A National Zoning Atlas to Inform Housing Research, Policy, and Public Participation

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Abstract

Through a unique combination of data science and legal analysis techniques, the National Zoning Atlas is creating the first public, online repository of standardized data about zoning. This article first discusses the context for and methodology behind the atlas. It then establishes three possibilities for using the atlas, including facilitating research (including fair housing research), strengthening planning, and empowering the public.

Introduction[1]

Thousands of local governments in the United States have exercised their power to adopt zoning codes through the legal framework articulated by the 1920s-era Standard State Zoning Enabling Act (SSZEA). The U.S. Department of Commerce drafted and promoted the SSZEA during a period of rapid urban growth in the United States. This federal effort ultimately led to all 50 state legislatures adopting fairly uniform statutes based on the SSZEA, which enabled local governments to control local land use. Uniformity at the state level did not lead to uniformity at the local level. Rather, the SSZEA's drafters anticipated—in fact, required—local governments to individually adopt codes. In drafting zoning codes, officials explicitly recognized various localized conditions, including geography, economic development, community preferences, and variation in juridical

[1] This article draws from a web publication, "An Invitation to Collaborate on a National Zoning Atlas," written for the 2022 Harvard Joint Center for Housing Studies *Bringing Digitalization Home: How Can Technology Address Housing Challenges?* Symposium, with the permission of the sponsors of that symposium.

interpretations (Eagle, 2005; Puentes, Martin, and Pendall, 2006). A century later, the fragmented zoning landscape has challenged our ability to understand zoning in detail and at scale.

Despite the significance of zoning, few people know much about how it operates where they live. Each jurisdiction's zoning laws are unique in terminology, structure, numerical standards, and regulatory scope, making them hard for a layperson to interpret easily. Moreover, codes can be difficult to locate, often embedded within an obscure chapter in municipal code; some are not even available online. This cross-jurisdictional inconsistency and inaccessibility pose challenges for scholars, policymakers, and the broader public. From a scholarly perspective, a lack of standardized information about zoning makes secondary research, including fair housing research, difficult. From a policy perspective, a lack of understanding of current zoning codes hinders the ability to identify, explain, and justify reforms for the future. For members of the public who simply wish to learn the rules in their communities, zoning remains hopelessly opaque.

Launched in 2022, the National Zoning Atlas has emerged to address these information gaps in service of better research, policy, and public participation outcomes. The atlas depicts key regulatory features of zoning codes in a free, online, user-friendly map. Its methodology requires close reading of zoning code texts to extract regulatory characteristics—such as the allowable number of units, height caps, and public hearing requirements—for every zoning district in covered jurisdictions. The methodology then requires merging this regulatory information with geospatial data to create the National Zoning Atlas.

By making zoning legible, the National Zoning Atlas will open up a rich array of possible uses. First, the atlas will facilitate research on the effects of zoning on a host of social and economic issues, from housing affordability and development to transportation and economic opportunity. Among relevant research outcomes, the atlas will enable a more accurate evaluation of whether particular zoning codes or provisions within codes advance equity or satisfy fair housing goals established in law. Second, the National Zoning Atlas will strengthen local, regional, statewide, and even national planning. It will show whether communities are concentrating development in natural hazard-prone areas, reveal allowable development density, and locate infrastructure needs. In turn, these revelations will enable planners to make more effective siting decisions and maximize public investment. Third, the atlas will empower the public to better understand and, thus, participate in land use decisions that affect them by narrowing a wide information gap that currently favors land speculators, institutional investors, and affluent homeowners over socioeconomically disadvantaged groups.

In the following section, this article identifies gaps in zoning data collection, emphasizing challenges previous efforts have faced. Then, it outlines how the National Zoning Atlas addresses these challenges through a rigorous methodology that focuses on zoning districts' regulatory and spatial contours. It concludes by highlighting how the atlas can facilitate research, strengthen planning, empower the public, and improve fair housing advocacy.

Current Gaps in Zoning Data Collection

To understand how a national zoning atlas can fill information gaps, we must first recognize zoning's highly decentralized regulatory landscape. In all 50 states, enabling statutes modeled after the SSZEA give general-purpose local governments the power to develop, adopt, and enforce zoning codes. In some cases, state legislatures have extended this power to certain special-purpose local governments, special districts, and private associations.[2] Of 38,779 general-purpose governments as of 2017, about 3,000 are county governments, nearly 20,000 are municipal governments, and only more than 16,000 are township governments, according to the U.S. Census Bureau's Census of Governments. The total also includes an additional 38,542 special districts. Given these figures, tens of thousands of local jurisdictions have likely enacted zoning. With so many distinctly regulated zoning jurisdictions, collecting and parsing uniform zoning data at scale has been difficult.

Existing zoning research with the largest geographic scope (that is, the largest number of jurisdictions) has primarily involved surveys of planners. Puentes, Martin, and Pendall (2006) created an early version of a land use survey for the 50 largest metropolitan areas, called the National Longitudinal Land Use Survey, which is the most prominent of these surveys. That survey solicits detailed information about permitting processes, maximum allowable densities, and the assessment of fees for new development (Gallagher, Lo, and Pendall, 2019). It allows respondents to base answers on any location within the jurisdiction or on estimated averages across zoning districts. The Wharton Residential Land Use Regulatory Index asks respondents 15 questions involving the general characteristics of the zoning process, the rules of local land use regulation, and the outcomes of zoning decisions (Gyourko, Saiz, and Summers, 2008). The final index measures the restrictiveness of local zoning through 11 subindices based on respondents' answers. The Residential Land Use Survey similarly polled planners from 252 California localities in 2017 and 2018 (Mawhorter et al., 2018). This survey asked respondents to assess standards for minimum lot size, density, floor area ratio, setbacks, and a few other regulation types; to categorize developable land; and to estimate variance and exception requests. These and other surveys provide general and often subjective assessments about a jurisdiction, and while useful to gauge attitudes and implementation practices, they cannot offer the same kind of specificity and precision of textual analysis of the code. (for example, Levine, 1999).

