1.0%	35,477	36,664	-3.2%	0.003
Westminster	1957	87.1%	66.0%	21.1%	89,701	88,207	1.7%	0.021
Beverly Hills	1914	83.0%	83.0%	0.0%	34,109	33,784	1.0%	0.003
Cudahy	1960	82.3%	73.7%	8.6%	23,805	24,208	-1.7%	0.002
Hawthorne	1922	77.2%	70.8%	6.3%	84,293	84,112	0.2%	0.084
Monterey Park	1916	76.1%	64.3%	11.8%	60,269	60,051	0.4%	0.091
Santa Monica	1886	75.4%	75.4%	0.0%	89,736	84,084	6.7%	0.001
Montclair	1956	75.3%	35.3%	40.0%	36,664	33,049	10.9%	0.058
Rosemead	1959	75.2%	75.2%	0.0%	53,764	53,505	0.5%	0.050
Covina	1901	74.3%	22.4%	51.9%	47,796	46,837	2.0%	0.079
El Monte	1912	74.3%	48.5%	25.8%	113,475	115,965	-2.1%	0.010
Pomona	1888	72.0%	29.4%	42.6%	149,058	149,473	-0.3%	0.053
West Covina	1923	71.4%	42.1%	29.3%	106,098	105,080	1.0%	0.076
Garden Grove	1956	71.1%	30.2%	40.9%	170,883	165,196	3.4%	0.009
Baldwin Park	1956	70.2%	46.6%	23.6%	75,390	75,837	-0.6%	0.016
South Gate	1923	69.5%	60.6%	8.9%	94,396	96,375	-2.1%	0.034
Costa Mesa	1953	67.8%	30.1%	37.7%	109,960	108,724	1.1%	0.037
Bell Gardens	1961	64.7%	62.2%	2.5%	42,072	44,054	-4.5%	0.001

[a] Calculated using 2010 jurisdictional boundaries and SCAG HQTA data layers, [b] Source: Census 2000 and 2010, [c] Source: Kim et al. (2018)

In terms of location, most of these high HQTA% cities (twenty-four out of thirty) are within Los Angeles County, while there are five municipalities located in Orange County (Santa Ana, Stanton, Westminster, Garden Grove, Costa Mesa) and one in San Bernardino County (Montclair). More importantly, all of these thirty cities are geographically inelastic, meaning that they cannot expand their jurisdictional boundaries easily as they are surrounded by other municipalities in the region (Kim et al., 2018). This territorial (locked-in) situation, combined with the fact that they have been largely built out, put them in a position to build up for future growth, and such densification (in these locations where high-quality transit services are available) would be desirable. However, this may not always take place as expected, especially when regulatory barriers exist.

Model and data

Zoning restrictions have long been viewed as a significant barrier to land use intensification (see, e.g., Knaap et al., 2007; Schuetz et al., 2018), but the restrictions do not always remain unchanged. Rather, zoning can be responsive to market demands and/or other forces (see, e.g., Pogodzinski and Sass, 1994; Gabbe, 2018). The important questions are how zoning has changed, to what extent zoning changes have led to shifts in actual land use patterns, and how changes in land use induce further zoning modifications in nearby areas.

This research project attempts to examine such complex mechanisms of land use intensification with a focus on residential densification and its association with zoning restrictions (or their relaxation over time). This is accomplished by employing a simultaneous equation model (SEM), in which explicit attention is paid to possible interactions between residential land use intensification (*Densification*) and relaxation of zoning restrictions (*Upzoning*). More specifically, a parcel-level SEM is developed, as illustrated in Figure 2, to better understand the joint determination of *Densification* and *Upzoning* dynamics between 2008 and 2016 in Southern California. While *Densification* is assumed to be determined by *Upzoning* as well as a range of other factors known to play a significant role in land use change in the literature, *Upzoning* is set as a function of *Nearby.Densification* measured in terms of the degree of residential densification in a 0.25-mile buffer area from each land parcel.

