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Building more housing near transit: A spatial analysis of residential densification dynamics

Abstract: Although building more housing near transit has gained increasing popularity as a strategy for addressing housing unaffordability while promoting sustainability, the effectiveness of this strategy has remained unclear, particularly in auto-oriented metropolises where land use planning authority largely rests with local governments. This article provides an analysis of how parcel-level residential land use intensification takes place under the influence of public transit expansion, with explicit attention to the interactions between current and planned land use changes, in a five-county Southern California region. The analysis using a generalized structural equation modeling approach shows that residential properties are more likely to be densified in transit-rich areas. This tendency is detected not only in the existing high-quality transit areas but also in locations where transit services will be available in the future. It is also found that relaxing zoning restrictions increases the probability of parcel-level densification, and the resultant density increase can induce further zoning or plan changes in nearby areas.

Keywords: Residential densification, Zoning, Housing, Transit

Highlights:

- Land use and zoning are jointly determined.
- Both residential densification and upzoning are more likely to take place near transit.
- Future transit accessibility appears to have a significant impact on densification dynamics.

1. Introduction

While land use and housing have never been neglected in modern transportation research and practice, recent years have seen increased emphasis on the systematic connections between transportation and land use, especially transportation-housing linkages. Profound housing challenges in many cities around the world have called for action to remove regulatory barriers to development and provide more dense and affordable units in close coordination with transportation plans (see, e.g., Levine and Inam, 2004; Guthrie and Fan, 2016; Kramer, 2018). In addition, it has been increasingly demanded that new transportation investments be made cautiously in a way that ensures housing affordability in nearby areas and thus minimizes possible displacement effects (see, e.g., Dawkins and Moeckel, 2016; Lin and Chung, 2017; Chapple and Loukaitou-Sideris, 2019).

Many of the recent planning initiatives in the state of California have exemplified this trend and the desire to overcome various challenges through a more systematic integration of transportation and land use in spatial planning processes. Among others, the state legislature passed Senate Bill 375 in 2008 and “became the first U.S. state to commit to assigning specific, mandated targets to regional transportation agencies for reducing greenhouse gas (GHG) emissions through coordinated planning for land use and transportation” (p.71, Barbour and Deakin, 2012). This legislation requires metropolitan planning organizations (MPOs) to adopt sustainable communities strategies (SCSs), as part of their regional transportation plans (RTPs), and stresses that “housing planning [should] be coordinated and integrated with the regional transportation plan” (Section 65584.04). To meet the requirements, MPOs have worked closely with local governments who are mainly responsible for housing and land use planning practice in the state. For instance, in their 2016-2040 RTP/SCS, the Southern California Association of Governments (SCAG) established the goal of "focusing new growth around transit," specifically directing approximately 50% of new housing and job growth to their High-Quality Transit Areas (HQTAs) (p.7-8, SCAG, 2016).

Over the last several years, the state has also paid special attention to the transportation-housing linkages when exploring ways to address housing unaffordability. There have been attempts by lawmakers to enact statewide legislation to tackle this critical issue. Most notably, Senate Bill 50 was proposed in an attempt to "undo California's decades-long reliance on single-family housing and suburban sprawl stretching inland by spurring a development boom near transit and job centers" (Dillon and Luna, 2020). Even though the bill failed to pass in January 2020, it has been widely assumed that transit areas present a valuable opportunity to provide more housing units through infill and redevelopment and that transit-based housing development holds great promise for the vibrancy of public transit systems and sustainable development (Cervero, 1994).

This notion is prevalent far beyond California (see, e.g., Cervero, 1998; Cao and Pan, 2016). However, despite the widespread interest in the promise of building more housing near transit, our knowledge is still limited about the complex and dynamic process of housing development in transit-rich areas. The reality of transit-based housing development can be quite different from its promise, especially when local land use authorities are exercised in a way that narrowly focuses on their own fiscal or economic interests (Boarnet and Crane, 1997). The dynamics are even more complicated and unpredictable, when it comes to the transformation of pre-developed areas in auto-oriented mature cities/regions. As Schuetz et al. (2018) suggested, auto-oriented zoning and other existing conditions can make it difficult to redevelop such areas in a way that creates desired housing opportunities sufficiently. In other words, it remains unclear whether and to what extent the promise of near-transit denser housing development is fulfilled in reality.

To fill this gap in the literature, this article provides an empirical investigation of how urban (residential) densification takes place within and outside of transit-rich areas in Southern California. More specifically, the present study examines the conversion of single-family housing to multifamily units at the parcel level. Explicit consideration is given to both current and planned land use changes and their interactions, which have often been neglected in previous micro-level studies, by employing a structural equation modeling (SEM) approach with spatial sampling. By doing so, this research attempts to provide a more nuanced understanding of the near-transit densification dynamics and lessons for building more housing in coordination with public transit decision making.

2. Literature Review

This study builds on and extends the following two lines of research in the literature: (1) the impacts of transit on land use/value and (2) the dynamics of urban densification.

2.1. Impacts of transit on land use/value

There is a significant body of literature on how transit systems shape the development dynamics in a city or region. Decades of research have examined this important question by analyzing the changes in nearby property values and/or land use patterns in relation to public transit investments or the announcement of transit development/expansion plans. In the literature, a great deal of attention has been paid to both bus and rail transit systems, and consideration has also been given to various contextual (or mediating) factors that may influence the impacts of transit systems (see, e.g., Knight and Trygg, 1977; Huang, 1996; Vessali, 1996; Stokenberga, 2014 for reviews of the literature).