When data collection involves textual analysis, it has had limited geographic scope and has proven both time-consuming and resource intensive. Prior textual analysis research tied to geospatial data has covered Massachusetts (Commonwealth of Massachusetts, n.d.; Dain, 2005; Evenson and Wheaton, 2003; MAPC, n.d.), the San Francisco Bay Area, greater Los Angeles, and the Sacramento region (Menendian et al., 2020), which has left most of the country undocumented. These methods of data collection are time-consuming to implement. For instance, the Metropolitan Area Planning Council's (MAPC) interactive online map of eastern Massachusetts covers 101 municipalities and took 10 years to create (MAPC, n.d.). In three separate projects, the University of California (UC) Berkeley Othering and Belonging Institute covered 101 municipalities in the San Francisco Bay area, 191 municipalities in greater Los Angeles, and 22 municipalities in the

[2] In Connecticut, for example, several special acts of the state legislature authorized a few specific private associations to adopt zoning codes.

Sacramento region.[3] In the MAPC and California maps, users can view areas subject to single- or multifamily zoning (defined as two or more units). In the MAPC map, users can also view a few other attributes, such as minimum lot size and permit type. The project teams at the MAPC (joined by Suffolk University) and UC Berkeley (joined by UC Davis) have standardized and expanded their data for the National Zoning Atlas, resulting in the Massachusetts and California Zoning Atlases. Forty-eight other states lack such a head start.

Some scholars have begun to apply machine learning techniques to analyze zoning rules. For instance, Song (2021) identified districts with different minimum lot sizes for nearly all municipalities in the 48 contiguous states and Washington, D.C., using an algorithm that detects clustering of lot areas just beyond the minimum size cutoff. Scholars have also used natural language processing of zoning code text to estimate jurisdiction-level measures of zoning restrictiveness and collect information about other measures, such as accessory dwelling unit allowances, building height maximums, and parking requirements (Mleczko and Desmond, 2023; Shanks, 2021). A new approach, using the National Zoning Atlas database of "answers" derived from the manual review process to develop large language models using zoning texts as the corpus, is further explained. Much more remains to be explored in this arena as machine learning becomes more sophisticated in reading complicated legal texts like zoning codes.

How the National Zoning Atlas Responds to Data Collection Challenges

With that brief background about the state of zoning data collection, this article now turns to the organizational structure and methods of the National Zoning Atlas. Its central team, housed in Cornell University's Legal Constructs Lab, coordinates the efforts, supports more than two dozen independent teams, and directly analyzes more than 4,000 jurisdictions nationwide. The independent teams typically cover a region or state and include academics, professionals, and students across planning, land use law, geographic information science (GIS), and related fields.

All participants adhere to a common methodology called *How to Make a Zoning Atlas 2.0: The Official Methodology for the National Zoning Atlas*, a living document publicly available through a website (Bronin et al., 2023). The document covers where to find zoning codes and geospatial files and how to identify zoning districts. The document then outlines how atlas makers should analyze the zoning text to classify zoning districts and catalog uses, structures, and lots. It further describes how atlas makers should gather, create, and clean geospatial data. It focuses on district-level data, because each district regulates land differently, and because only by understanding the particulars of every district can users get a sense of the whole regulatory scheme. *How to Make a Zoning Atlas* also includes detailed instructions to help users translate zoning codes and import cleaned geospatial data into the web-based interface, the National Zoning Atlas Editor, or "the Editor," which stores and displays the data. The Editor assists with document collection, expedites analysis, and reduces human error at every step of the process. It also allows team members to store files in a centralized location, schedule data checks, and easily publish finalized data straight to the national map.

The methodology outlined in *How to Make a Zoning Atlas* is partly based on the techniques used to create the Connecticut Zoning Atlas, the first interactive statewide map of local zoning codes,

[3] The Bay Area and Sacramento maps are interactive, whereas the Los Angeles region map is not: https://belonging.berkeley.edu/.

illustrating housing-related characteristics for more than 2,000 zoning districts across 183 jurisdictions.[4] Broadly, this methodology is composed of the following steps:

1. Assemble a team consisting of a team leader with a thorough knowledge of zoning, one or more zoning code analysts to review zoning code texts, and one or more geospatial analysts to manage geospatial vector files.

2. Confirm the names of jurisdictions with zoning authority in the state or region, then import those jurisdiction names, along with their geospatial boundaries, into the Editor.

3. Gather and upload the zoning code text, official zoning map, and geospatial files for each jurisdiction to the Editor and enter other information relevant to the jurisdiction, including its website, staff contact information, and government type.

4. Enter zoning district names and attributes into the appropriate fields in the Editor, including information on each district's land use types, density allowances, height limits, setback requirements, and more.

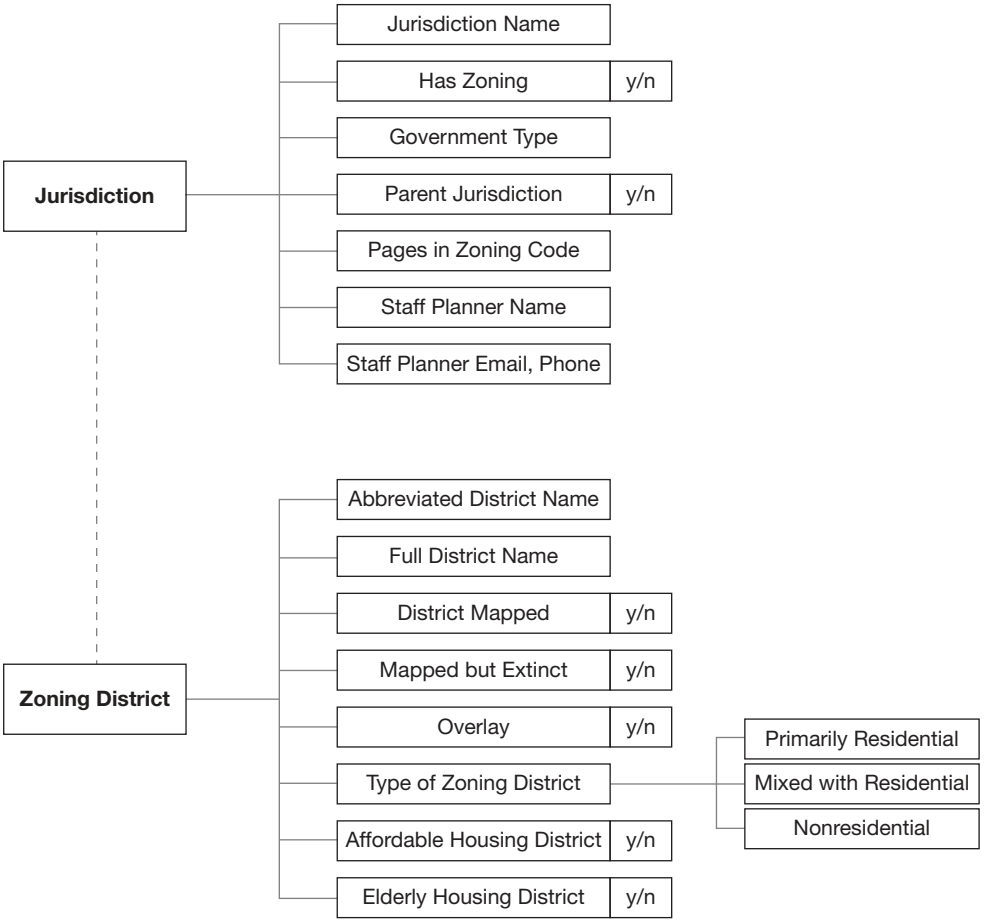
5. Gather, create, and clean the geospatial layers of the zoning districts by conforming to their boundaries and cross-checking to ensure that district names match what has been entered into the Editor. Then, import the cleaned geospatial files into the Editor.