To empirically examine the *Densification* and *Upzoning* dynamics using the SEM, this project combines several sources of information for the five-county Southern California metropolitan region. Most importantly, it utilizes the fine-grained land use data layers (2008 existing land use, 2008 general plan land use, 2016 existing land use, and 2016 general plan land use layers) provided by SCAG, which (when integrated) allow us to determine the detailed changes in actual and planned land uses between 2008 and 2016 for over 4.6 million land parcels in the region. It should be noted that the general plan land use layers are assumed to reveal parcel-level zoning changes (given the limited availability of zoning data), although they are not necessarily identical to each other.

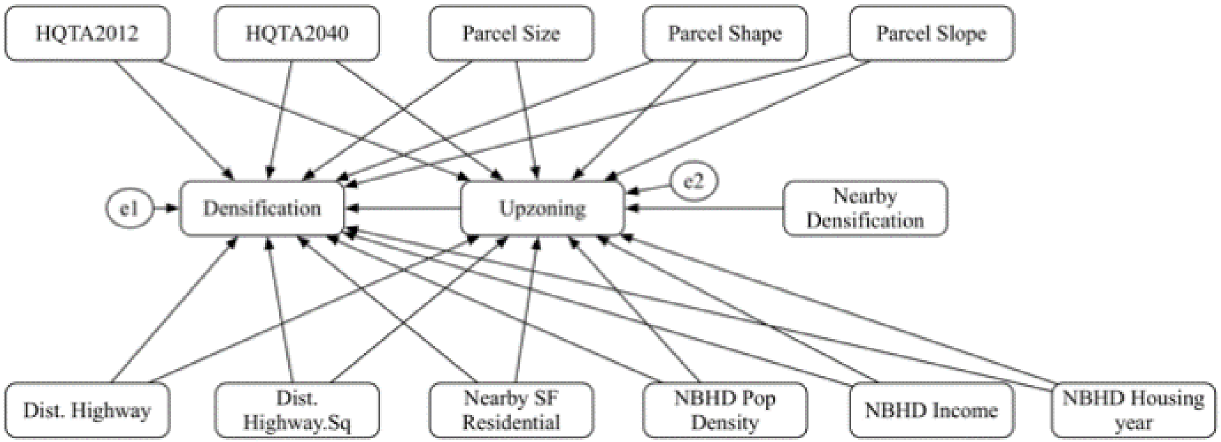


Figure 2. Model Structure

Densification and *Upzoning* are captured based on the SCAG's land use coding scheme. While urban land use intensification takes place in various forms (sometimes involving non-residential or mixed land uses), this project focuses on narrowly defined residential densification only. To be more specific, in this empirical investigation, *Densification* and *Upzoning* indicate the following changes in the existing and general plan land uses that took place during the post-recession period (2008-2016, when the real estate development became active in Southern California), respectively.[1]

- 2008: Single-family Residential (SCAG codes: 1110 and its subcategories)
- 2016: Multi-family Residential (SCAG codes: 1120 and its subcategories)

In addition, to assess the potential impacts of the (existing and future) availability of public transit services, the present work uses the SCAG's HQTA boundary shapefiles for years 2012 and 2040, presented in Figure 1 above. The boundary shapefiles and the four (parcel-level) land use layers are integrated to construct a geo-dataset for our investigation of the *Densification* and *Upzoning* dynamics. Other data are further incorporated into the dataset in order to determine what factors might influence the current and planned land use change processes and how. Table 2 summarizes all the variables and the data sources used in the present empirical analysis.

Spatial sampling and sensitivity analysis

It should be noted that parcel-level modeling of the *Densification* and *Upzoning* dynamics poses some methodological challenges, while this scale of analysis is theoretically plausible. Among others, careful consideration should be given to intrinsic spatial interdependence at this level,

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[1] In 2008, there were approximately 1.5 million parcels that were single-family residential in terms of both existing and general plan land uses, and these land parcels were used for spatial sampling and subsequence SEM analysis, as explained in the next section.

since zoning changes (as well as urban densification through redevelopment projects) often take place on a larger scale. Another methodological challenge arises due to the uneven distribution of the binary dependent variables – i.e., much smaller proportions of 1s (*Densification* in this case) than 0s (absence of *Densification*). In the literature, this type of rare event has been known to be difficult to explain or predict, and various sampling strategies have often been employed to handle such challenges and make data collection more efficient (King and Zeng, 2011).