Specifically, a substantial number of studies have been devoted to measuring the effects of transit investments on property values. While the detailed findings vary from one study to another, many of the empirical studies have shown that the benefits of public transit investments are capitalized into land or housing values. Koutsopoulos (1977), for instance, provided an early assessment of the impacts of transit and showed that the introduction of new bus routes in the Denver metropolitan area in 1971 increased nearby housing prices noticeably. Another notable study was conducted by Bowes and Ihlanfeldt (2001) in which the authors classified near-transit locations into several categories representing varying distances from the nearest Metropolitan Atlanta Rapid Transit Authority (MARTA) stations (less than 0.25 mile, 0.25~0.5 mile, 0.5~1 mile, 1~2 miles, 2~3 miles) in their analysis of the effects of transit on property values in Atlanta. They found that the sale prices of properties in 1~2- and 2~3-mile contour rings were significantly higher than those farther away, indicating the benefits of transit accessibility; whereas the houses located very close to a station (within 0.25 mile) appeared to receive "negative externality effects emitted by the station, such as noise, pollution, and the unsightliness of the station (especially if it includes a parking lot) ... [as well as a concern that] crime may be higher in station areas, because of the improved access to the neighborhood provided to outsiders" (p.2, Bowes and Ihlanfeldt, 2001). Using a quasi-experimental method, Gibbons and Machin (2005) also provided strong evidence for the positive impact of transit, specifically rail access, on property values. Their analysis results suggest that a reduction in the distance to the nearest station can increase house prices significantly within a certain boundary (2 kilometers in their case), because consumers tend to value travel time savings and other potential benefits that can offset the negative externalities, such as noise and crime increases, mentioned above.

To gain deeper insights into the capitalization process, Duncan (2008) compared the benefits of (rail) transit for single-family housing and condominium units using data for the San Diego region and found that condominiums tended to receive more benefits, while housing values captured the benefits of transit in both cases. In a more recent study, Zhong and Li (2016) suggested that the effects of transit on property values would also depend on other factors, including development phases and the presence/absence of park-and-ride facilities; and similarly varying effects have been reported by studies in other countries (see, e.g., Munoz-Raskin, 2010; Ma et al., 2014). Specifically, they found that "multi-family market showed large speculative appreciation toward the system during the proposed stage and then … a larger premium during the mature stage, … [but it had] little appreciation toward transit access at the newly open stage" (p.39, Zhong and Li, 2016). Such premiums, however, were not evident in the cases of single-family housing and park-and-ride stations, although the appreciation of single-family housing prices appeared to be responsive to access to heavy-rail transit.

It is important to stress that property value increases can occur even before the development (or expansion) of transit systems. Knaap et al. (2001) examined this phenomenon by analyzing vacant land sales data in Washington County, Oregon, where a new light rail system was developed in the 1990s. They found increased property values in the proposed station areas after the plan's announcement (but before the opening of the light rail system) which, according to the authors, can "discourage the development of low-density housing in the station areas, thus avoiding potentially costly redevelopment in future years, … [and] encourage high-density, transportation-oriented development" (p.38, Knaap et al., 2001). Evidence of the significance of such announcement effects has also been detected by McMillen and McDonald (2004), Cao and Porter-Nelson (2016), Ke and Gkritza (2019) and other studies, although their interpretations and perspectives differ on whether the findings can be viewed as an opportunity to guide future development near transit or an unfavorable outcome of real estate market speculation.

Building on the aforementioned studies showing the impacts of transit on nearby property values, some recent studies have paid explicit attention to how transit investments shape (micro-level) land use change dynamics. For example, Cervero and Kang (2011) assessed the land use impacts of the bus rapid transit (BRT) system in Seoul, Korea (as well as its effects on nearby property values) and found that single-family residential units were increasingly converted to multifamily housing and mixed development units near the BRT lines after the creation of dedicated bus lanes that significantly improved the performance of the BRT system. Hurst and West (2014) also reported evidence of such land use intensification near transit in their study focusing on the Metro Blue Line in Minneapolis. Similarly, Kim and Houston (2016) analyzed the detailed land use changes in Los Angeles County where its rail transit system has expanded over the last few decades and showed that parcel-level land use conversions were highly associated with the proximity to new and existing transit stations.

Although these studies have demonstrated that transit investments can have significant impacts on the intensity of land use, the land use impacts of transit are not uniform but rather context-specific. It has been suggested that the way in which public transit influences land use is largely dependent on zoning, specific plans, and various local initiatives (Loukaitou-Sideris, 2010; Kim and Houston, 2016; Schuetz et al., 2018). Little attention, however, has been directed to the mechanisms through which zoning and other contextual factors mediate the relationship between transit and land use. Furthermore, in exploring the land value/use impacts of transit, existing studies have treated zoning as an exogenously given constraint rather than capturing its dynamics over time. The present study attempts to tackle this limitation by analyzing both current and planned land use changes explicitly (see Section 3 for details).

2.2. The dynamic of urban densification

Another body of literature has examined the dynamics of urban densification, but not necessarily in relation to public transit investments.[1] In this strand of research, the focus is often on why more compact development (i.e., "building up") is needed, especially in places where "building out" is the norm; and what benefits this form of development can provide in combination with a greater mix of land uses and improved street connectivity (see, e.g., Ewing, 1997; Ewing and Hamidi, 2015). In other words, scholars have often viewed urban densification as an essential part of smart growth strategies and/or as a pathway towards achieving sustainable urbanism, while there have been calls for more critical evaluations of the pursuit of higher densities (see, e.g., Bramley et al., 2009; Lehmann, 2016; Long and Rice, 2019).

However, not much systematic investigation of the mechanisms or drivers behind urban densification has been made. Besides Cervero and Kang (2011), Hurst and West (2014), and few others mentioned above, a small number of studies have examined densification dynamics in a

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[1] There are studies that have examined how the spatial organization of population and economic activities might be shaped by investments in transportation infrastructure, including public transit systems. Although many of these studies do not focus on densification (as opposed to the growth of cities or districts), they provide useful insights into the workings of urban systems and systems of cities, more broadly. One notable study is that of Mayer and Trevien (2017) who investigated the impacts of rail transit on population, employment, and firm growth rates at the municipality level using a difference-in-differences method. See also Redding and Turner (2015) for a review of other studies.

spatially explicit manner. Some of these studies analyzed changes in lot sizes, floor-to-area ratios, dwelling units per acre, and/or housing composition to capture the detailed patterns of densification processes (see, e.g., Atkinson-Palombo, 2010; Broitman and Koomen, 2015; Kopits et al., 2012; Delmelle et al., 2014). More recent work, such as Gabbe (2018) and Kim et al. (2018), explored what facilitated or impeded the more intensive use of urban land parcels using comprehensive land use datasets, as done in this study.