Exhibit 1 lists the major attributes of the zoning districts produced from the National Zoning Atlas methodology. In the Editor, these attributes include fields with specific data types, including dropdown menus with a prescribed range of options, text entries for alternative options, and numerical entries. The dropdown menus standardize data entry. For example, a required dropdown field provides three options for single-family housing and various multifamily housing types: allowed by right, requires a public hearing, or prohibited entirely. This standardized format avoids subjective entries and enables cross-jurisdiction comparisons of these variables for the whole country. In addition to these standardized entries, users log specific information about a range of other attributes, including those in exhibits 2 and 3. Users can also create custom fields for their region or state and add contextual notes.

[4] National Zoning Atlas, Connecticut Zoning Atlas: https://www.zoningatlas.org/connecticut/.

Exhibit 1

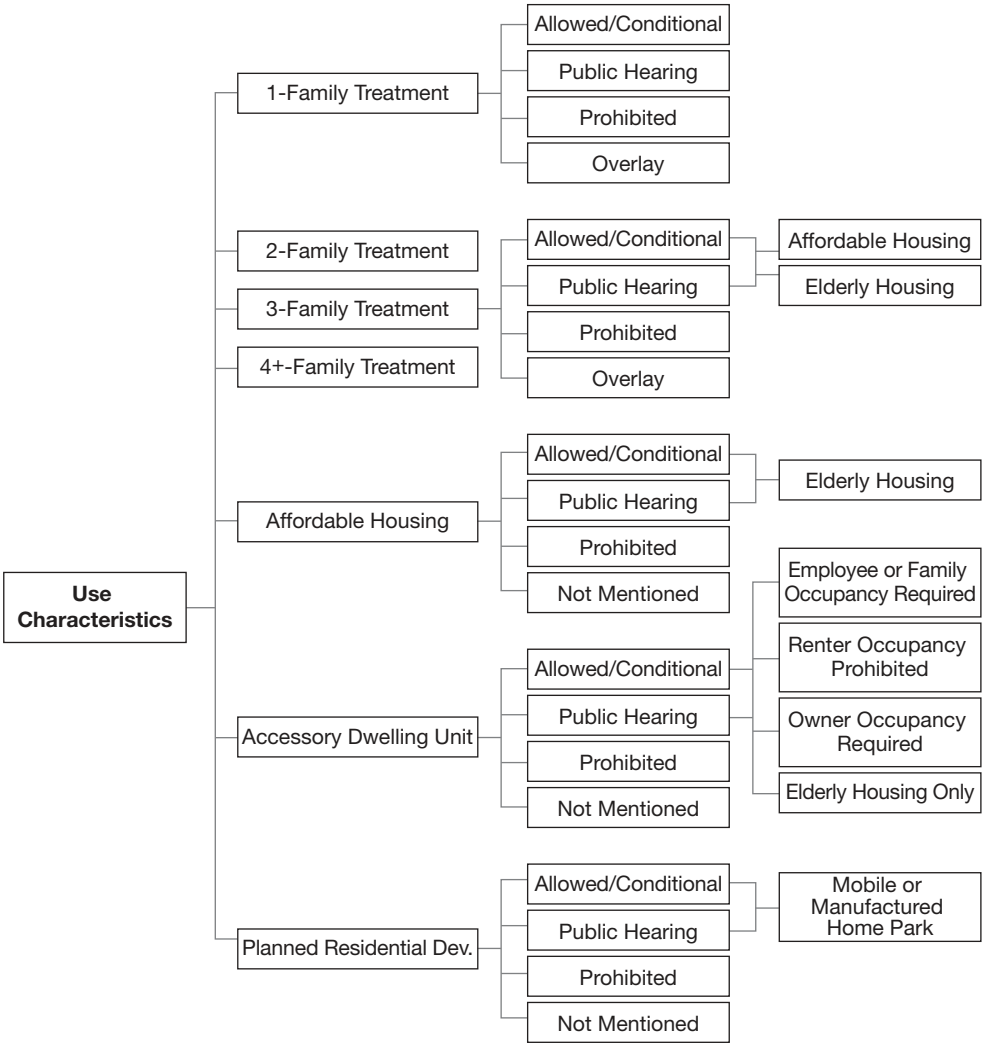
Major Attributes for Zoning Districts From National Zoning Atlas Methodology