In this project, a spatial sampling strategy has been developed to deal with these methodological issues effectively, even though several neighborhood-level and buffer-based variables are added to the model for the same purpose. As illustrated in Figure 3, our sampling approach is designed to come up with a sample having a specific ratio of 1s and 0s, while maintaining statistical randomness and distance between selected observations (land parcels). The latter part of the sampling is accomplished (as shown in the bottom of Figure 3) "through an iterative two-step process of (1) random (one) parcel selection and (2) exclusion of all nearby parcels (within a … [certain search] radius of the selected one), repeated until nothing is left in the selection pool" (Kim et al., 2018, p.49-50). As noted in Kim et al. (2018, p.50), this type of spatial sampling approach has been employed to handle potential spatial autocorrelation issues in the empirical land use literature, and it has been suggested that such a method is "effective at minimizing spatial dependence, [although] . . . results are not always robust to the sampling routines" (Brady and Irwin, 2011, p.499).

For the baseline SEM analysis, a random sample with a 1:1 ratio is drawn through the spatial sampling procedure using a 0.25-mile radius (n=1,810, which is endogenously determined by the sampling procedure when a radius is given). Additionally, the project team conducts sensitivity analysis by creating 17 additional samples with varying ratios of 1s and 0s and an alternative radius: 0.5 miles, as follows.[2]

A total of 18 samples (including one for the baseline SEM analysis) = 3 (random) sets × 3 ratios of 1s and 0s (1:1, 1:2, 1:3) × 2 radius settings (0.25, 0.5 miles)

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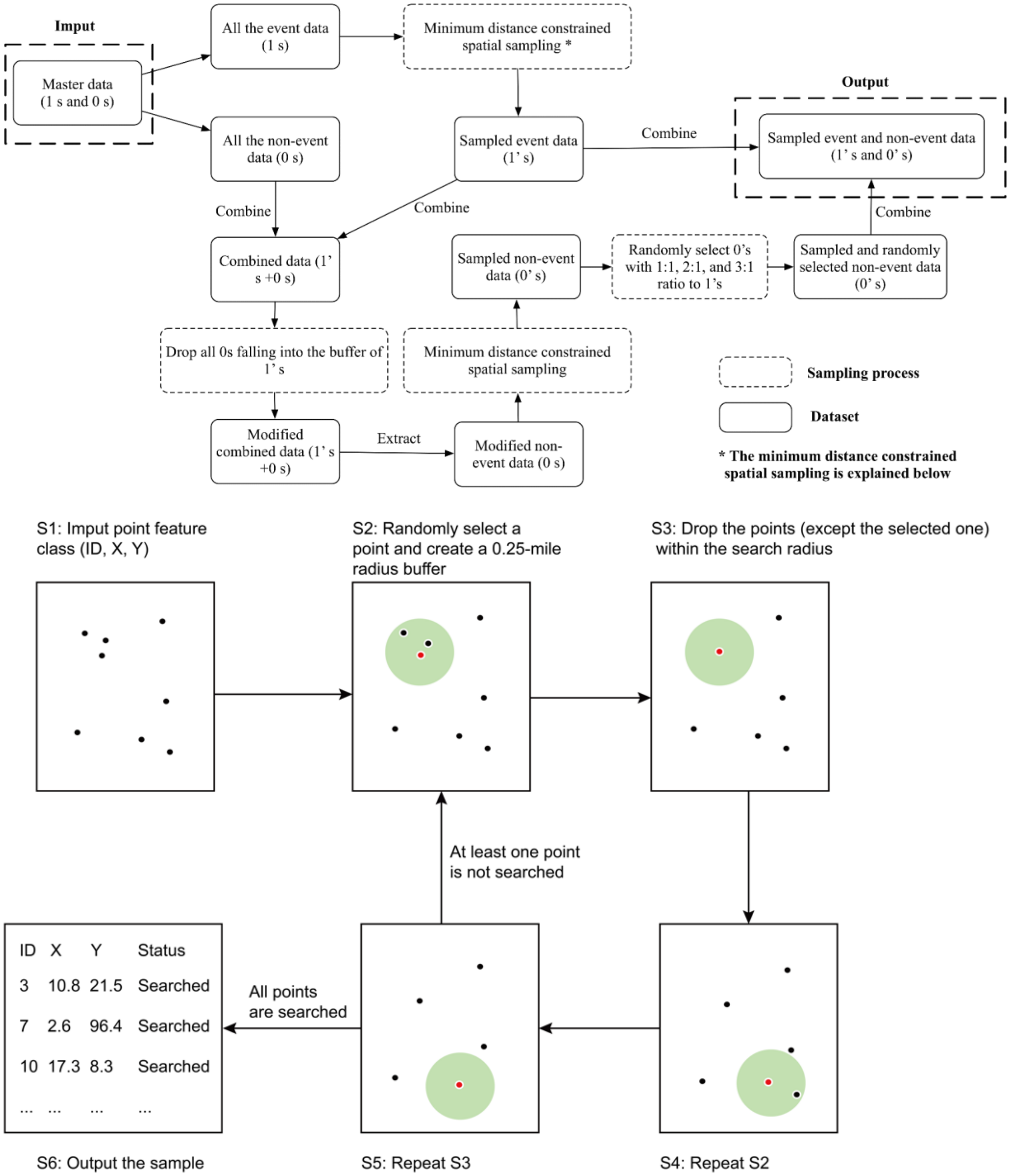
[2] See Appendix 1 for the results of the sensitivity analysis using the 18 samples generated through the procedure described in this section.