It should be noted that existing research is somewhat equivocal regarding how and where densification tends to occur. While evidence of densification has often been detected in central locations and busy transportation corridors, some recent studies have challenged and defied the conventional view of the definition pattern. For instance, through an investigation of the patterns of new housing construction in Phoenix, Atkinson-Palombo (2010) showed that "[d]ensification 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 in response to the 'sustainability turn' in contemporary planning" (p.77). That is, urban densification is not a uniform process, but rather it takes place in various ways both spatially and temporally.

To what extent zoning constraints densification processes on the ground is also an open question. According to Kopits et al. (2012), zoning rules may not restrict higher density development all the time, even though housing development activities are constrained by such regulatory barriers in some areas where minimum lot size requirements are large and restrictive. Schuetz et al. (2018) also reported that "zoning may constrain redevelopment, but that TOD-compatible zoning alone will not induce development" (p.1675), suggesting that the zoning–development interplay is worthy of further investigation.

3. Research Methodology

3.1. Study area

This study focused on parcel-level residential densification dynamics in a five-county Southern California region, including Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties. This large metropolitan area has made a significant commitment in the past few decades to compact development and sustainable urbanism through a range of targeted plans and public transportation improvement initiatives. Especially in the post-2008-financial-crisis era, while experiencing a rapid rebound of the housing market, Southern California has continued to expand its public transit systems in various ways, including the construction of the Metro's Expo Line, the Gold Line Foothill Extension, and other projects. In addition, efforts have been made to redirect new growth to areas where transportation and other infrastructures are available in order to achieve the sustainability goals it established both regionally and locally (Kim and Houston, 2016). Despite all these efforts, however, this growing metropolitan region still suffers from many transportation problems, some of which can be attributed to the so-called dysfunctional density distribution (Boarnet, 2008; Eidlin, 2010).

As briefly mentioned in the introduction, a centerpiece of the region-wide planning strategies for addressing these problems is "focusing new growth around transit." To make this possible, the SCAG has identified the HQTAs, namely the "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). The designation of the HQTAs is a continuous and collaborative effort. The SCAG has updated the coverage of

HQTAs across the region with careful consideration of detailed transit information on existing transit stops/corridors and relevant future plans and worked together with transit agencies in the region to ensure the accuracy and timely delivery of the information (SCAG, 2016). Figure 1 shows the HQTA boundaries in which a significant amount of new growth will occur, if the efforts to build more housing near transit are effective, within the study region. As shown in the figure, the current HQTAs are more widely distributed in Los Angeles County compared to the other four counties. The high-quality transit service availability, however, is expected to expand substantially, particularly in Orange County and parts of the inland area (Riverside and San Bernardino counties) by 2040.

<< Insert Figure 1 about here >>

It should be noted that the control of land use is in the hands of individual municipalities, even though state-level guidelines, as well as interjurisdictional collaboration through SCAG and other venues, do exist. Not all municipalities are equally cooperative in establishing visions and planning strategies for the entire region. Rather, in this large metropolitan region with over 180 cities, land use decisions are largely influenced by each city's unique situation and municipal planning contexts (Kim et al., 2018). Recent years have witnessed rising tensions over the extent to which cities control land use and the exclusiveness of local land use power (Stahl, 2020).

3.2. Model and data

As discussed in the preceding section, it has been suggested that transit systems can increase nearby property values and induce more intensive land uses, but such a transformation (i.e., more compact development) may not necessarily take place due to various barriers, especially zoning restrictions. However, local zoning ordinances are not fixed or temporally invariant, although the dynamic nature of zoning has often been neglected in previous studies. Rather, zoning is endogenously determined often in response to market demands or other evolving factors (see, e.g., Pogodzinski and Sass, 1994; Evenson and Wheaton, 2003; Gabbe, 2018). In other words, urban densification takes place in conjunction with zoning changes, and a more complete understanding of the urban densification process in transit-rich areas can be obtained when explicit consideration is given to the interplay between actual land use and zoning changes.

In California, every locality is required to update its housing and land use plans to provide its fair share of regional housing needs determined through the state's unique housing needs allocation process which is repeated every eight years (Lewis, 2005; Clare, 2019). For this and other reasons, local governments periodically change their zoning and land use plans, although this process is often contentious involving homeowners, developers, and other stakeholders who do not necessarily agree with the changes. Such actions, especially upzoning, can lead to the redevelopment of some single-family residential land parcels. In turn, the resultant land use change, namely residential densification, can further influence the planned use of nearby locations, even though, again, this is a political process in which various stakeholders are involved. This may happen because multifamily housing is often separated from single-family homes rather than being mixed up to combat segregation (Baar, 1996; Owen, 2019).

This process can be expressed, as follows. First, *Densification* of a land parcel *i* can be viewed as a function of *Upzoning*, transit, and other sets of potential determinants (*X*) that can increase or decrease the profitability of redeveloping the parcel.

$$Densification_i = f(Upzoning_i, Transit_i, X_i) \qquad (1)$$

Second, as discussed above, *Upzoning* of a parcel *j* may be influenced to some extent by the degree to which *Densification* takes place in areas surrounding the land parcel. In other words, it can be set as a function of *Nearby.Densification*, as well as transit and other factors (*Z*) as shown below, where *Nearby.Densification* indicates the proportion of nearby (single-family) residential land parcels that are converted to multifamily housing.

$$Upzoning_j = g\left(Nearby.Densification_j, Transit_j, Z_j\right) \qquad (2)$$

Based upon this conceptualization of the process, in this study, a parcel-level model of urban densification is developed to examine the simultaneous determination of (1) the residential land use intensification (*Densification*) and (2) the relaxation of zoning restrictions (*Upzoning*) from 2008 to 2016, while capturing the effects of transit and other factors on the two processes. Figure 2 shows the model structure designed to capture the dynamic process in which *Upzoning* is assumed to have an impact on *Densification*; and *Densification*, if it occurs, can possibly induce *Upzoning* in nearby areas. Given that the model has two noncontinuous variables (i.e., parcel-level *Densification* and *Upzoning*), its estimation requires a generalized structural equation model (GSEM) estimation technique that allows for more flexible forms of response variables and nonnormal error distributions. Specifically, the model can be estimated using the widely used mean-variance adaptive Gauss-Hermite quadrature integration method based upon Rabe-Hesketh et al. (2005).