Source: National Zoning Atlas

Exhibit 2

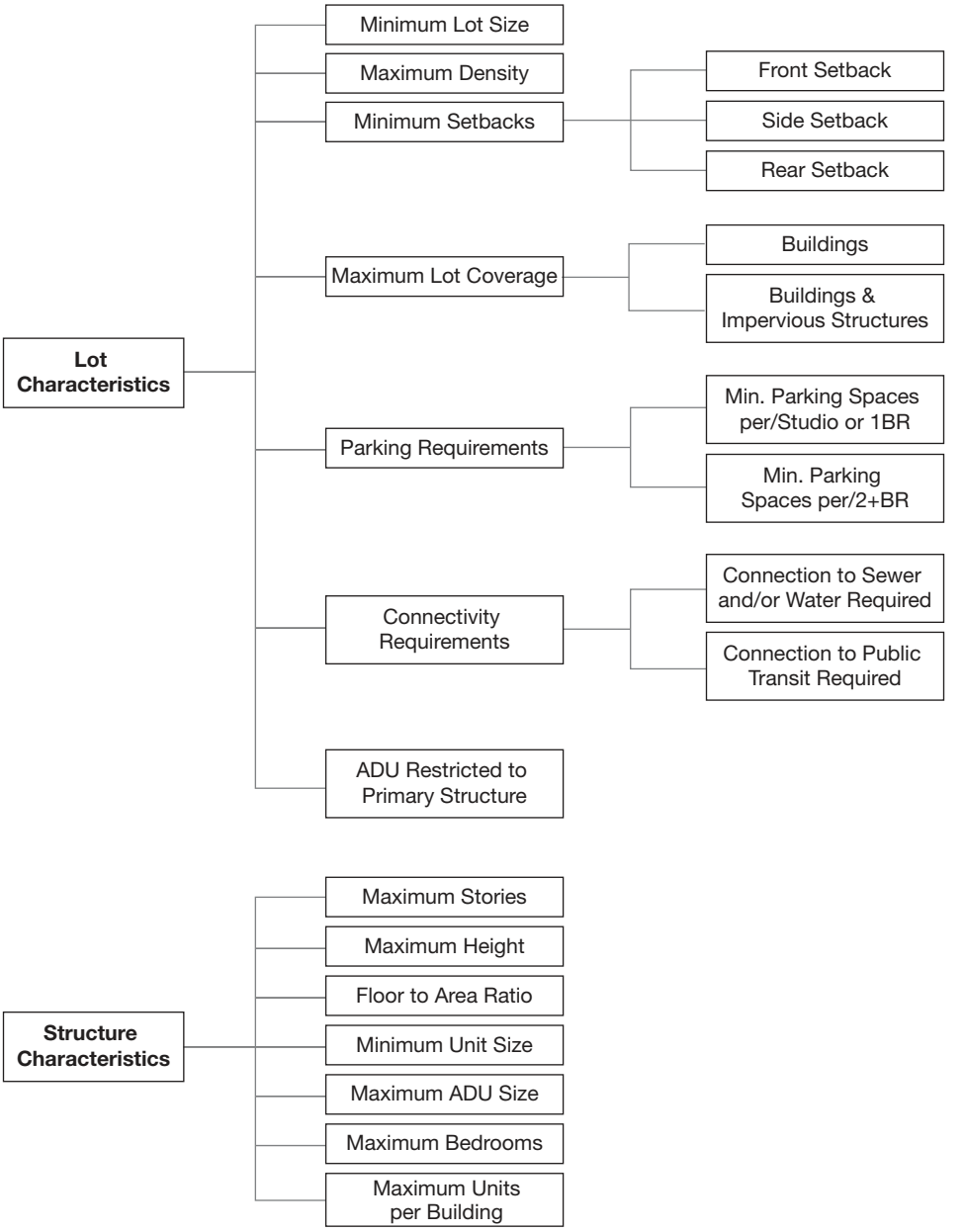
Regulated Use Characteristics From National Zoning Atlas Methodology



Source: National Zoning Atlas

Exhibit 3

Lot and Structure Characteristics From National Zoning Atlas Methodology



Source: National Zoning Atlas

Although locating each jurisdiction's zoning code text is fairly straightforward in most cases, the effort to gather and clean the geospatial files can vary substantially from place to place. Many larger municipalities provide zoning district layers on their websites or the ArcGIS REST service. In these cases, teams download these files, confirm they are up to date by consulting the jurisdiction's zoning map or contacting a staff planner or GIS official, ensure the zoning district names match the official text and map, and correct any administrative boundary discrepancies using the U.S. Census Bureau's TIGER files. This last point is crucial, because many local GIS offices draw their layers independently, meaning the geospatial layers in one jurisdiction will sometimes not align with the geospatial layers in a neighboring jurisdiction. This work can all be done using common GIS software like QGIS or ArcGIS Pro.

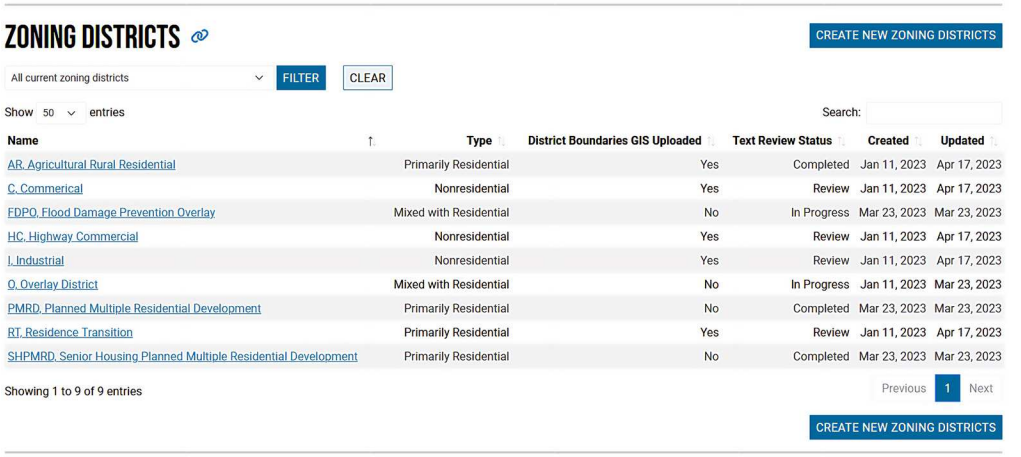
Many smaller jurisdictions have not put geospatial zoning files online. Teams may request these files directly from the local zoning, planning, or GIS offices. When a jurisdiction has no geospatial files on hand, teams must build them from scratch. This process can be done most efficiently using parcel polygons, which are often more available than zoning polygons. If the parcels do not have a zoning district attribute, teams can georeference the official zoning map, select the parcel polygons a given zoning district covers, then assign the appropriate zoning district name. From there, teams need only to dissolve the parcel layer into the zoning districts.

After analysts enter their zoning codes and geospatial information into the Editor, they can submit it to the team leader for review. This quality-control step allows team leaders to ensure proper coding, make corrections, and, if necessary, return it to the analyst with comments. This internal validation technique complements the suggested external validation procedures, which involve communicating with staff planners to resolve any discrepancies we find in the codes. External validation is also important for the geospatial steps, because some map layers available online may have become outdated. Establishing contact with local staff planners and GIS practitioners helps our analysts stay up to date as zoning codes change.