Table 2. Variables and Data Sources

Variables	Description	Data sources
Densification	1: Land use transition from single-family to multi-family residential, 0: Otherwise	SCAG [a]
Upzoning	1: General plan change from single-family to multi-family residential, 0: Otherwise	SCAG
Nearby.Densification	Proportion of densified (single-family residential) parcels in a 0.25-mile circle	SCAG
HQTA2012	1: Located within the HQTAs in 2012, 0: Otherwise	SCAG
HQTA2040	1: Located within the planned 2040 HQTAs, 0: Otherwise	SCAG
Parcel.Size	Parcel size (in square feet), logged	SCAG
Parcel.Shape	Area/perimeter ratio	SCAG
Parcel.Slope	Parcel slope	SCAG, USGS [b]
Dist.Highway	Distance to the nearest highway exit (in miles)	SCAG, ESRI [c]
Dist.Highway.Sq	Distance to the nearest highway exit (in miles) squared	SCAG, ESRI
Nearby.SF.Residential	Proportion of single-family residential parcels in a 0.25-mile circle	SCAG
NBHD.Pop.Density	Population density of the census block group in which the parcel is located	SCAG, EPA [d]
NBHD.Income	Median household income of the census tract in which the parcel is located	SCAG, Census [e]
NBHD.Housing.Year	Median housing age of the census tract in which the parcel is located	SCAG, Census

[a] Southern California Association of Governments; [b] USGS National Elevation Dataset (1/3-arc-second resolution); [c] ESRI's North America Highway Exits data layer; [d] US EPA Smart Location Database; [e] US Census American Community Survey 5-year Estimates, 2006-2010.



ID	X	Y	Status
3	10.8	21.5	Searched
7	2.6	96.4	Searched
10	17.3	8.3	Searched
…	…	…	…

Figure 3. Spatial Sampling Procedure

SEM Results

Given the binary nature of the outcome variables (i.e., *Densification* and *Upzoning*), the model estimation is performed using the GSEM (Generalized Structural Equation Model) function available in Stata 14. Specifically, the SEM is estimated through maximum likelihood with the use of the Mean and Variance Adaptive Gauss-Hermite Quadrature integration method. Our baseline model converged with six iterations, and the results are presented in Table 3.

The results shown in the table reveal the degree to which actual residential densification is in line with upzoning and the mechanisms through which public transit and other factors shape the dynamics of densification and upzoning in Southern California. Among others, the parcel-level probability of *Densification* (here narrowly defined as a transition of land use from single-family residential to multi-family residential, as noted in the previous section) is found to be significantly promoted by Upzoning (+0.206***). *HQTA2040* also has a sizable positive impact (+0.109***) on the *Densification* probability, while *HQTA2012* does not turn out to add an extra benefit in a statistically significant manner.

