III
THE POLICY AGENDA

Next-Generation American Suburbs

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Whether hundreds of years ago or today, the far-reaching environmental impacts of urbanization are because cities are "a node of pure consumption existing parasitically on an extensive external resource base."[1] These environmental impacts have been catastrophic, with 78 percent of carbon emissions, 60 percent of residential water use, and 76 percent of wood used for industrial purposes attributed to cities over the past century.[2]

Cities have always relied on peripheral areas for environmental resources, ecosystem services, and other crucial supplies, such as food. Given the major differences of size and quantity of leftover green spaces in dense cities versus suburbs, the abundance and potential continuity of landscapes in suburbs present a distinct advantage for retrofitting crucial ecological functions and landscape productivities. The heterogeneous spatial conditions in suburbia create an abundance of environmental opportunities that urban core cities could never achieve.[3]

Often castigated as environmental disasters, suburbs are actually crucial to preserving ecosystem services—including clean air, water, energy, and food—for entire metropolitan areas. Newer developments, of course, can be designed for this effect, but older suburbs also often can be retrofitted to integrate new low-carbon transportation technologies, making low-density suburban development a better environmental alternative to compact, vertical density. Such a concept is not entirely new, though the original inspiration was for health reasons; it dates back to Ebenezer Howard's garden city, a planning breakthrough that used landscape production *and* new transportation technologies (steam railroads and electrification) to argue for better living environments than in congested, overcrowded, and unhealthy city cores.[4]

Since its inception, the city planning movement looked to transportation technology as a solution to decompress and decongest unhealthy city cores.[5] Social reformer Benjamin Marsh, a founder of the first National Conference on City Planning and author of the earliest American book dedicated to city planning, spent his long career advocating for various decentralizing policies to address population congestion.[6] He led the National Conference on City Planning and the Problems of Congestion, which in part led to the American City Planning movement.[7] The American City Planning movement, the first motorized parkway, and Henry Ford's Model T were all initiated within a few years of each other (1907–09).

As historian Kenneth T. Jackson astutely noted in his canonical *Crabgrass Frontier: The Suburbanization of the United States*, transportation enabled the earliest US suburbanization in the late 1800s, as America replaced the limitations of horse-powered mobility with steam railroads and electrification.[8] The combination of landscape availability and transportation technology led to suburbia becoming the dominant form in metropolitan evolution over the next century.

The Polycentric Metropolis

The notion of contained garden-city nodes has now matured into one of widespread polycentric urbanization, a phenomenon first examined by Jean Gottmann in his 1961 book *Megalopolis: The Urbanized Northeastern Seaboard of the United States*.[9] The result is that today's suburbanization is less tied to the urban core, with the highest-growth areas consisting of multiple employment centers and commercial development.[10] The latest edition of *Commuting in America* estimates that almost 70 percent of metropolitan area workers now live and work in the suburbs.[11] Today, there are more than double the number of trips within suburbs or suburb-to-suburb commutes than there are US metropolitan commutes that have the central business district as the final destination.[12]

In this new world, despite opposition from many planners, the car is king and likely will remain so. More than 93 percent of US households own cars.[13] Only about 5 percent of the US working population uses public transit to get to work. This dominance is likely to continue in the aftermath of the COVID-19 pandemic, with people desiring more safe, private space while they travel.[14] For the majority of the US population, travel without a car is not an attractive option. Automobile usage is, and will remain, largely inelastic to most viable policy changes in the near future.

The Problem with Densifying the Middle

Yet with the growing demand for suburban living and the serious lack of affordable housing in urban cores, planners and politicians have turned their playbook to increasing the density of existing inner suburban neighborhoods, trying to ex post facto add housing around transit hubs to increase ridership and persuade residents to get rid of their cars.[15] Density advocates argue that retrofitting so-called "middle neighborhoods" of single-family housing with higher-density housing will yield lower car use and thus reduce greenhouse gas (GHG) emissions while increasing sustainability, affordability, and urban vitality in general.[16] This kind of thinking is predominant in the urban density lobby's push for single-family suburban zoning laws, with new policies that eliminate or limit single-family zoning in favor of denser alternatives passing in Minneapolis, Minnesota; Portland, Oregon; and San Jose, California.[17]

Numerous studies show that densifying (i.e., "upzoning") residential land use in suburban settings doesn't influence transportation choices, given the efficiencies of car travel and the difficulties of creating transit systems for a spread-out suburb. Research has shown that even doubling density doesn't get people out of their cars.[18] Decisions made in the past on where to place new roads, buildings, and other facilities constrain development options available today.[19]

Hastily increasing density in suburban middle neighborhoods to try to get more people out of their cars is more likely to spur the removal of open space, lower the real estate value of neighboring areas, and add traffic congestion. In full disregard of the negative effects of such strategies, the planners' creative tool kit for suburbia is blindly reduced to eliminating single-family zoning and creating density overlays that will primarily benefit real estate developers and tax collectors, to the detriment of the people who actually live there.[20]

The dominance of the US suburban form and its car dependence can't be overstated, because transportation patterns intimately relate to land-use zoning and landscape conversion patterns, which largely determine regional ecological functions. Missing from these conversations, however, is new evidence that single-family housing and density-infill strategies can in fact reduce GHG emissions, along with social, economic, and other environmental benefits.

Underlying Environmental Arguments Surrounding Suburban Expansion

With the above constraints, my research group at the Massachusetts Institute of Technology has turned its focus to how the newest promising transportation technologies can influence the future of suburbs. In doing so, we hope to integrate into the suburban form near-zero carbon mobility, such as autonomous electric vehicles (AEVs) and mobility platforms, while increasing the ecological health and diversity of the larger metropolitan regions where they are situated.[21] While a preview of this work is presented at the end of the chapter, several underlying environmental arguments discussing suburban expansion must be considered to fully appreciate the outcomes of our research.

Existing Car-Based Suburban Forms. Traditionally, new development patterns along the outer edges of metropolitan areas produce car-based, low-density suburbs with repetitive, single-family houses that rest on uniform, private lots, set back from overscale roadways. Everything about the typical suburb—including homogeneous land-use regulations, wide streets and excessive parking lots, redundant driveways and garages, and the residential floor-plan entry sequence (that is, the sequence of how one enters a house, for example, from the driveway to the front door or from the garage to an interior door)—is based on the speeds, geometries, and material requirements of the car. Cars require wasteful investment in redundant infrastructure. These design features have not changed meaningfully since the postwar housing boom that initially gave birth to the modern suburban era.