<< Insert Figure 2 about here >>

While the data used in this study were from multiple sources, the key variables are constructed by combining the following four GIS data layers provided by the SCAG: (1) the 2008 existing land use, (2) the 2016 existing land use, (3) the 2008 general plan land use, and (4) the 2016 general plan land use data layers. The combined database allows one to investigate the fine-grained actual land use change and planned land use change in an 8-year time period, during which housing construction activities were active in Southern California, for over 4.6 million land parcels in the region. In this study, *Densification* and *Upzoning* are coded in a binary manner, as follows, for each of the approximately 1.5 million land parcels that were used for single-family housing units in 2008.

- 1: if the parcel's land use was converted from single-family residential (SCAG codes: 1110 and its subcategories) to multifamily residential (SCAG codes: 1120 and its subcategories) in terms of existing land use (*Densification*) or general plan land use (*Upzoning*)[2] from 2008 to 2016
- 0: otherwise

In other words, the present analysis focuses on the transformation of single-family housing to multifamily units, which have been crucial to housing affordability and equity in this region, while urban densification can take place in other forms. Single-family homes have long been a dominant form of housing in the U.S. with the prevalence of the so-called R1 zoning which has been criticized by an increasing number of recent studies, such as Manville et al. (2020) and Wegmann (2020). Constructing multifamily units, in contrast, often has to deal with regulatory barriers and NIMBYism (see, e.g., Pendall, 1999; Knaap et al., 2007; Kim et al., 2020). Converting single-family residential parcels to multifamily housing can be more difficult in part due to the delays, price premium, and transaction costs involved in land assembly and redevelopment processes (Brooks and Lutz, 2016).

To distinguish transit-rich areas from other locations in investigating the residential densification dynamics, this study uses both the current and future HQTA boundaries provided by the SCAG (Figure 1). As mentioned above, the HQTAs are areas, delineated based upon the

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[2] Although general plan land use is not identical to zoning, it provides a good proxy for capturing detailed zoning changes. The state law of California requires that zoning be consistent with the maps and policies in local general plans.

current and projected transit service levels, where new development needs to be directed to achieve the goal of building more housing near transit. These transit-rich areas have expanded in an incremental and path-dependent fashion, as the region's public transit system has grown over the last several decades (see, e.g., Barret, 2006; Kim and Houston, 2016).

Consideration is also given to a range of other determinants that were found to be significant in shaping parcel-level land use change in the literature. These control variables include each parcel's physical characteristics, locational attributes, and neighborhood conditions, all of which are summarized in Table 1. It is worth mentioning that *Nearby.SFResidential.Ratio* is included to capture the composition of surrounding land uses from each land parcel. If a parcel is located within a single-family dominant area, the probabilities of upzoning and densification can be lower due to the opposition of homeowners or other barriers to mixing housing types (see, e.g., Perrin and Grant, 2014; Brewer and Grant, 2015; Owen, 2019), as briefly mentioned above. *NBHD.Pop.Density*, *NBHD.HH.Income*, and *NBHD.Housing.Age* are additionally taken into account to differentiate areas with varying neighborhood qualities and development trajectories.

<< Insert Table 1 about here >>

3.3. Spatial sampling and sensitivity analysis strategies

There are two methodological challenges that require special treatment in estimating the model to elucidate the mechanisms of parcel-level land use intensification dynamics. The first challenge is spatial autocorrelation that often arises in analyzing land use change dynamics at the parcel level (see, e.g., Carrion-Flores and Irwin, 2004; Huang et al., 2009; Brady and Irwin, 2011). The second challenge is associated with the uneven distribution of 1s and 0s for the binary outcome variable, namely, rare events (many more 0s than 1s in the dataset), which are known to be difficult to predict or explain effectively without appropriate data sampling schemes.

To deal with these challenges, this study employs a spatial sampling procedure, as shown in Figure 3. The goal is two-fold: First, it attempts to avoid the use of observations located in close proximity to one another to mitigate the spatial autocorrelation issue. This approach, used by Nelson and Hellerstein (1997) and subsequent studies, is effective in dealing with spatial autocorrelation when analyzing micro-level land use change dynamics by intentionally dropping nearby data points that are likely to cause spatial error dependence due to unobserved spatially correlated variables or other reasons (p.499, Brady and Irwin, 2011). In this study, as illustrated in Figure 3, the third step of the sampling procedure ensures that all the land parcels included in the sample are apart from each other by a certain distance (i.e., 0.25 and 0.5 miles for sensitivity analysis). Second, it is attempted to have enough 1s (i.e., densified land parcels) in the sample for the model estimation. To accomplish this, given that densification is a rare event, the sampling procedure here is designed to (1) first select densified land parcels (1s) in a random fashion with the minimum distance and (2) then choose a matched number of non-densified parcels (0s) in the same manner, as presented in Figure 3.[3] By doing so, this spatial sampling approach provides a desired ratio of 1 and 0 observations, all of which are spaced apart from each other, while ensuring statistical randomness as much as possible in the iterative selection process, as done in Kim et al. (2018).

<< Insert Figure 3 about here >>

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[3] According to King and Zeng (2001), the marginal contribution of an extra zero observation diminishes as the number of 0s passes the number of 1s in the sample. Therefore, a commonly used practice in determining the ratio of 1s and 0s is sequential, “involving first the collection of all ones and an equal number of zeros” (King and Zeng, 2001, p.143).

Using the sampling procedure, this study first draws a 1:1 sample with a minimum distance of 0.25 miles between the chosen data points for its baseline analysis. Since a single sample is unlikely to enable one to form a robust conclusion, this study creates additional samples and estimates the model with a total of 18 samples to check the sensitivity of the GSEM estimation results. This is accomplished by generating three (quasi-random) samples for each of the following six (3×2) parameter settings: three different ratios of 1s and 0s (1:1, 1:2, and 1:3) combined with two minimum distances (0.25 and 0.5 miles).

4. Results

The model is estimated via maximum likelihood using a mean and variance adaptive Gauss-Hermite quadrature integration method, and three versions of the baseline analysis results are presented in Table 2. As seen in the table, all three versions of the baseline model estimation show evidence of the systematic connections between *Densification* and *Upzoning* and the influence of HQTA variables on the densification dynamics, which can be summarized as follows.