There are several other factors that appear to play an important role in determining the residential densification dynamics in Southern California. *Parcel.Size*, for instance, shows a positive coefficient indicating that larger single-family residential parcels were more likely to be redeveloped for multi-family residential purposes in the study region. Consistent with our expectation, *Dist.Highway* has a negative relationship with Densification. This result implies that residential densification took place near highways more frequently, while a negative coefficient on *Dist.Highway.Sq.* suggests that such a pattern of the association between densification and proximity to highways might disappear as the distance further increases.

Furthermore, it is detected that *Nearby.SF.Residential* has a negative effect on Densification. In other words, with all other conditions held constant, the probability of densification tended to be lower, if the land parcel was surrounded by single-family residential units. Two neighborhood-level variables, *NBHD.Pop.Density* and *NBHD.Housing.Year*, also yield significant estimates with an expected sign (+) suggesting that the conversion of single-family residential housing to multi-family residential units occurred in older and more populated areas.

On the side of *Upzoning*, *Nearby.Densification* (i.e., the proportion of densified, single-family residential, parcels in a 0.25-mile circle) is found to play the most influential role (+0.106***). This finding deserves attention since it suggests that the way in which *Densification* and *Upzoning* are associated with one another is not unidirectional. Instead, *Densification* and *Upzoning* can promote each other, and evidence for such reciprocal interactions can be detected when the joint dynamics are modeled explicitly (and analyzed with the data for a reasonably long period of time) as done in this project. The finding defies a conventional, one-way, view of urban land use change dynamics that fails to recognize the dynamic nature of zoning and the possibility of feedback loops: densification – relaxation of zoning restrictions – further densification in nearby areas.

Table 3. Baseline SEM Results

Variables	Densification			Upzoning		
	Est. coeff.	Std. error	z-stats.	Est. coeff.	Std. error	z-stats.
Upzoning	0.206 ***	0.055	3.77			
Nearby.Densification				0.106 ***	0.019	5.70
HQTA2012	0.040	0.032	1.25	–0.038 **	0.014	–2.79
HQTA2040	0.109 ***	0.027	4.00	0.045 ***	0.012	3.82
Parcel.Size	0.049 **	0.018	2.71	–0.001	0.008	–0.14
Parcel.Shape	–0.005	0.003	–1.72	–0.001	0.001	–0.55
Parcel.Slope	–0.003	0.003	–1.13	–0.001	0.001	–0.85
Dist.Highway	–0.034 ***	0.007	–4.71	0.001	0.003	0.39
Dist.Highway.Sq	0.001 **	0.000	2.60	0.000	0.000	–0.51
Nearby.SF.Residential	–0.108 *	0.047	–2.32	–0.086 ***	0.020	–4.32
NBHD.Pop.Density	0.013 ***	0.001	8.82	0.001	0.001	1.47
NBHD.Income	–0.024	0.029	–0.85	–0.002	0.012	–0.19
NBHD.Housing.Year	0.010 ***	0.001	13.22	0.000	0.000	0.07
Intercept	–0.055	0.352	–0.16	0.106	0.151	0.71
Count R-squared	0.786					

*** 0.1% level, ** 1% level, * 5% level significant.

The probability of residential upzoning is also found to be associated with the existing and future availability of public transit services captured using HQTA variables in this analysis. As in the case of *Densification*, *HQTA2040* again shows a substantial positive impact (+0.045***) on *Upzoning*. In contrast, *HQTA2012* turns out to have a statistically significant negative estimate (–0.038**), which should be interpreted with caution. As noted above, the SCAG's HQTA2040 boundaries include all HQTA2012 areas, and therefore *HQTA2012*=1 and *HQTA2040*=1 are assigned to all the parcels in the HQTA2012 boundaries. Thus, the negative coefficient does not simply mean that the single-family residential parcels located within the HQTA2012 areas were less likely to be upzoned, compared to those outside of any HQTA boundaries. Rather, the net impact of public transit services on these land parcels should be measured through the summation of the two HQTA estimates which is positive (+0.007=0.045–0.038), indicating that these parcels were relatively more likely to experience upzoning than non-HQTA locations.

Many other explanatory variables tested, such as *Parcel.Size* and *Dist.Highway*, do not exhibit significant effects on *Upzoning*, whereas they are found to play an important role in explaining the parcel-level *Densification* probability variation. It should be stressed, however, that *Nearby.SF.Residential* turns out to have a significant negative effect on *Upzoning* as well as *Densification*. This finding, which is consistent with our expectation, suggests that zoning (change) decisions are largely influenced by the surrounding land use patterns. It further implies that neither densification nor upzoning can easily take place in the single-family housing dominant areas.