Exhibit 4 shows how the Editor allows teams to track the progress of data entry for each zoning district within a jurisdiction. A zoning district module on each jurisdiction home page includes the type of district (whether primarily residential, nonresidential, or mixed with residential), the upload status of the boundary GIS files, the status of the zoning text review (whether in progress, in review, or completed), the entry's creation date, and the date of the most recent update.

Exhibit 4

Zoning District Module of the Home Page for a Sample Jurisdiction



ZONING DISTRICTS

CREATE NEW ZONING DISTRICTS

All current zoning districts | FILTER | CLEAR

Show 50 entries | Search:

Name	Type	District Boundaries GIS Uploaded	Text Review Status	Created	Updated
AR, Agricultural Rural Residential	Primarily Residential	Yes	Completed	Jan 11, 2023	Apr 17, 2023
C, Commerical	Nonresidential	Yes	Review	Jan 11, 2023	Apr 17, 2023
FDPO, Flood Damage Prevention Overlay	Mixed with Residential	No	In Progress	Mar 23, 2023	Mar 23, 2023
HC, Highway Commercial	Nonresidential	Yes	Review	Jan 11, 2023	Apr 17, 2023
I, Industrial	Nonresidential	Yes	Review	Jan 11, 2023	Apr 17, 2023
O, Overlay District	Mixed with Residential	No	In Progress	Jan 11, 2023	Mar 23, 2023
PMRD, Planned Multiple Residential Development	Primarily Residential	No	Completed	Mar 23, 2023	Mar 23, 2023
RT, Residence Transition	Primarily Residential	Yes	Review	Jan 11, 2023	Apr 17, 2023
SHPMRD, Senior Housing Planned Multiple Residential Development	Primarily Residential	No	Completed	Mar 23, 2023	Mar 23, 2023

Showing 1 to 9 of 9 entries | Previous 1 Next

CREATE NEW ZONING DISTRICTS

Source: National Zoning Atlas Editor Tool

When a jurisdiction updates its zoning code, analysts can enter the new zoning code information and geospatial boundaries directly into the Editor as before, but this time after specifying that these updates are due to a legislative change. Although the online atlas will display the most up-to-date zoning districts available, the older codes are still stored in the system, allowing future comparisons of current and historical zoning district boundaries and attributes. Analysts can use this information to assess the effects of legislative changes to the zoning code over time.

After a team leader approves a jurisdiction's text-based data entries and geospatial files, these data and files can be merged to produce an interactive online map that allows users to toggle between one-, two-, three-, and four-or-more-family housing districts, see accessory dwelling unit allowances, review minimum lot sizes and permit types, and compare residential versus nonresidential and mixed districts, among other features. The online map includes about one-third of the more than 100 regulatory features logged in the database. It also includes ancillary land use categories, such as water surfaces, tribal lands, and other state and federally protected lands such as parks and national forests.

Machine learning can accelerate this manual data collection process, which involves time-consuming reviews of lengthy texts. Building on a shorter collaboration between the Urban Institute (Axelrod, Lo, and Bronin, 2023), the Legal Constructs Lab has embarked on a National Science Foundation-funded initiative of extracting machine-readable structured data from code text. Professor Bronin's partner researcher in these efforts, Cornell Tech professor Alexander Rush, is designing a methodology to use large language models efficiently for this task. Specifically, methods will use pretrained large-language models such as Transformer models designed to handle long-text for extraction of entities and relations (Beltagy, Peters, and Cohan, 2020; Devlin et al., 2019). Models will be trained and tested on manually coded and verified datasets that Legal Constructs Lab researchers have collected. Despite the rapidly developing popularity of large

language models such as ChatGPT, they are imperfect predictors (Day, 2023; Gravel, D'Amours-Gravel, and Osmanlliu, 2023). Nonetheless, these natural language processing efforts have the potential to reduce human effort in collecting and maintaining data and to improve data accuracy and consistency.

The National Zoning Atlas Opens New Possibilities

Prior to the National Zoning Atlas, the dearth of high-quality zoning data left scholars, policymakers, and the general public without a common understanding of a central policy instrument that shapes the urban built environment, social relations and hierarchies, and geographies of opportunity. The data shortfall diminished the collective ability to reimagine future, alternative, and reparative trajectories. A national zoning dataset will open new possibilities for facilitating research, strengthening planning tools, and empowering public participation and power over land use decisions.

First, a national zoning atlas will provide baseline information for researchers to explore the effects of land use regulations. Existing research suggests that zoning laws influence housing availability, affordability, and neighborhood diversity (Lens, 2022; Manville, Monkkonen, and Lens, 2020; Stacy et al., 2023; Wegmann, 2020). For instance, research has shown that constraints on housing supply can inflate marginal prices compared with costs and create housing price-driven income and class inequality and racial segregation and stratification while also reducing aggregate economic output (Glaeser, Gyourko, and Saks, 2005; Ganong and Shoag, 2017; Hsieh and Moretti, 2019; Lens and Monkkonen, 2016; Massey and Rugh, 2017; Rothwell, 2011; Rothwell and Massey, 2010; Sahn, 2021; Trounstine, 2018, 2020).

Although a handful of studies have compared certain zoning laws across cities (for instance, Sahn, 2021), the difficulty of compiling detailed zoning data across cities and regions has resulted in the instances of granular focus on only a handful of places (Resseger, 2022; Shertzer, Twinam and Walsh, 2016; Twinam, 2020). Therefore, findings are scattered and, thus, remain largely inconclusive on a number of key questions (Freemark, 2023). Addressing these issues at the individual zoning district level and with a national scope, which is unique in zoning data-collection efforts, the National Zoning Atlas records pertinent information at the district and lot levels—including minimum lot sizes, permitted densities, and residence type—allowing researchers to conduct larger scale, inter-jurisdiction, and cross-state analyses of zoning's relationship with housing costs, housing densities, vacancies, and residential segregation. The National Zoning Atlas also includes information that can assist researchers in studying subtler forms of exclusion, such as public hearing requirements for multifamily housing developments.