<< Insert Table 2 about here >>

First, *Densification* and *Upzoning* appear to reinforce each other at the parcel level. Specifically, the probability of residential *Densification* is found to be significantly increased by *Upzoning*, suggesting that relaxing zoning restrictions can promote the conversion of single-family housing to multifamily units, although it does not always lead to densification of the parcel. In addition, the results indicate that *Upzoning* is more likely to occur when surrounding areas are densified (i.e., a higher value of *Nearby.Densification*). In other words, zoning change is dependent on nearby land use changes. This finding may also imply that densification can generate a sort of ripple effect over space: densification of a parcel (say *i*) – upzoning of a nearby parcel (say *j*) – densification of *j*.

Second, the availability of high-quality transit services (*HQTA.Current*) seems to increase the probability of parcel-level residential *Densification* by over 10 percent, suggesting that the densification activities are much more active in transit-rich areas. The variable is also positively associated with *Upzoning*, indicating that zoning restrictions are more likely to be removed within the HQTA boundaries, all other things being equal. However, the magnitude of the coefficient is much smaller than that of its impact on *Densification.* In fact, when all control variables are included, the estimated coefficient turns out to be statistically insignificant in this case.

Last but not least, the future availability of transit services (*HQTA.Future*) is found to have a significant positive association with both *Densification* and *Upzoning*. The coefficients remain substantial and statistically significant even when the influences of various other variables, including the proximity to highways, are controlled for. This finding, which is consistent with those from Knaap et al. (2001) and a few other studies on the so-called announcements effects, suggests that the information about future transit availability, when disseminated, can guide development processes in the field. Furthermore, it reveals the alignment of the future transit investment plans with zoning changes that can induce more residential densification in subsequent years.

The results also show that there are several other factors playing important roles in determining micro-level residential densification dynamics. *Parcel.Size* is positively associated with *Densification* since it would be more financially attractive to convert larger land parcels to multifamily units than assembling many small single-family residential parcels. The negative coefficient on the distance from highways (*Dist.Highways*), combined with the positive but much smaller influence of *Dist.Highways.Sq,* indicates that residential densification is more likely to take place in highway corridors, even though the effect of the proximity to highways may disappear in a quadratic fashion as the distance increases further.

More importantly, the proportion of nearby single-family residential land parcels (*Nearby.SFResidential.Ratio*) shows a negative association with *Densification*. This finding indicates the separation of multifamily and single-family housing units, a notable pattern of American metropolises reported by Baar (1996), Owens (2019), and other studies. Despite ongoing efforts to combat residential segregation, this tendency seems to persist at the micro level. One can also interpret the result as an indication that spot-densification is rare, and multifamily housing development tends to be clustered perhaps due to scale economies.

Other neighborhood-level variables, such as the population density (*NBHD.Pop.Density*) and median age of housing (*NBHD.Housing.Age*), are also found to be highly associated with the probability of residential densification in an expected manner, that is, the redevelopment of single-family residential parcels for multifamily housing units is more likely to occur in older and more populated areas. Similarly, the patterns of the estimates of the county dummy variables are consistent with the expectation that *Densification* would occur less frequently in peripheral counties (Riverside, San Bernardino and Ventura counties) where the incentive to redevelop single-family housing tends to be low since vast amounts of undeveloped space are available there.

In addition to the baseline analysis, as noted in the previous section, sensitivity analysis is conducted with additional samples. Here, the key issue is to what extent the major findings reported above, particularly (1) the reciprocal interactions between *Densification* and *Upzoning* and (2) the significance of the HQTA variables, still exist when new samples are used. Whether a certain sampling parameter (e.g., an increased minimum distance between the selected observations or a change in the ratio of 1s and 0s) would change the analysis results is also of interest.

Tables 3 reports the key results from the eighteen sample sets, including the baseline. The results are largely consistent with what was found through the baseline GSEM analysis. Specifically, evidence of the bidirectional interplay between *Densification* and *Upzoning* is strong regardless of the sampling parameters used. The coefficients of the HQTAs are also found to be quite robust, although there is some variation in the magnitude and significance level of the estimates.

<< Insert Table 3 about here >>

5. Conclusion

Transforming auto-oriented metropolises, such as Los Angeles and its vicinity, into more transit-friendly environments is an arduous process. Challenges can arise in many ways, especially in areas where land use planning authority largely rests with the local government and thus systematic inter-governmental coordination is required. Public transit service expansions are not always welcomed (see, e.g., Dixit et al., 2010; Manville and Cummins, 2015). Additionally, rigid zoning restrictions often prevent communities from realizing the benefits of building more housing near transit.

Nevertheless, transit-rich areas present valuable opportunities to create activity centers and encourage a more sustainable form of development, and the findings of this study generally support this view. As explained in the previous section, all other things being equal, the single-family residential land parcels with better access to transit services showed a higher probability of densification (i.e., being converted to multifamily housing units). These land parcels also exhibited an increased probability of upzoning during the study period. Moreover, *HQTA.Future* (indicating the locations where public transit services are expected to be available in the future) was also found to be positively associated with these (residential) densification and upzoning processes. This finding, which is in part attributable to the forward-looking nature of real estate development decision-making, shows the complexity of (micro-level) land use change dynamics. From a policy-making point of view, it underscores the importance of transportation plan making and announcement in guiding land use/development decisions and thus creating more sustainable and inclusive communities.

The present parcel-level analysis also highlights the possibility of reciprocal interactions between urban residential densification and the relaxation of zoning restrictions. It appears that upzoning can increase the likelihood of denser development, although it does not always trigger immediate land use changes, such as the conversion of single-family housing to multifamily units, in all locations. In addition, these zoning changes tended to take place in locations where the surrounding areas are densified, indicating that land use intensification and zoning change processes interacted in a mutually reinforcing way at this geographical scale. This means that market forces and planning actions are tightly interwoven. The joint dynamics, however, do not necessarily act in a way that leads to a more desirable outcome. Rather, it depends on how we manage the dynamics in envisioning a better future and taking action to promote accessibility, affordability, and equity in the provision of housing and transportation services.