As mentioned earlier, additional rounds of model estimation are conducted with the use of more samples drawn through a spatial random sampling procedure explained in the previous section. These sensitivity analysis results are summarized in Appendix 1, focusing on the following three main coefficients of interest in each part of the SEM:

- Densification equation: Estimates on *Upzoning*, *HQTA2012*, and *HQTA2040*
- Upzoning equation: Estimates on *Nearby.Densification*, *HQTA2012*, and *HQTA2040*

As shown in the appendix, the key findings reported above (particularly the significant, positive, bidirectional interactions between *Densification* and *Upzoning*) are upheld, even though there is a noticeable variation in some estimates and their significance levels.

Densification Hop-spots in Southern California

The SEM provides an opportunity to explore how the probability of *Densification* may vary across space within the region. Although there are some limitations (as discussed in the following section), the model enables us to calculate the predicted *Densification* probability value for each of the land parcels that were single-family residential in terms of both existing and general plan land uses in 2008. The parcel-level predicted values can further be aggregated to better inform stakeholders, as shown in Figure 4 where 1km×1km grid cells are used for effective illustration and communication.

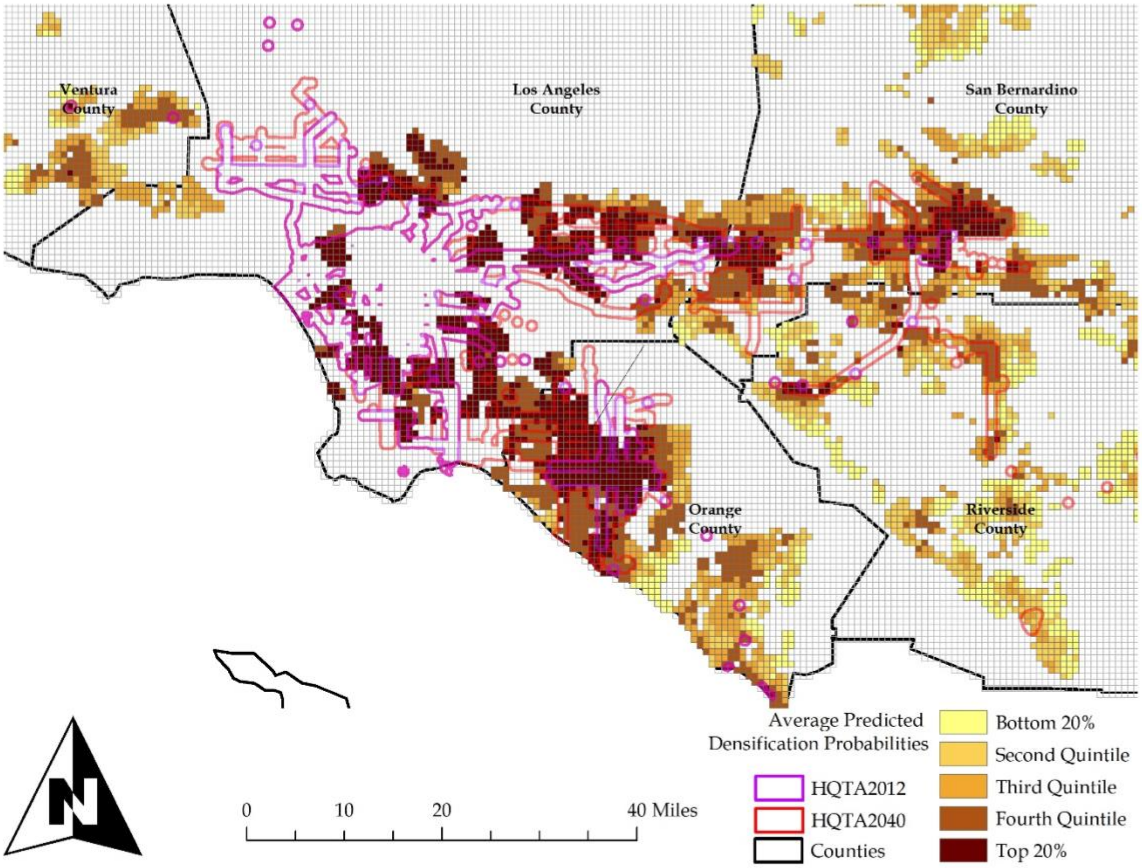


Figure 4. High Densification Probability Locations

This exercise allows us to identify potential hotspots where urban densification can be achieved more successfully in the future. It is shown that a large proportion of HQTA areas exhibit a relatively higher value of the *Densification* probability, while some other HQTA locations do not have relevant land parcels (that were single-family residential in both existing and general plan land use classifications) or turn out to have a lower predicted value, given their parcel attributes and/or locational characteristics. It is important to note, however, that there are a considerable number of grid cells with similarly high probabilities outside of the HQTA boundaries that deserve special attention.

A further aggregation of the predicted probabilities up to the municipality level reveals which cities can embrace density concentrations in the future. A majority of the high *Densification* probability cities are those with a high HQTA% listed in Table 1, including Bell, Cudahy, Huntington Park, South Gate, Monterey Park, Inglewood, and Culver City. A few other municipalities in Los Angeles County, such as Paramount, Lynwood, and Compton, are also ranked high, indicating their great potential for urban densification. Among cities outside of Los Angeles County, Santa Ana shows the highest level of the mean predicted value. As shown in Table 1, HQTAs are projected to cover nearly 95% of the City of Santa Ana by 2040.