Energy Use and GHG. Other concerns about traditional car-based suburbs relate to higher energy use and GHG. Studies are mixed regarding energy use and density. Major studies found that individuals living in the suburbs generate similar amounts of GHG as those living in the inner city, challenging a widely held assumption that living in the urban center is more sustainable.[22] These comparative calculations do not account for commercial buildings, industry, urban infrastructure, 24-hour communal-space energy use in apartment buildings, and other travel modes.[23]

While the direct energy use for transportation and heating and cooling may be more efficient in dense areas, the indirect energy and material demands of an urban area are rarely accounted for in energy-use comparisons.[24] The few studies that do account for a more complete life-cycle assessment of the goods and services flowing to an urban area do not find a significant difference between dense and less-dense areas, as discussed below.[25]

Planners and environmentalists continue to confuse how compactness and density affect energy use and GHG. Research shows that

> urban form policies can have important impacts on local environmental quality, economy, crowding, and social equity, but their influence on energy consumption and land use is very modest; compact development should not automatically be associated with the preferred spatial growth strategy.[26]

The silver-bullet argument that density fixes all simply does not apply to all types of density, nor is all suburban development bound to increase GHG.

Another recent study by Francisco Pomponi et al. suggests that the standard measure used by planners to determine density—floor area ratio (FAR)—is obfuscating the GHG-and-density arguments that planners use.[27] This is because FAR does not factor in the height of buildings nor the space between them, which can be filled with carbon sequestering landscape such as parks, gardens, and tree plantings.[28] Another issue is that most GHG-and-density studies don't include calculations on a building's life-cycle GHG emissions (LCGE), as Pomponi et al. state:

> The design of urban environments has not rigorously considered life cycle GHG emissions (LCGE hereon), focusing instead on reducing the operational energy demand and the carbon emissions associated with the energy used to operate buildings. . . . LCGE includes these operational emissions as well as the embodied emissions of the entire system. Embodied energy and CO_2e emissions are the hidden, "behind-the-scenes" energy and emissions that are used or generated during the extraction and production of raw materials, the manufacture of the building components, the construction and deconstruction of the building, and the transportation between each phase.[29]

What these authors discovered was that increasing building height significantly increases LCGE emissions. Using real neighborhood case studies, they reveal the true trade-offs between constructing higher buildings versus using more land to accommodate people: "Taller urban environments significantly increase life cycle GHG emissions (+154%) and low-density urban environments significantly increase land use (+142%)."[30] The latter is largely an unfounded concern in the US because agricultural production is not threatened by building cities outward, nor is the US generally in danger of running out of land.[31]

In summation, these studies reveal that there is no silver bullet for reducing GHG. Neither urban development nor suburban infill will greatly affect this problem. Any new development, dense or not, will lead to additional carbon emissions. If we are to follow the science on GHG reduction in suburban typologies, then we should be finding ways to add more density without significantly increasing the height of buildings and optimizing the land where shorter buildings can infill. This would not significantly increase LCGE and may require less land that needs to be developed for the same additional population, which gives tremendous credence to retrofitting older suburban neighborhoods without adding height to buildings. This is explored in the case study below.

New Energy and Mobility Technologies and Zoning. The most crucial environmental question about the consequences of land-use patterns in traditional car-based suburbs is not how to halt suburban growth but rather how to reduce GHG related to car use. Even with the modest reduction in commuting from the work-at-home transition, transportation is the largest source of planet-warming GHG in the US. And according to the United States Environmental Protection Agency, nearly 60 percent of those emissions come from the country's millions of passenger cars, sport utility vehicles, and pickup trucks.[32]

In today's polynodal metropolis—where jobs are spread across a wide area—and with the post-COVID-19 work-from-anywhere model here to stay, we must turn to new energy and mobility technologies to change the way we zone, plan, and build suburban areas. The eventual shift from fossil fuel to renewable fuel and the automation and optimization of mobility systems present a generational opportunity to prepare for near-zero carbon suburbia. These changes will take time—perhaps two to three decades—to shift toward electric autonomous driving (AD) and AEVs and renewable energy platforms, as there are 285 million cars in the US but only 14 million of them are retired each year.[33]

There is already evidence that suburban growth and innovative car-based mobility systems can reduce emissions. California, for example, was able to grow its population while reducing air pollution due to technological advances that reduced emissions in vehicles.[34] The near-term promise of a zero-emissions AEV fleet has enormous potential.

Heterogeneity and Biodiversity and Other Carbon Sequestration. A growing number of researchers extol the virtues of low density and the ecological benefits of suburban landscapes. Among these environmental benefits are metabolic capacities latent in suburban open space—capacities that can contribute to the larger metropolitan area having a lower overall environmental impact (such as more trees planted for carbon sequestration, animal habitat creation, stormwater storage, and overall diversity of landscapes to increase biodiversity of the larger built-up urban area).

In ecological terms, dense urban development is extremely detrimental to ecological processes and is a major cause of biotic homogenization; highly built-up habitats are so similar that they only support a few species.[35] Suburbia's heterogeneity is the result of various land-use types, including developed areas but also open areas, such as parks, preserves, brownfields, hydrologic features, and agricultural land, that are of different sizes, ages, and quality, offering "contrasting environmental conditions."[36] Urban ecologists are now discovering that biodiversity (defined as species richness) actually peaks in suburban environments and that suburban environments are "more heterogeneous and dynamic over space and time than natural ecosystems . . . [as] loci of novelty and innovation."[37]

New research shows that certain types of residential landscaping in suburbs could store more carbon—for example, areas with mature trees, areas with dense foliage and shrubs, areas of undisturbed soil, and areas with litter left in place.[38] Another study found that developed open spaces between buildings that are primarily turfgrass, including parks and home lawns, store almost 53.7 megatons of carbon a year—the equivalent of taking about 17 million US passenger cars off the road annually.[39]

Other research suggests that new planting and maintenance regimes (i.e., the way that neighborhoods are planted with vegetative materials such as trees, shrubs, and grasses and how these materials are maintained over time to absorb more carbon by allowing them to develop deeper root systems) should be targeted at the level of the whole neighborhood, not individual lots—especially in the lower-density areas on the exurban edge, where water-quality regulations allow for larger lots.[40]

The Future Autonomous Neighborhood

The case study below is from a research group called the Next Generation American Suburbs project, which focuses on designing for future metropolitan sustainability and is organized at the Massachusetts Institute of Technology's P-REX lab. The project studies how to optimize landscape performance in the design of future suburbs in tandem with emergent AEV technology.