It is important to acknowledge some limitations of this study. The present analysis focused on residential densification, specifically, the conversion of single-family housing to multifamily units, measured in a binary fashion. No consideration was given to other forms of urban densification, such as the reuse of underperforming retail or industrial sites for high-density residential or commercial purposes, that are equally important in understanding the full picture of the transformation of a metropolitan spatial structure. Also excluded was land use change in an opposite direction (or downzoning) that can take place as part of the complex transformation that many contemporary metropolises undergo.

Furthermore, as in many other studies focusing on a single region, to what extent the findings here are applicable to other regions remains unresolved. Related to this, one could raise a question about potential endogeneity between transit and land use decision making processes, which was not addressed in this study. The endogeneity issue is likely to be more critical in regions where land use and transit decisions are jointly made by a single agency or at the same decision level. Some regions may have detailed land use and transit data for every year and thus provide an enhanced opportunity to examine the dynamics in a more precise manner. Due to the limited data availability for the entire region, this study analyzed changes over 8-year period (from 2008 to 2016) in an aggregated fashion, and additional explanatory variables could be tested given greater data availability.

Despite the limitations, however, this study extends the literature by examining the parcel-level dynamics of urban densification and zoning change together with explicit attention given to the important role of transit availability in shaping the two processes. Even though what is presented here (with a focus on Southern California) may not necessarily hold true in other contexts, the findings can inform ongoing efforts to better integrate transportation and land use decision-making and better deal with the housing shortages and associated challenges prevalent in many cities/regions around the world. Building more housing near transit is a promising agenda, but it requires coordination and planning. Future research that addresses the aforementioned limitations would contribute to closing the knowledge gap and support turning vision into action.

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Table 1. Variables and Data Sources

Variable name	Description	Data sources
Densification	1: Land use transition from single-family to multifamily residential, 0: Otherwise	SCAG [a]
Upzoning	1: General plan change from single-family to multifamily residential, 0: Otherwise	SCAG
Nearby.Densification	Proportion of densified (single-family residential) parcels in a 0.25-mile circle	SCAG
HQTA.Current	1: Located within the HQTAs in 2012, 0: Otherwise	SCAG
HQTA.Future	1: Located within the planned 2040 HQTAs but not in the HQTA.Current, 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.Highways	Distance to the nearest highway exit (in miles)	SCAG, ESRI [c]
Dist.Highways.Sq	Distance to the nearest highway exit (in miles) squared	SCAG, ESRI
Nearby.SFResidential.Ratio	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.HH.Income	Median household income of the census tract in which the parcel is located, logged	SCAG, Census [e]
NBHD.Housing.Age	Median housing age of the census tract in which the parcel is located	SCAG, Census
County.Orange	1: Located in Orange County, 0: Otherwise	SCAG
County.Riverside	1: Located in Riverside County, 0: Otherwise	SCAG
County.SanBernardino	1: Located in San Bernardino County, 0: Otherwise	SCAG
County.Ventura	1: Located in Ventura County, 0: Otherwise	SCAG

[a] Southern California Association of Governments; [b] USGS National Elevation Dataset; [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.

Table 2. Baseline Analysis Results

Variables	Model #1		Model #2		Model #3	
	Densification	Upzoning	Densification	Upzoning	Densification	Upzoning
Upzoning	0.274 *** (4.49)		0.206 *** (3.77)		0.178 *** (3.34)	
Nearby.Densification		0.117 *** (6.39)		0.106 *** (5.70)		0.108 *** (5.46)
HQTA.Current	0.488 *** (16.91)	0.022 * (2.02)	0.148 *** (4.96)	0.007 (0.51)	0.109 *** (3.68)	0.006 (0.44)
HQTA.Future	0.326 *** (11.60)	0.052 *** (4.82)	0.109 *** (4.00)	0.045 *** (3.82)	0.094 *** (3.50)	0.045 *** (3.81)
Parcel.Size			0.049 ** (2.71)	-0.001 (-0.14)	0.059 *** (3.36)	-0.002 (-0.20)
Parcel.Shape			-0.005 (-1.72)	-0.001 (-0.55)	-0.006 * (-2.08)	-0.001 (-0.54)
Parcel.Slope			-0.003 (-1.13)	-0.001 (-0.85)	-0.002 (-0.62)	-0.001 (-0.71)
Dist.Highways			-0.034 *** (-4.71)	0.001 (0.39)	-0.028 *** (-3.92)	0.002 (0.59)
Dist.Highways.Sq			0.001 ** (2.60)	-0.000 (-0.51)	0.001 * (2.18)	0.000 (-0.68)
Nearby.SFResidential.Ratio			-0.108 * (-2.32)	-0.086 *** (-4.32)	-0.061 (-1.33)	-0.082 *** (-4.07)
NBHD.Pop.Density			0.013 *** (8.82)	0.001 (1.47)	0.008 *** (4.92)	0.001 (0.96)
NBHD.HH.Income			-0.024 (-0.85)	-0.002 (-0.19)	-0.177 *** (-5.51)	-0.008 (-0.56)
NBHD.Housing.Age			0.010 *** (13.22)	0.000 (0.07)	0.006 *** (6.67)	0.000 (-1.00)
County.Orange					0.005 (0.19)	-0.017 (-1.37)
County.Riverside					-0.261 *** (-6.52)	-0.031 (-1.78)
County.SanBernardino					-0.306 *** (-8.77)	-0.020 (-1.31)
County.Ventura					-0.158 ***	-0.031

					(-3.65)	(-1.66)
Intercept	0.344 ***	0.007	-0.055	0.106	1.896 ***	0.205
	(25.70)	(1.41)	(-0.16)	(0.71)	(4.75)	(1.17)
Log likelihood	-520.5		-286.1		-234.9	
AIC	1060.9		628.3		541.9	
BIC	1115.9		782.3		739.9	
Efron’s R-squared	0.179		0.357		0.458	