It is possible to carry out additional probability calculations with modified values of the input variables to explore alternative scenarios, but it should be acknowledged that the (average) predicted probabilities alone do not necessarily represent the most promising areas for densification. Some of the high probability places have only a small number of single-family land parcels limiting their potential contribution to improving the overall density distribution of the region. Moreover, as noted above, the SEM used in this analysis focuses on the conversion of single-family residential to multi-family residential units, which is only one of many possible ways to achieve more compact development and promote more strategic concentration of densities in the metropolitan region.

Nevertheless, it is not meaningless to conduct such (simulation) experiments. Although not perfect, the residential densification probability surface generated based on the SEM estimates can enable us to detect where opportunities may exist. This piece of information can also support ongoing efforts to improve the distribution of densities in Southern California which has been described as dysfunctional.

Summary & Discussion

This research project attempts to bridge the gap in understanding the complex mechanisms of urban land use densification (and its connections with planned land use – or zoning – change and public transit accessibility). Even though the interplay between market forces and planning interventions has recently attracted a great deal of attention, there is a dearth of empirical research that addresses how the market–planning interplay may reconstruct urban/metropolitan spatial structure. In the context of Southern California specifically, little is known about why the dysfunctional density problems (and the lack of residential densification) have persisted and how local/regional planners can make a meaningful difference and eventually achieve more sustainable land use-transportation outcomes.

Through parcel-level SEM analysis, this project examines the joint dynamics of residential land use intensification (*Densification*) and relaxation of zoning restrictions (*Upzoning*) and shows that these two processes are, in general, mutually reinforcing. It appears that *Upzoning* can promote the probability of *Densification* significantly, although it does not always lead to an immediate market response in all locations. It is also found that *Upzoning* is more likely to take place in areas where nearby land parcels are densified (captured using a 0.25-mile buffer area from each parcel in the present analysis), and these findings are quite robust when tested with alternative samples.

The SEM results also provide some evidence of the positive influence of public transit services and their expansion in the region. Single-family residential parcels with greater access to high-quality transit services tend to exhibit a higher level of *Densification* and *Upzoning* probabilities, while there are many other (parcel- and neighborhood-level) factors that can shape the dynamics. Regarding the influence of transit, it should be emphasized that *HQTA2040* (indicating the future availability of transit services) shows significant, positive impacts both on *Densification* and *Upzoning*, suggesting that land use/development dynamics do not simply consider what is available at the time but respond to planned investments (or plan information).[3] This result is somewhat promising in that the *HQTA2040* areas still have much room to accommodate future growth and thereby contribute to improving the overall density distribution of the region.