Collaborating with our stakeholders, the Toyota Mobility Foundation, and the city planning office in McKinney, Texas, we launched a two-year project to study McKinney's transportation future and how people will travel for their daily needs within the city as it grows over time. We were given access to the city planners' 2040 vision plan to imagine how the future could look if autonomous technologies were optimized and implemented in development.

Hundreds of companies have begun work on various dimensions of AD. Collectively, their investments have already topped $200 billion in public disclosures.[41] These technological investments, ranging from manufacturing new sensors to artificial intelligence research, are merely the *first-order* wave of the benefits of AD (e.g., safety efficiencies, services provided by autonomous vehicles, and reduced costs).

Of greater consequence may be the *second- and third-order* effects of AD technologies. Given that 70 percent of the American population lives in suburban areas, AD will most likely have the greatest impact in these zones, outside the reaches of established mass-transit systems, where personal vehicular transport is the most ubiquitous. This also has potential benefits for cities in developing countries, where transportation accessibility is limited and would be greatly aided by autonomous vehicle technology, for example, for taxis or shuttles.

The question before us is how the relationships among society, urbanization, and the environment will change in response to the newfound freedom of movement enabled through AD mobility, specifically in US suburbs. In current suburban areas, access to transit for the elderly, people with disabilities, and those with a lower socioeconomic status is extremely limited. Analysts expect that by 2035, in the US alone, more than 31 million households will have a member who has some form of disability.[42] The distributed, hyper-flexible future offered by fully automated mobility systems could provide the most equitable remedy to this systemic mobility-access deficit.

McKinney's Legacy Middle Neighborhoods. Between 1930 and 1960, the population of McKinney, Texas, which served as the principal agribusiness center for Collin County, doubled from 7,000 to 14,000 residents.[43] During this same period, the city expanded its geographic footprint westward into adjacent agricultural fields, toward the Highway 75 corridor. This first wave of suburban development was characterized by modest single-family homes (on average, 1,100 square feet) built on small parcels (on average, 0.2 acres), laid out on a tight urban grid composed of small rectangular blocks (about 2.4 acres each), with each block bisected by a service alleyway (Figure 1).

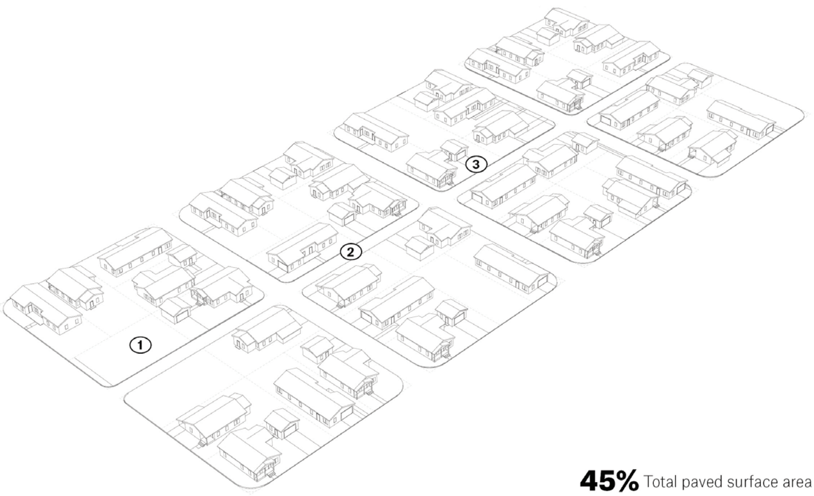
By 1970, McKinney was surpassed in size by several neighboring cities, and by the mid-1980s, it had become a commuter center for residents who worked in either Plano or Dallas. Since then, the population of this bedroom community has surged, growing 600 percent between 1990 and 2010. In contrast to the first wave of suburban development, this more recent growth has left a markedly different footprint, with the average home, block, and subdivision size all considerably larger and more car dependent.[44]

According to 2019 American Community Survey data from the US Census Bureau, more than 82.2 percent of McKinney residents drive alone to work.[45] Meanwhile, the entire city has earned a walk score of only 27 of 100, indicating that most errands require a vehicle.[46] This provides disproportionate challenges for working-class families, who typically spend a substantially higher percentage of their income on transportation costs.[47] Based on data from the Trust for Public Land, only 4 percent of McKinney's land is used for parks and recreation, which is far lower than even the paltry national median of 15 percent.[48]

Existing Conditions. Over the past four decades, many legacy middle neighborhoods have become increasingly neglected as they have become hemmed in by high-capacity arterial roadways and commercial strips. Today, many parcels (nearly 10 percent) in this district are vacant or blighted (Figure 1), and residents here rank among the most underserved in Texas in terms of mobility access.[49] Yet this neighborhood's proximity to the historic town center and other walkable amenities makes it a prime target for rebuilding and gentrification.

Despite accelerating regional pressures to densify these middle neighborhoods, upzoning processes often incentivize predatory development and fail to provide adequate equity for existing community residents. Furthermore, these wholesale land-use modifications strain neighborhood infrastructures. The smaller block size and alleyway features that are more typical in these legacy neighborhoods—along with anticipated shifts in mobility paradigms vis-à-vis new shared, autonomous, and micromobility services (i.e., short-distance transportation, usually within one mile and provided by lightweight, usually single-person vehicles such as bicycles, scooters, and Segways, sometimes with built-in electric-motor assistance)—offer a unique opportunity to rethink land-use code that can yield design changes to prioritize the equity of existing residents and reduce the overall impact on local infrastructure systems.

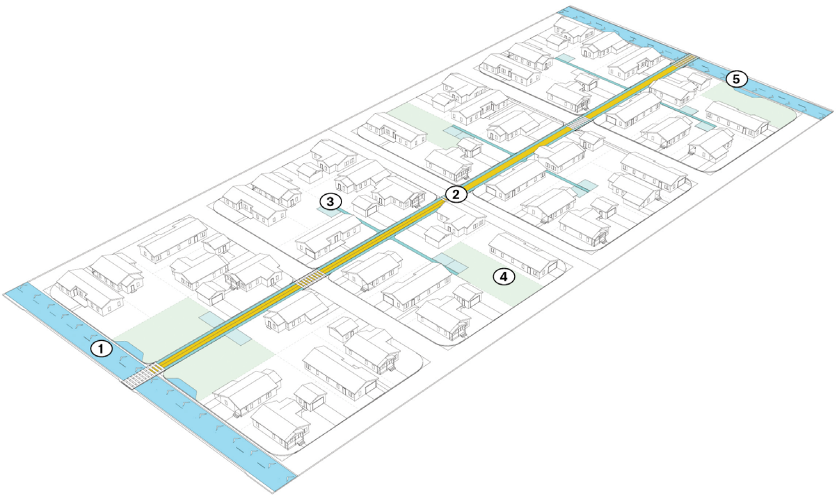
Figure 1. Legacy Residential Middle Neighborhood, McKinney, Texas



1. Vacant lots are common across blocks
2. Interior alleyway conditions vary from overgrown and inaccessible, to paved and highly used
3. Detached garages and driveways increase the overall footprint of each household

Source: Drone aerial and rendering by P-REX lab.