Although zoning data are still in the early stages of collection, new research already confirms previous studies that exclusionary zoning correlates with unequal access to housing along race, ethnicity, and income lines. Among its most cogent findings, the Connecticut Zoning Atlas reveals that zoning assigns 90.6 percent of the state's land to as-of-right single-family housing compared with 2.2 percent of land to as-of-right four-or-more-family housing (Bronin, 2023). In New Hampshire, whose team completed the second-ever statewide zoning atlas, researchers similarly found that zoning assigns 90 percent of the state's buildable acres to as-of-right single-

family housing, 86 percent of which requires lots sizes of more than 1 acre with more than 200 feet of road frontage (Sorens, 2023). Restrictions on multifamily housing were less extreme than Connecticut's, with five-or-more-family housing permitted as-of-right or with a public hearing on 44.2 percent of the state's buildable area (Saint Anselm College, 2023).

Further, secondary research using the Connecticut Zoning Atlas exposed how the state's zoning codes correlate with inequality. This study found a negative relationship between a jurisdiction's non-White population share and its percentage of tracts allowing as-of-right single-family zoning, where 60 percent of land zoned for three-or-more-family housing is in cities with populations larger than 40,000, which tend to be more racially diverse than surrounding small and mid-sized towns. The study also found a corresponding positive relationship between income and as-of-right single-family zoning (Bronin, 2023). Building on this study, a recent report provides new evidence of the correlations between number-of-unit zoning (single-, two-, three-, and four-or-more-family housing) and particular socioeconomic and property-related outcomes (Freemark, Lo, and Bronin, 2023). Using data from the Connecticut Zoning Atlas, this research shows that residents of single-family residential areas are more likely to be White, have higher household incomes, and be homeowners.

Moreover, the study found that single-family zoning is associated with a higher concentration of residents from these categories, whereas three-or-more housing units per parcel zoning is associated with higher concentrations of low-income and minority residents. The National Zoning Atlas presents researchers with the opportunity to scale up these types of studies. Because it is built to track local zoning changes, it can enable further analysis of the effects of zoning reform.

A national zoning atlas can also enable more accurate evaluations of whether particular zoning codes or provisions within codes advance social equity. For example, Davidson (2022), a leader of the New York City Zoning Atlas, argues that digitalization of zoning could help better understand whether communities are satisfying fair housing goals established in the U.S. Department of Housing and Urban Development's Affirmatively Furthering Fair Housing initiative. State and federal governments will have a new opportunity to build a common language and understanding of residential zoning laws across municipalities and states. This opportunity could, for instance, facilitate state-level assessments of affordable housing production shortages and targets. For instance, New York State Governor Hochul's plan to increase the housing supply by 3 percent during 3 years could benefit from this type of stock-taking. Federal policy such as the Biden Administration's Housing Supply Action Plan, which promises federal grants to local governments that reform their zoning codes, will also benefit from the atlas's ability to consistently measure exclusionary zoning. Moreover, attorneys and advocates will have a much easier time characterizing zoning in court filings if they can accurately compare codes.

Beyond housing, a national zoning dataset can also highlight the mechanisms by which zoning restrictions can affect access to transportation, labor market opportunities, healthy food, schools, and other social services that improve residential opportunity. For instance, one important area of expanded research is transit-oriented development, a planning approach that aims to encourage public transit usage and growth in areas surrounding transit hubs through land use changes, among other mechanisms. To explore the relationship between zoning and transit, scholars have variously studied the effects of transit-oriented development on the surrounding area through

parcel-level case studies and city-level comparisons (Freemark, 2020; Thrun, Leider, and Chriqui, 2016), painting only a partial picture. The National Zoning Atlas would introduce new opportunities to evaluate zoning regulations such as mixed-use zoning, density regulations, and parking requirements in specific districts and their effects at the national scale on affordability, transit use, walkability, and other transit-oriented development aims.

Second, the National Zoning Atlas will strengthen local, regional, statewide, and national planning. Perhaps most pressingly, the atlas can help governments better plan for climate change. In Connecticut, the atlas shows that some communities have been concentrating development in natural hazard-prone areas, including places likely to be inundated with ocean water within the next few decades. Building from this finding, a research team led by the Regional Plan Association is exploring the New York Zoning Atlas data across the Greater New York City region to create a tool that investigates the impending "climate change housing deficit" resulting from the destruction and degradation of housing through climate events leading to the loss of shoreline land. With this tool, these researchers will improve their understanding of the effects of climate change on New York's housing stock, developing actionable and scalable policies for constructing more affordable housing in climate-appropriate locations and creating an advocacy strategy to implement these policies. With a national zoning atlas, other regional, state, and federal agencies can likewise develop policy interventions to manage the transition out of the highest risk areas.

Relatedly, the atlas will reveal allowable development density, enabling infrastructure planners to make more effective siting decisions for transportation, sewer, and climate resiliency infrastructure. At the same time, the atlas will enable these planners to seek local zoning changes that maximize public investment in those projects. With the National Zoning Atlas, planners and policymakers at all levels of government will have, for the first time, a way to systematically monitor the effects of zoning changes across jurisdictions, especially because research has shown that zoning change is heterogeneous and defies the standard narrative of increasingly exclusionary practices (Freemark, 2023; Pendall, Lo, and Wegmann, 2022). Previous measures of changes in zoning regulation have typically relied on updates to survey-based indices, such as the National Longitudinal Land Use Survey and the Wharton Residential Land Use Regulatory Index. Updating these indices requires significant time and effort, meaning changes are typically recorded only once a decade at best. Because the Editor allows analysts to add and edit zoning data in real-time, the National Zoning Atlas is equipped to register zoning code changes quickly. In addition, because this information is logged in the system, users can assess how zoning codes have changed over time. Given recent efforts in states like Alaska, California, Florida, Montana, and others to enact rapid, sweeping zoning reform, the need for updated zoning data has become even more essential.

Third, the National Zoning Atlas can empower the public to understand and participate in land use decisions that affect them. To find complete information on the types of regulations permitted in their zoning districts, people currently have to pore through a jumble of maps, tables, and documents, often hundreds of pages long. The information in the text can be hard to read in isolation, and the many code exceptions are explained in complicated terms. A comprehensive understanding of the regulations underlying everything from housing markets to parking requirements has previously been accessible only to those with the wherewithal or training to read dense and arcane legal texts.

Presenting zoning information in a free and publicly accessible format can help demystify every layer of a zoning code, enabling community advocates and elected officials to compare jurisdictions and see regional and statewide trends. Addressing this information gap, which currently favors land speculators, institutional investors, and homeowners over socioeconomically disadvantaged groups, is an important component of addressing overall housing inequality. In Connecticut, a greater understanding of zoning has strengthened an advocacy movement pushing for local and statewide regulatory reform. Digitizing the regulatory environment can play an important role in democratizing local-, state-, and national-level zoning.