Admittedly, this project is not without limitations. It adopts a narrow definition of residential densification and focuses on the single-family residential to multi-family residential transition. In addition, the densification and upzoning are measured in a dichotomic fashion (yes: 1 vs. no: 0) without differentiating different types or magnitudes of density increase. As noted above, urban densification can be realized through various pathways, including more dramatic conversion of land use from single-family residential (or vacant) to high-rise office buildings. Furthermore, the opposite change and downzoning, which are not covered in this project, often take place as part of the restructuring of urban/metropolitan spatial structure.

Despite these limitations, however, this project sheds new light on the complex mechanisms of urban densification by looking into the (micro-level) dynamics of residential density change and upzoning together and revealing what drives (or constraints) these processes. It would also enable planners and other policy-makers to better understand why some upzoning actions have failed to promote density increase and where more promising densification opportunities exist. Some of the findings presented here may be particularly relevant to those who seek to integrate land use and transportation planning more systematically and/or jurisdictions that have been built out and geographically inelastic (Kim et al., 2018). Future research that addresses how densification dynamics vary across jurisdictions (and why) would be extremely valuable, since such studies can not only provide additional insights into detailed mechanisms and barriers to urban land use intensification but enhance our understanding of the challenges faced by various localities in taking part in broader region-wide initiatives for sustainable urbanism.

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[3] This finding may highlight the importance of plan information examined in an earlier project of the research team (Kim and Li, 2018). For a more detailed exploration of how plans can shape urban development patterns, see e.g., Hopkins (2001), Knaap et al. (2001), Hopkins and Knaap (2018).

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Appendix 1. Sensitivity Test Results

Sensitivity Test Results – Densification

Variable	Sample	Minimum spacing 0.25 mile			Minimum spacing: 0.5 mile		
		Ratio 1:1	Ratio 1:2	Ratio 1:3	Ratio 1:1	Ratio 1:2	Ratio 1:3
Upzoning	Set 1	0.206 ***	0.262 ***	0.290 ***	0.250 **	0.324 ***	0.392 ***
	Set 2	0.278 ***	0.357 ***	0.365 ***	0.207 *	0.355 ***	0.371 ***
	Set 3	0.269 ***	0.338 ***	0.382 ***	0.220 **	0.321 ***	0.333 ***
HQTA2012	Set 1	0.040	0.082 **	0.147 ***	0.069	0.059	0.062
	Set 2	0.100 **	0.158 ***	0.186 ***	0.039	0.091 *	0.096 **
	Set 3	0.056	0.077 **	0.107 ***	0.039	0.085 *	0.121 **
HQTA2040	Set 1	0.109 ***	0.080 ***	0.064 ***	0.069	0.086 **	0.091 **
	Set 2	0.085 **	0.060 **	0.072 ***	0.131 **	0.088 **	0.083 **
	Set 3	0.066 *	0.075 **	0.066 ***	0.102 **	0.111 ***	0.091 ***

*** 0.1% level, ** 1% level, * 5% level significant.

Sensitivity Test Results – Upzoning

Variable	Sample	Minimum spacing 0.25 mile			Minimum spacing: 0.5 mile		
		Ratio 1:1	Ratio 1:2	Ratio 1:3	Ratio 1:1	Ratio 1:2	Ratio 1:3
Nearby.Densification	Set 1	0.106 ***	0.116 ***	0.120 ***	0.149 ***	0.159 ***	0.165 ***
	Set 2	0.100 **	0.110 ***	0.113 ***	0.110 ***	0.122***	0.127 ***
	Set 3	0.123 ***	0.128 ***	0.135 ***	0.109 ***	0.123 ***	0.126 ***
HQTA2012	Set 1	-0.038 **	-0.023 *	-0.014	-0.036	0.029	0.024
	Set 2	0.043 ***	0.026 *	-0.021*	0.000	0.005	0.002
	Set 3	-0.061 ***	-0.045 ***	-0.038 ***	-0.026	-0.017	0.001
HQTA2040	Set 1	0.045 ***	0.029 **	0.022 **	0.044 *	0.030 *	0.025 *
	Set 2	0.055 ***	0.039 ***	0.031 ***	0.036 *	0.024 *	0.021 *
	Set 3	0.056 ***	0.039 ***	0.034 ***	0.037 *	0.027 *	0.020 *

*** 0.1% level, ** 1% level, * 5% level significant.