Figure 2. AD1 Transition of Alleyways



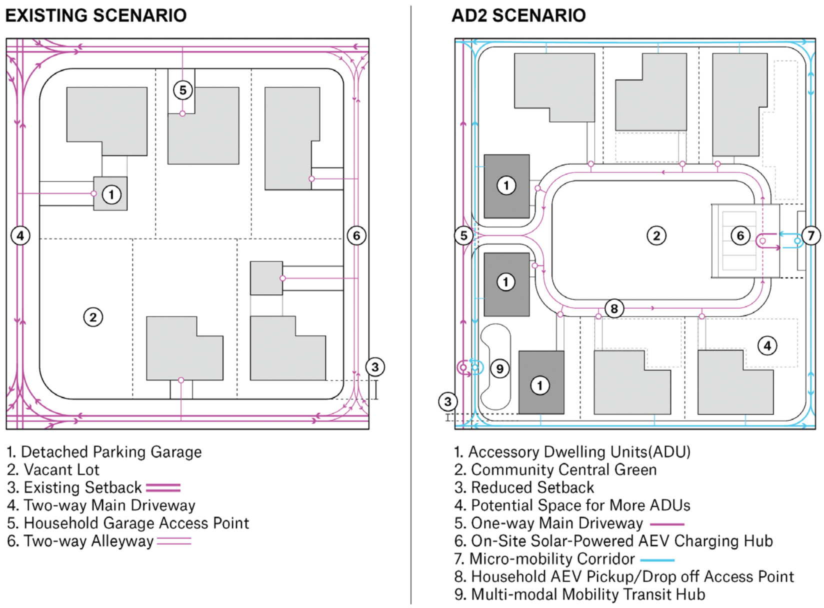
1. Dedicated pickups for local rideshare programs
2. Multi-modal mobility system takes advantage of interior alleyways
3. Shared charging stations increase access to emergent technologies by sharing capital expenses
4. Vacant lots are transformed into verdant public spaces
5. Roads alternate direction to allow for shared vehicle and EV-specific lanes

Source: Design and rendering by P-REX lab.

AD1 Retrofit (Circa 2025–35). In this scenario, designed by P-REX lab for the city of McKinney (Figure 2), as much as 0.5 acres of vacant lots per block are transitioned into high-value public open spaces that can support enhanced recreational opportunities for residents. Rideshare stations are distributed at intervals along existing arterials to provide designated pickup and drop-off points for community residents. These stations can facilitate seamless mode transfers between shared vehicle services and more agile last-mile options. Additionally, designated areas in each block have electric vehicle charging sheds for neighborhood residents.

In the near term, 2025–35 (referred to as AD1), the interior alleyways between blocks can be converted into a connective, car-free corridor supporting a range of short-trip scenarios for an evolving cross section of end users, including the elderly and those with disabilities.[50] We also anticipate how the AD1 design evolves over the long term, to 2035 and later (referred to as AD2).

Figure 3. AD2 New Block Typology Allows for Additional Housing and Shared Amenities

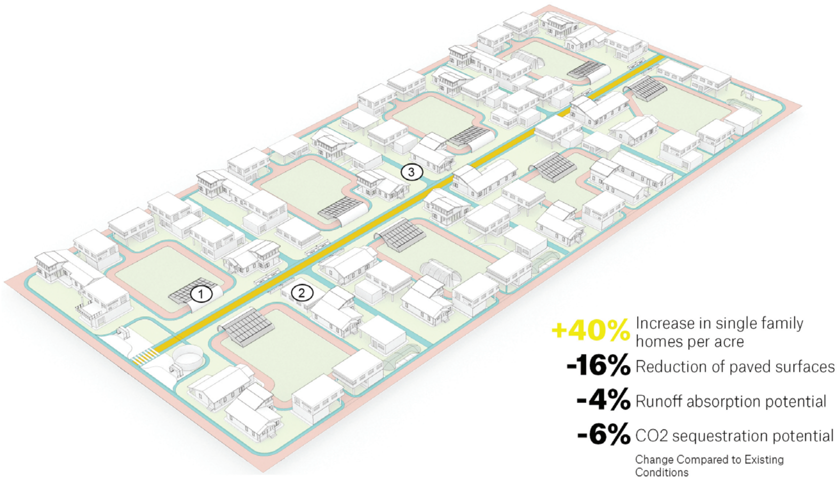


Source: Design and rendering by P-REX lab.

AD2 (Circa 2035 or Later) Redesign. Over time, AEVs could promote greater changes than are already anticipated, requiring planners and urban designers to rethink how residential blocks function without allowing personal vehicle access to every home. Figures 3 and 4 show how larger residential blocks could be subdivided or rezoned so that a portion of the aging housing stock can be infilled with smaller, single-family housing such as accessory dwelling units or multifamily options with smaller-than-average footprints.