*** 0.1% level, ** 1% level, * 5% level significant. Numbers in parentheses are z-statistics. *n*=1,810.

Table 3. Sensitivity Analysis Results

Outcomes	Variables	Sample	Minimum distance: 0.25 mile			Minimum distance: 0.5 mile		
			Ratio 1:1	Ratio 1:2	Ratio 1:3	Ratio 1:1	Ratio 1:2	Ratio 1:3
Densification	Upzoning	#1	**0.178** ***	0.237 ***	0.263 ***	0.216 **	0.286 ***	0.357 ***
		#2	0.231 ***	0.308 ***	0.327 ***	0.170 *	0.317 ***	0.342 ***
		#3	0.238 ***	0.312 ***	0.360 ***	0.197 **	0.297 ***	0.309 ***
	HQTA.Current	#1	**0.109** ***	0.121 ***	0.172 ***	0.085	0.100 *	0.111 **
		#2	0.142 ***	0.173 ***	0.218 ***	0.127 **	0.136 ***	0.133 ***
		#3	0.084 **	0.115 ***	0.141 ***	0.113 **	0.167 ***	0.182 ***
	HQTA.Future	#1	**0.094** ***	0.072 ***	0.060 ***	0.046	0.074 *	0.082 **
		#2	0.073 **	0.055 **	0.070 ***	0.112 **	0.075 *	0.075 **
		#3	0.063 *	0.069 **	0.062 ***	0.095 *	0.109 ***	0.090 ***
Upzoning	Nearby.Densification	#1	**0.108** ***	0.120 ***	0.123 ***	0.154 ***	0.162 ***	0.167 ***
		#2	0.102 ***	0.110 ***	0.114 ***	0.117 ***	0.125 ***	0.131 ***
		#3	0.122 ***	0.130 ***	0.137 ***	0.116 ***	0.129 ***	0.130 ***
	HQTA.Current	#1	**0.006**	0.005	0.006	0.004	-0.003	-0.003
		#2	0.011	0.010	0.007	0.034	0.027 *	0.021
		#3	-0.007	-0.008	-0.005	0.009	0.008	0.018
	HQTA.Future	#1	**0.045** ***	0.029 ***	0.022 **	0.045 **	0.030 *	0.024 *
		#2	0.056 ***	0.040 ***	0.031 ***	0.038 *	0.025 *	0.021 *
		#3	0.057 ***	0.039 ***	0.034 ***	0.038 *	0.027 *	0.020 *