Digitizing zoning code data has also given advocates a sharper tool to measure the source of affordable housing shortages and to advocate for land use and zoning changes. The Frontier Institute in Montana, using its recently completed Montana Zoning Atlas, found that exclusionary zoning laws that favor single-family units dominate the state's zoning practices; penalize higher density homes such as duplexes, triplexes, and affordable dwelling units; and mandate larger property areas by requiring minimum lot sizes. Within Montana's 13 fastest growing cities, two-or-more-family homes are prohibited or penalized in 50 percent of the city land, whereas three-or-more-family homes are allowed in an average of 29 percent of city land (Frontier Institute, 2022). The Frontier Institute also found that cities that eliminated or reformed minimum lot sizes were relatively more affordable than those that did not. These findings provided the basis for reform proposals, spurring an unprecedented bipartisan anti-exclusionary zoning campaign in the months leading up to the 2023 legislative session. This data-driven advocacy facilitated the passage of two Senate bills: SB 323 and SB 245. The former allowed for duplex, triplex, and fourplex housing by-right in areas currently zoned exclusively for single-family housing, and the latter allowed multifamily and mixed-use development in certain urban areas while prohibiting municipalities from certain density, height, lot coverage, setback, and parking requirements.

By providing zoning codes in a user-friendly map interface, the National Zoning Atlas enables these types of comparative analyses. In addition, publicly accessible zoning data can help foster greater inclusion, in Davidson's (2022) words, "by exposing inequity, encouraging dialogue and debate, [and] making developers and cities more accountable."

Conclusion

National attention has turned toward zoning as a major influence on social patterns and economic growth. Federal, state, and local policymakers have focused on the effects of exclusionary zoning on the national housing shortage, housing affordability, and racial-ethnic segregation. Unfortunately, as this article describes, much of the research asserting this connection relies on only limited evidence relating to the actual contents of zoning codes. The dearth of reliable zoning information hinders data-driven policymaking and makes it difficult for people to easily compare one zoning jurisdiction with another or track progress over time. The National Zoning Atlas will fill this knowledge gap by demystifying and democratizing zoning data through novel research and data collection methods that will support deeper research inquiries, better planning, and more meaningful public involvement in zoning.

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References

Axelrod, Judah, Lydia Lo, and Sara C. Bronin. 2023. *Automating Zoning Data Collection: Results from a Pilot Effort to Automate National Zoning Atlas Methodologies*. Washington, DC: Urban Institute.

Beltagy, Iz, Matthew E. Peters, and Arman Cohan. 2020. "Longformer: The Long-Document Transformer." https://arxiv.org/abs/2004.05150.

Bronin, Sara C. 2022. "An Invitation to Collaborate on a National Zoning Atlas." Proceedings from Bringing Digitalization Home: How Can Technology Address Housing Challenges? Symposium, Cambridge, MA: Harvard Joint Center for Housing Studies.

———. 2023. "Zoning by a Thousand Cuts," *Pepperdine Law Review* 50 (4): 719–784.

Bronin, Sara C., Scott Markley, Aline Fader, and Evan Derickson. 2023. *How to Make a Zoning Atlas 2.0: The Official Methodology of the National Zoning Atlas*. DOI: 10.2139/ssrn.4476927.

Commonwealth of Massachusetts. n.d. "MassGIS Data: 2001 & 2003 Aerial Imagery." https://www.mass.gov/info-details/massgis-data-2001-2003-aerial-imagery.

Dain, Amy. 2005. *Residential Land-Use Regulation in Eastern Massachusetts: A Study of 187 Communities*. Boston, MA: Pioneer Institute.

Davidson, Nestor. 2022. "Bringing Digitalization Home: How Can Technology Address Housing Challenges." Joint Center for Housing Studies Symposium, Cambridge, MA, March 24–26.

Day, Terence. 2023. "A Preliminary Investigation of Fake Peer-Reviewed Citations and References Generated by ChatGPT," *The Professional Geographer* 0 (0): 1–4.

Devlin, Jacob, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. 2019. "BERT: Pre-Training of Deep Bidirectional Transformers for Language Understanding." In *Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers)*. DOI: 10.48550/arXiv.1810.04805.

Eagle, Steven J. 2005. *The Birth of the Property Rights Movement*. Washington, DC: Cato Institute. https://www.cato.org/policy-analysis/birth-property-rights-movement-0.

Evenson, Bengte, and William C. Wheaton. 2003. "Local Variation in Land Use Regulations," *Brookings-Wharton Papers on Urban Affairs*. 221–260.

Freemark, Yonah. 2020. "Upzoning Chicago: Impacts of a Zoning Reform on Property Values and Housing Construction," *Urban Affairs Review* 56 (3): 758–789. DOI: 10.1177/1078087418824672.

———. 2023. "Zoning Change: Upzonings, Downzonings, and Their Impacts on Residential Construction, Housing Costs, and Neighborhood Demographics," *Journal of Planning Literature*. DOI: 10.1177/08854122231166961.

Freemark, Yonah, Lydia Lo, and Sara C. Bronin. 2023. *Bringing Zoning into Focus: A Fine-Grained Analysis of Zoning's Relationships to Housing Affordability, Income Distributions, and Segregation in Connecticut*. Washington, DC: Urban Institute.

Frontier Institute. 2022. "The Montana Zoning Atlas 2.0." https://frontierinstitute.org/reports/the-montana-zoning-atlas-2-0/.

Gallagher, Megan, Lydia Lo, and Rolf Pendall. 2019. *An Introduction to the National Longitudinal Land Use Survey and Data*. Washington, DC: Urban Institute.

Ganong, Peter, and Daniel Shoag. 2017. "Why Has Regional Income Convergence in the U.S. Declined?" *Journal of Urban Economics* 102: 76–90.

Glaeser, Edward L., Joseph Gyourko, and Raven Saks. 2005. "Why Is Manhattan So Expensive? Regulation and the Rise in Housing Prices," *The Journal of Law and Economics* 48: 331–369. DOI: 10.1086/429979.

Gravel, Jocelyn, Madeleine D'Amours-Gravel, and Esli Osmanlliu. 2023. "Learning to Fake It: Limited Responses and Fabricated References Provided by ChatGPT for Medical Questions," *Mayo Clinic Proceedings: Digital Health* 1 (3): 226–234.