These parcel-scale developments can be done by existing residents on their own properties in response to both market demand and personal needs. Not only does this approach reduce the threat of gentrification and displacement, but it also establishes an equity-building framework, supports aging in place, and can significantly reduce overall household transportation costs.[51] Former service alley right-of-ways can be upgraded

Figure 4. Possible AD2 Final Condition



1. AEV storage and charging stations
2. Smaller-footprint infill housing
3. Multi-modal transportation lanes are expanded to accommodate last-mile electric vehicle travel

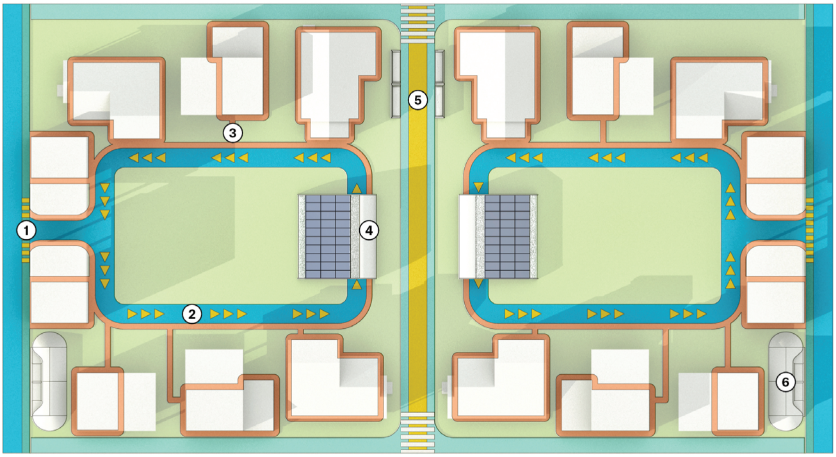
Source: Design and rendering by P-REX lab.

to accommodate autonomous service bots for package delivery, further reducing the strain on traditional roadway infrastructure.

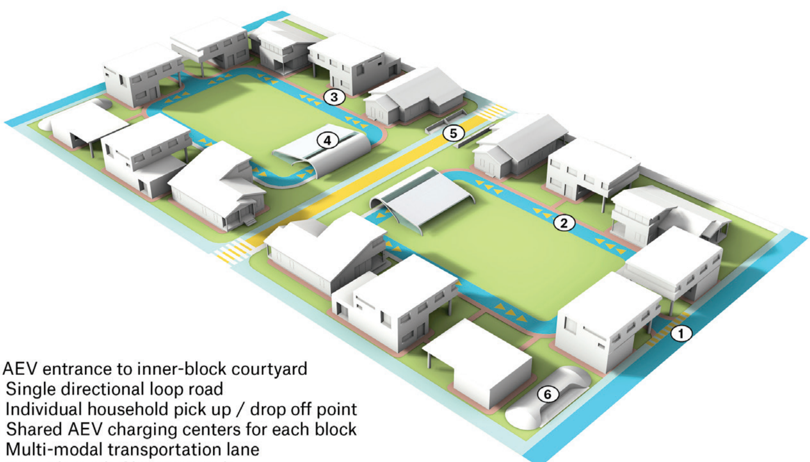
The de-paving of obsolete driveways, excessive street parking, and other unnecessary or redundant hardscape features will increase overall recreational landscaping. Our model predicts the new block design can reduce pavement by 16 percent, reduce stormwater runoff by 4 percent, sequester 6 percent more CO_2, and add 40 percent more park space—even while increasing residential density by as much as 40 percent.[52]

Given that AEV charging scenarios require significantly less space per vehicle (compared to existing parking requirements), each block will be able to support an average of one six-car AEV charging and dispatch station for its own residents by converting detached garage footprints (Figure 5). This will help ensure access to both private and shared transportation options without sacrificing open-space amenities. This scenario takes advantage of the reduced need for individual household vehicle storage by converting the middle of the block

Figure 5. AD2—Turning the Block Inside Out, Shared AEV Parking



1. AEV entrance to inner-block courtyard
2. Single directional loop road
3. Individual household pick up / drop off point
4. Shared AEV charging centers for each block
5. Multi-modal transportation lane
6. Pass Through Charging Pads



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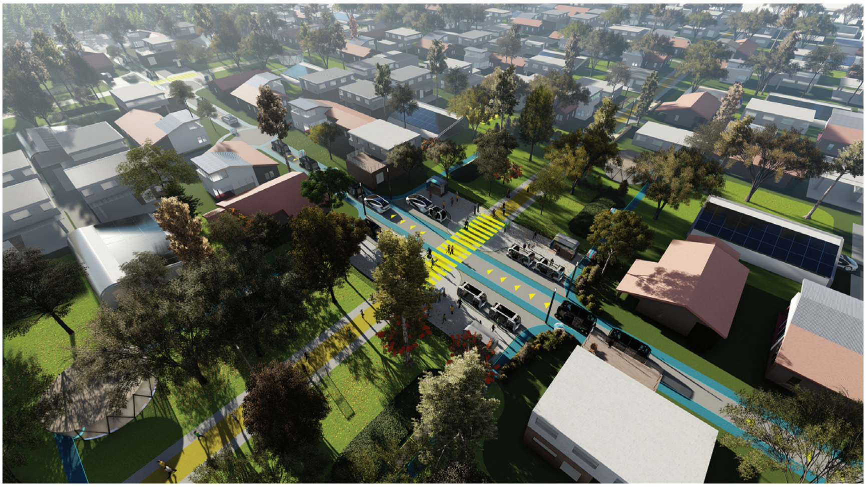
Source: Design and rendering by P-REX lab.

to a shared recreational space ringed by a low-volume, semipermeable one-way road for ensuring direct vehicular access to those with disabilities (Figure 6).

Figure 6. AD2 Interior Block Access for All

Source: Design and rendering by P-REX lab.

Figure 7. AD2 Mobility-Hub Smart Stops at Major Intersections



Source: Design and rendering by P-REX lab.

AD2 Redesign—Arterial Edge and Intersection. Figure 7 details how smart stops can be installed at the end of each block cluster, where multimodal transportation lanes intersect with AEV lanes. These intersections provide a natural place for supporting other mobility opportunities,

Figure 8. New AD2 Block Fully Retrofitted

Source: Design and rendering by P-REX lab.

including AEV bus stops for school-age children, pass-through charging pads for smaller vehicles, higher-volume charging stations for autonomous service bots, and household parcel delivery lockers for ground-shipped items. Along these arterial roadways, neighborhood-scale mobility options connect to other modes that span the larger regional transportation networks (Figure 7).

This planning and design framework establishes a viable alternative to tabula rasa middle neighborhood upzoning strategies that neglect considerations of existing infrastructural overburden, destruction of neighborhood social fabric, and further gentrification. The strategy prioritizes equitable development by supporting existing residents through increased mobility access and neighborhood green space while thoughtfully adding reasonable new density to housing scenarios (Figure 8).