*** 0.1% level, ** 1% level, * 5% level significant. Bold underlined indicates the baseline results.

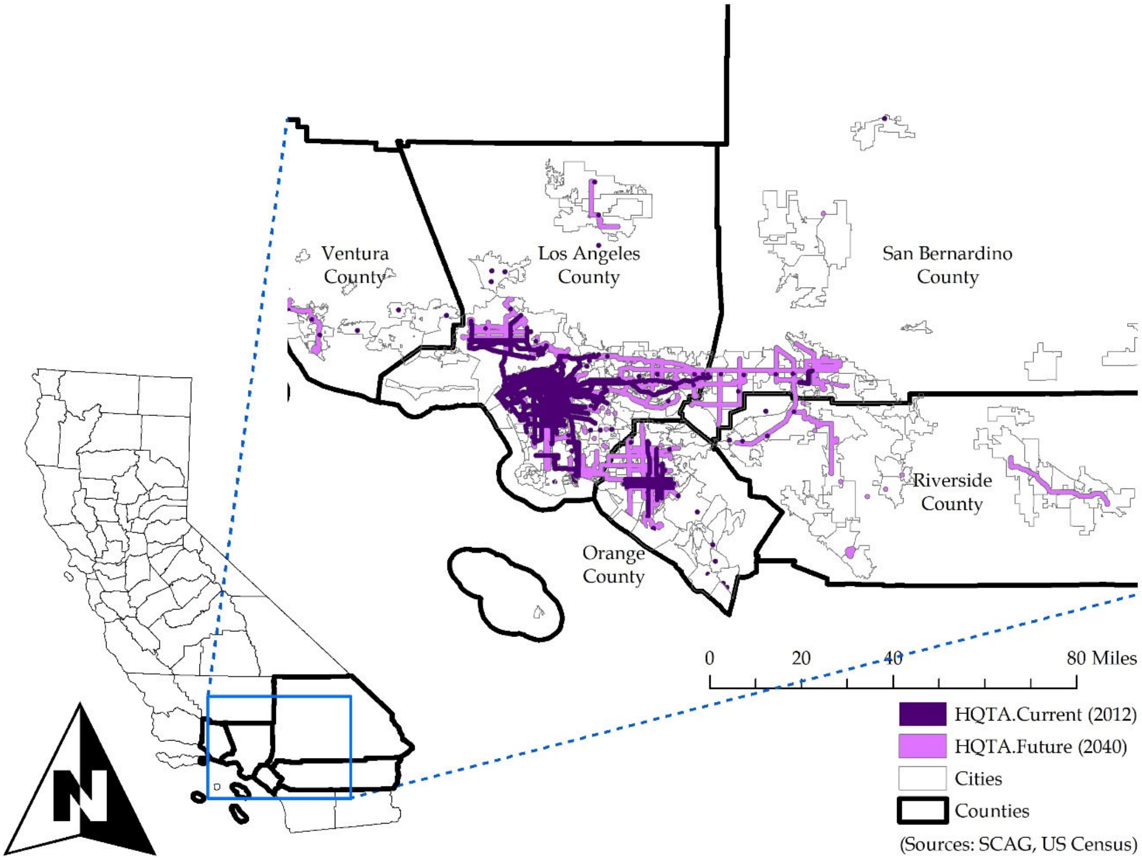

Figure 1. Study Region

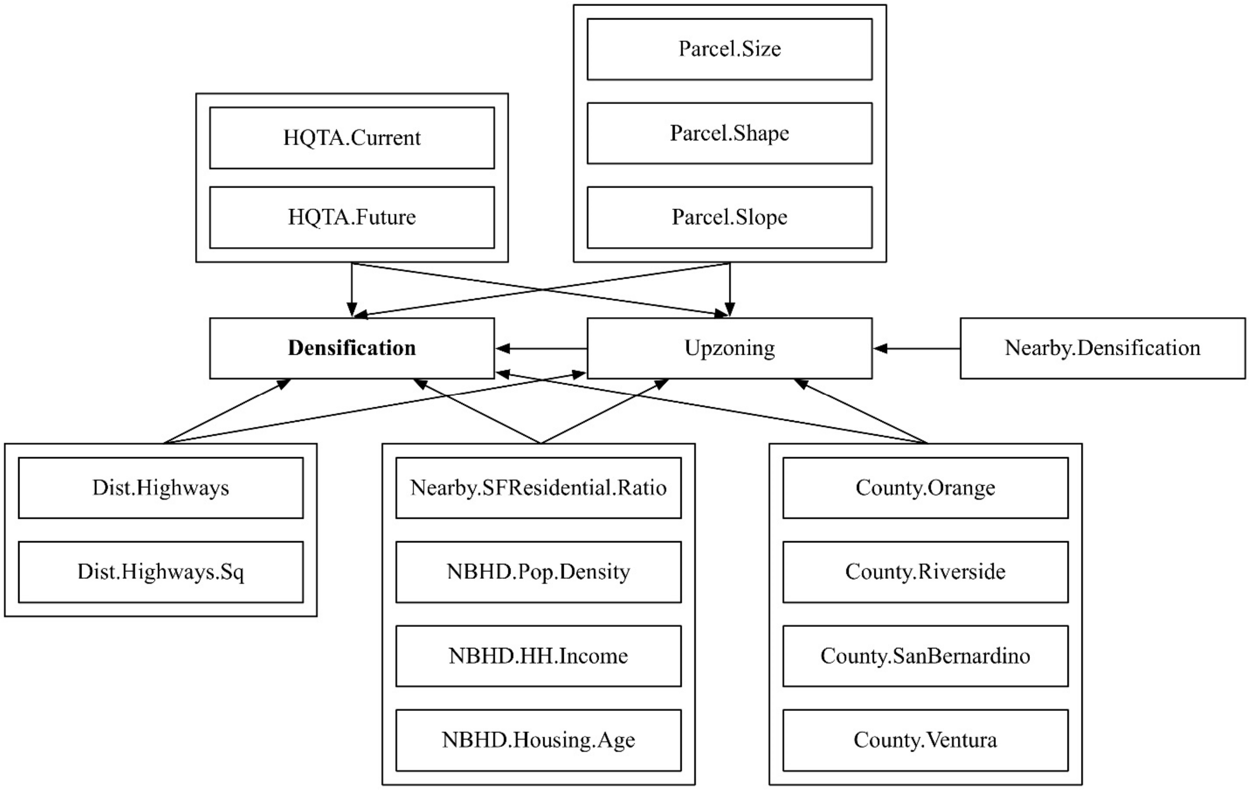

Figure 2. Model Structure

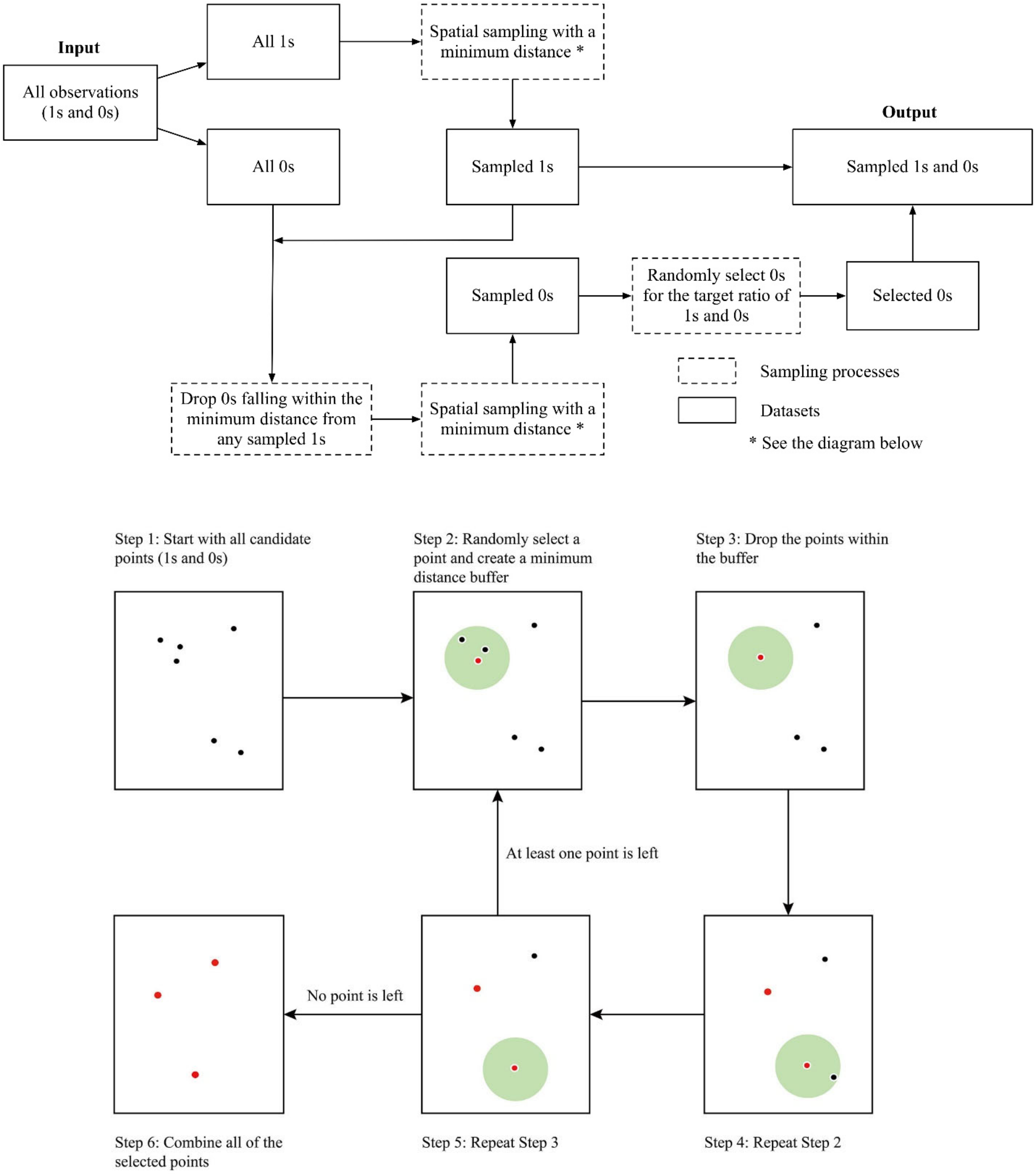

Figure 3. Sampling Procedure