Gyourko, Joseph, Albert Saiz, and Anita Summers. 2008. "A New Measure of the Local Regulatory Environment for Housing Markets: The Wharton Residential Land Use Regulatory Index," *Urban Studies* 45 (3): 693–729.

Hsieh, Chang-Tai, and Enrico Moretti. 2019. "Housing Constraints and Spatial Misallocation," *American Economic Journal: Macroeconomics* 11 (2): 1–39.

Lens, Michael C. 2022. "Zoning, Land Use, and the Reproduction of Urban Inequality," *Annual Review of Sociology* 48: 421–439. DOI: 10.1146/annurev-soc-030420-122027.

Lens, Michael C., and Paavo Monkkonen. 2016. "Do Strict Land Use Regulations Make Metropolitan Areas More Segregated by Income?" *Journal of the American Planning Association* 82 (1): 6–21.

Levine, Ned. 1999. "The Effects of Local Growth Controls on Regional Housing Production and Population Redistribution in California," *Urban Studies* 36 (12): 2047–2068.

Manville, Michael, Paavo Monkkonen, and Michael C. Lens. 2020. "It's Time to End Single-Family Zoning," *Journal of the American Planning Association* 86 (1): 106–112.

Massey, Douglas S., and Jacob S. Rugh. 2017. "The Intersections of Race and Class: Zoning, Affordable Housing, and Segregation in U.S. Metropolitan Areas." In *The Fight for Fair Housing*, edited by Gregory D. Squires. New York: Routledge: 245–265.

Mawhorter, Sarah, Carolina Reid, Liana Arnold, Derek Taylor, Julia Morris, and Ryan Kelley-Cahill. 2018. *Local Housing Policies Across California: Presenting the Results of a New Statewide Survey*. Berkeley: University of California, Terner Center for Housing Innovation.

Menendian, Stephan, Samir Gambhir, Karina French, and Arthur Gailes. 2020. *Single-Family Zoning in the San Francisco Bay Area*. Berkeley: University of California, Othering & Belonging Institute. https://belonging.berkeley.edu/single-family-zoning-san-francisco-bay-area.

Metropolitan Area Planning Council (MAPC). n.d. "Zoning Atlas." https://zoningatlas.mapc.org/.

Mleczko, Matthew, and Matthew Desmond. 2023. "Using Natural Language Processing to Construct a National Zoning and Land Use Database," *Urban Studies*. DOI: 10.1177/00420980231156352.

Pendall, Rolf, Lydia Lo, and Jake Wegmann. 2022. "Shifts Toward the Extremes: Zoning Change in Major U.S. Metropolitan Areas from 2003 to 2019," *Journal of the American Planning Association* 88 (1): 55–66. DOI: 10.1080/01944363.2021.1894970.

Puentes, Robert, Jonathan Martin, and Rolf Pendall. 2006. "From Traditional to Reformed: A Review of the Land Use Regulations in the Nation's 50 Largest Metropolitan Areas." https://www.brookings.edu/articles/from-traditional-to-reformed-a-review-of-the-land-use-regulations-in-the-nations-50-largest-metropolitan-areas/.

Resseger, Matthew. 2022. The Impact of Land Use Regulation on Racial Segregation: Evidence From Massachusetts Zoning Borders. Mercatus Research Paper, Arlington, VA: George Mason University.

Rothwell, Jonathan T. 2011. "Racial Enclaves and Density Zoning: The Institutionalized Segregation of Racial Minorities in the United States," *American Law and Economics Review* 13 (1): 290–358.

Rothwell, Jonathan T., and Douglas S. Massey. 2010. "Density Zoning and Class Segregation in U.S. Metropolitan Areas," *Social Science Quarterly* 91 (5): 1123–1143.

Sahn, Alexander. 2021. Racial Diversity and Exclusionary Zoning: Evidence from the Great Migration. Working paper. Santa Barbara: University of California. https://youngamericans.berkeley.edu/wp-content/uploads/2021/02/Sahn_BIFYA_Working-Paper.pdf.

Saint Anselm College. 2023. "New Hampshire Zoning Atlas." https://www.anselm.edu/about/offices-centers-institutes/centers-institutes/center-ethics-society/nh-zoning-atlas.

Shanks, Brendan. 2021. "Land Use Regulations and Housing Development: Evidence from Tax Parcels and Zoning Bylaws in Massachusetts." https://brendanshanks.com/wp-content/uploads/shanks_jmp.pdf.

Shertzer, Allison, Tate Twinam, and Randall P. Walsh. 2016. "Race, Ethnicity, and Discriminatory Zoning," *American Economic Journal: Applied Economics* 8 (3): 217–246.

Song, Jaehee. 2021. "The Effects of Residential Zoning in U.S. Housing Markets," *SSRN Electronic Journal*. DOI: 10.2139/ssrn.3996483.

Sorens, Jason. 2023. "The New Hampshire Zoning Atlas." https://www.anselm.edu/sites/default/files/2023-04/New%20Hampshire%20Zoning%20Atlas.pdf.

Stacy, Christina Plerhoples, Christopher Davis, Yonah Freemark, Lydia Lo, Graham MacDonald, Vivian Zheng, and Rolf Pendall. 2023. "Land-Use Reforms and Housing Costs: Does Allowing for Increased Density Lead to Greater Affordability?" *Urban Studies*. DOI: 00420980231159500.

Thrun, Emily, Julien Leider, and Jamie F. Chriqui. 2016. "Exploring the Cross-Sectional Association Between Transit-Oriented Development Zoning and Active Travel and Transit Usage in the United States, 2010–2014," *Frontiers in Public Health* 4 (113). DOI: 10.3389/fpubh.2016.00113.

Trounstine, Jessica. 2018. *Segregation by Design: Local Politics and Inequality in American Cities*. United Kingdom: Cambridge University Press.

Trounstine, Jessica. 2020. "The Geography of Inequality: How Land Use Regulation Produces Segregation," *American Political Science Review* 114 (2): 443–455.

Twinam, Tate. 2020. "The Long-Run Impact of Zoning in U.S. Cities." In *Measuring the Effectiveness of Real Estate Regulation: Interdisciplinary Perspectives*. Cham, Switzerland: Springer: 35–59.

Wegmann, Jake. 2020. "Death to Single-Family Zoning… and New Life to the Missing Middle," *Journal of the American Planning Association* 86 (1): 113–119.