New Possibilities for Suburbia and the Metropolitan Future

Throughout the 20th century, the rise of US suburbs coincided with increased adoption of single-purpose zoning practices, which resulted

Figure 9. Single-Purpose Zoning Creates Unfriendly Pedestrian Environments and Prevents Land-Use Mixing, McKinney, Texas

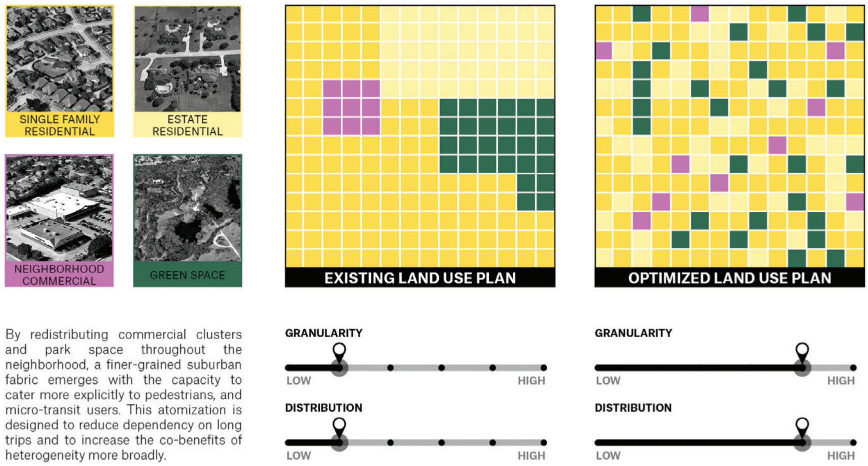
Source: Drone aerial by P-REX lab.

in highly standardized development and car-dependent neighborhoods. These forms are often comprised of large, homogeneous residential areas with minimal distribution of public open space, bounded by higher-volume arterial roads and commercial and retail strips (Figure 9).

New residential planning principles need to be aimed at increasing social equity, environmental performance, health benefits, and overall access to new mobility paradigms.[53] Three big factors are driving these changes: the oncoming proliferation of AEVs, the rapid transition of post-COVID-19 work from home, and the massive population of new millennial home buyers.[54] As these forces grow, they will challenge the fundamental assumptions that have guided land-use planning, zoning ordinances, and roadbuilding projects over the past century.

A transition from traditional car-based urbanism to autonomous, on-demand mobility will further support a shift toward more detailed land-use planning in suburbia. In this scenario, the existing land-use plan is redistributed such that each individual land-use type is given the same amount of total area. But in the optimized scenario, 95 percent of households are located within a five-minute walk of a park, and 85 percent are within a five-minute walk of a neighborhood commercial amenity (Figures 10

Figure 10. Atomizing Land Use for Optimized Performance



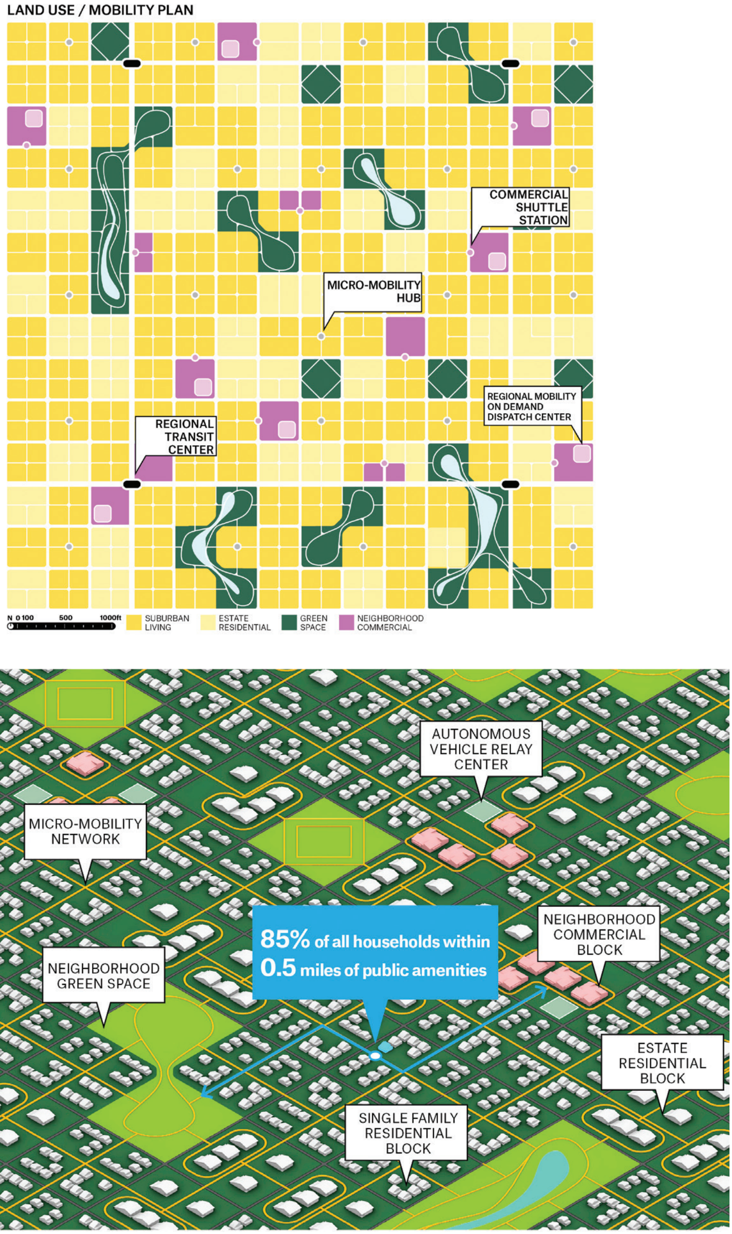
Source: Design and rendering by P-REX lab.

and 11). In the optimized future AEV suburb, homes on the same block can be designed with 47 percent more tree canopy, 40 percent more permeable surfaces, and 40 percent less paving, for vastly better environmental outcomes (Figure 12).

While car sharing remains limited in the US, with no growth since 2014, ride-hailing services have grown substantially since they were first introduced in 2011.[55] When redesigned for projected shared autonomous vehicle fleets and ride hailing, street widths can be dramatically reduced. Dedicated street parking can be replaced by pickup and drop-off zones. Garages and driveways can be eliminated or reincorporated into the floor plan as home offices and gardens.

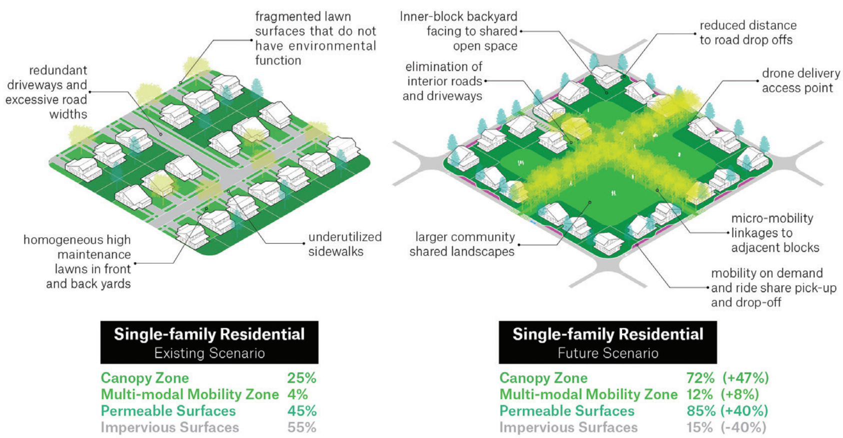
Through a modest reduction in private yard space, a large communal area (separated from vehicular traffic) can be gained. Not only can these larger open spaces provide environmental benefits, but expanded access to outdoor space may also offer important public health benefits (as has been demonstrated throughout the COVID-19 crisis). Such benefits may be even more significant in the case of multifamily household zoning, where large parking areas typically built on the block's interior can be replaced by on-site stormwater capture systems and expanded recreational amenities.

Figure 11. Optimized AD2 Neighborhood Land Use and Layout Views



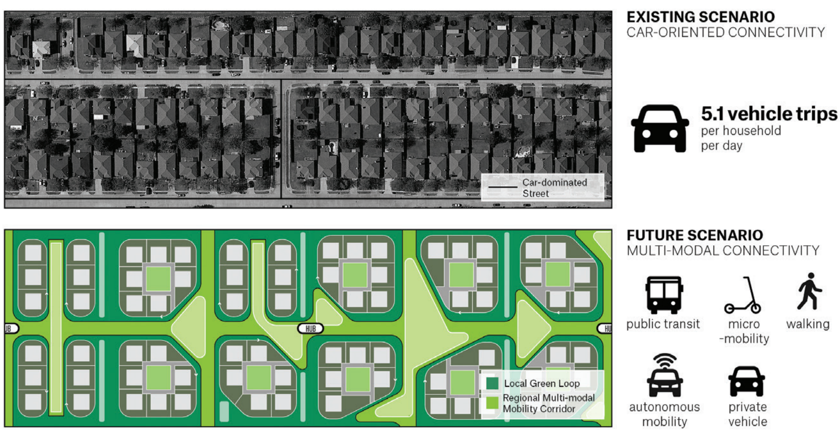
Source: Design and rendering by P-REX lab.

Figure 12. Prototypical Traditional Car-Based Suburban Block for Single-Family Detached Zoning vs. the Future AEV Suburb



Source: Design and rendering by P-REX lab.

Figure 13. Micromobility Corridor Connecting Blocks Through the Larger Neighborhood



Source: Design and rendering by P-REX lab.

When this redesigned block concept is repeated to form a multi-block corridor, the optimized structure allows for a potential 50 percent increase in permeable surface area. If planted with trees, this can substantially decrease summer temperatures and increase carbon sequestration capacity by more than 300 percent (Figures 12 and 13).[56]

Conclusion

The evolution of suburban mobility systems will significantly influence how environmental benefits can be accrued in existing and future suburban forms and equitably distributed throughout metropolitan regions. New autonomous mobility technology can be deployed to create new types of mixed-use neighborhoods that are walkable and filled with public landscape amenities. Designing suburbs in tandem with autonomous and near-zero carbon mobility options allows planners to hasten the end of sole-use zoning practices while making more equitable development patterns in the future. Modeling for and anticipating the adoption of AEV technology allows planners and designers to prioritize people over vehicles from the outset.

If politicians and planners seriously want to reduce GHG emissions in suburban areas, they shouldn't be blinded by the fallacy of "density fixes all." Rather, they should consider enacting new land-use regulations to accommodate physical planning and design innovations built around less energy-intensive autonomous mobility technologies. Attaching ecological performance requirements to the retrofitting of middle suburban neighborhoods and new greenfield suburban development could improve the overall environmental impact by removing wasteful paving and integrating ecological corridors, continuous canopy habitats, and hydrological catchments, which can all buffer the impact of land consumption.

As the case study reveals, a future near-zero carbon suburbia is achievable. Emerging autonomous mobility technologies provide a way to accommodate residents' desires for low to moderate density without causing undue harm to the environment, restoring the promise first advanced by the garden-city visionaries more than a century ago.

Acknowledgments

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Notes

1. William E. Rees, "Ecological Footprints and Appropriated Carrying Capacity: What Urban Economics Leaves Out," *Environment and Urbanization* 4, no. 2 (October 1992), https://journals.sagepub.com/doi/pdf/10.1177/095624789200400212; and Cecilia Tacoli, *The Earthscan Reader in Rural-Urban Linkages* (Oxfordshire, UK: Routledge, 2006), 292.

2. André Botequilha-Leitão, "Eco-Polycentric Urban Systems: An Ecological Region Perspective for Network Cities," *Challenges* 3, no. 1 (2012): 1–42.

3. Susannah Hagan, "Metabolic Suburbs, or the Virtue of Low Densities," *Architectural Research Quarterly* 16, no. 1 (2012): 11, https://www.cambridge.org/core/journals/arq-architectural-research-quarterly/article/metabolic-suburbs-or-the-virtue-of-low-densities/C00493519F20E2D9C7B57E5D8EFE74E4.

4. Ebenezer Howard and Frederic J. Osborn, *Garden Cities of To-Morrow* (Cambridge, MA: Massachusetts Institute of Technology Press, 1965). For a comprehensive catalog of garden suburbs, see Robert A. M. Stern, David Fishman, and Jacob Tilove, *Paradise Planned: The Garden Suburb and the Modern City* (New York: Monacelli Press, 2013).

5. Carl Abbott, "The Landscape Tradition," in *Planning and Urban Design Standards,* ed. Frederick R. Steiner and Kent Butler (Hoboken, NJ: John Wiley & Sons, 2006).

6. Jon A. Peterson, "The Birth of Organized City Planning in the United States, 1909–1910," *Journal of the American Planning Association* 75, no. 2 (2009): 123–33, https://www.tandfonline.com/doi/abs/10.1080/01944360802608484?journalCode=rjpa20; and Harvey A. Kantor, "Benjamin C. Marsh and the Fight over Population Congestion," *Journal of the American Institute of Planners* 40, no. 6 (1974): 422–29, https://www.tandfonline.com/doi/abs/10.1080/01944367408977500.

7. *Proceedings of the National Conference on City Planning and the Problems of Congestion* (Cambridge, MA: 1912), https://nrs.lib.harvard.edu/urn-3:gsd.loeb:ocp_des_641638.

8. Kenneth T. Jackson, *Crabgrass Frontier: The Suburbanization of the United States* (Oxford, UK: Oxford University Press, 1985).

9. Jean Gottmann, *Megalopolis: The Urbanized Northeastern Seaboard of the United States* (New York: Twentieth Century Fund, 1961).

10. Peter Hall and Kathy Pain, *The Polycentric Metropolis: Learning from Mega-City Regions in Europe* (Oxfordshire, UK: Routledge, 2006).

11. American Association of State Highway and Transportation Officials, *Commuting in America 2013: The National Report on Commuting Patterns and Trends*, January 2015, 15:1–24, https://traveltrends.transportation.org/wp-content/uploads/sites/62/2019/07/B15_Commuting-Flow-Patterns_CA15-4_web.pdf.

12. For example, see Kenneth P. Laberteaux, Casey Lance Brown, and Alan M. Berger, "Interburbia: Ground Truthing US Metropolitan Urbanization," in *Infinite Suburbia*, ed. Alan Berger, Joel Kotkin, and Celina Balderas Guzman (New York: Princeton Architectural Press, 2017); and Alan Pisarski, "Driving While Suburban," in *Infinite Suburbia*, ed. Alan Berger, Joel Kotkin, and Celina Balderas Guzman (New York: Princeton Architectural Press, 2017).

13. Adella Santos et al., *Summary of Travel Trends: 2009 National Household Travel Survey*, US Department of Transportation, Federal Highway Administration, June 2011, https://nhts.ornl.gov/2009/pub/stt.pdf. For example, see US Department of Commerce, Census Bureau, "American Community Survey (ACS)," https://www.census.gov/programs-surveys/acs.

14. Kim Hart, "Coronavirus May Prompt Migration out of American Cities," Harris Poll, 2020, https://theharrispoll.com/coronavirus-may-prompt-migration-out-of-american-cities.

15. For example, see California's S.B. 837, S.B. 50, and S.B. 902, introduced by state Sen. Scott Weiner. Jenna Chandler, "Proposal to Add Density near Transit Stations Quickly Rejected in California Senate," Curbed Los Angeles, April 17, 2018, https://la.curbed.com/2018/4/17/17249654/california-senate-bill-827-housing-transit-vote; and Evan Symon, "Senator Wiener Introduces 'SB 50 Lite' Housing Bill to End Single-Family Zoning in CA," California Globe, May 22, 2020, https://californiaglobe.com/section-2/senator-wiener-introduces-sb-50-lite-housing-bill.

16. Adie Tomer et al., "We Can't Beat the Climate Crisis Without Rethinking Land Use," Brookings Institution, May 12, 2021, https://www.brookings.edu/research/we-cant-beat-the-climate-crisis-without-rethinking-land-use; Daniel Parolek, "Why 'Middle Neighborhoods' Are the Sweet Spot Between the City and the Suburbs," *US News & World Report*, July 15, 2020, https://www.usnews.com/news/cities/articles/2020-07-15/meet-middle-neighborhoods-the-sweet-spot-between-the-city-and-the-suburbs; John Mirisch, "Meet Me in St. Louis: When One Golden Gate Closes, Another May Open," NewGeography.com, November 8, 2021, https://www.newgeography.com/content/007239-meet-me-st-louis-when-one-golden-state-closes-another-may-open; Maggie Angst, "Will San Jose Move to Densify Single-Family Neighborhoods Like Sacramento Just Did?," *East Bay Times*, January 25, 2021, https://www.eastbaytimes.com/2021/01/25/will-san-jose-move-to-densify-single-family-neighborhoods-like-sacramento-just-did-5; and Alan Mallach, "America's Middle Neighborhoods: Setting the Stage for Revival" (working paper, Lincoln Institute of Land Policy, Cambridge,

MA, November 2018), https://www.lincolninst.edu/sites/default/files/pubfiles/mallach_wp18am2.pdf.

17. Conor Dougherty, "The Great American Single-Family Home Problem," *New York Times*, December 1, 2017, https://www.nytimes.com/2017/12/01/business/economy/single-family-home.html.

18. Transportation Research Board and National Research Council, *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions* (Washington, DC: National Academies Press, 2009).

19. Reid Ewing and Robert Cervero, "Travel and the Built Environment," *Journal of the American Planning Association* 76, no. 3 (2010): 265–94, https://www.tandfonline.com/doi/abs/10.1080/01944361003766766.

20. David Brownstone, "Key Relationships Between the Built Environment and VMT," in *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions*, Transportation Research Board and National Research Council (Washington, DC: National Academies Press, 2009), https://onlinepubs.trb.org/Onlinepubs/sr/sr298brownstone.pdf.

21. Alan M. Berger, "Research," P-REX Lab, https://www.alanmberger.com/research.

22. Jeffrey Wilson et al., "Blame the Exurbs, Not the Suburbs: Exploring the Distribution of Greenhouse Gas Emissions Within a City Region," *Energy Policy* 62 (November 2013): 1329–35, https://www.sciencedirect.com/science/article/abs/pii/S0301421513006551; and Matthew E. Kahn, "The Environmental Impact of Suburbanization," *Journal of Policy Analysis and Management* 19, no. 4 (September 2000): 569–86, https://onlinelibrary.wiley.com/doi/abs/10.1002/1520-6688%28200023%2919%3A4%3C569%3A%3AAID-PAM3%3E3.0.CO%3B2-P.

23. Marilyn A. Brown and Elise Logan, "The Residential Energy and Carbon Footprints of the 100 Largest U.S. Metropolitan Areas" (working paper, Georgia Tech, Ivan Allen College, School of Public Policy, Atlanta, GA, May 2008), https://smartech.gatech.edu/bitstream/handle/1853/22228/wp39.pdf.

24. John W. Day and Charles Hall, "The Myth of the Sustainable City," *Scientific American*, August 21, 2016, https://www.scientificamerican.com/article/the-myth-of-the-sustainable-city.

25. Jukka Heinonen and Seppo Junnila, "Implications of Urban Structure on Carbon Consumption in Metropolitan Areas," *Environmental Research Letters* 6, no. 1 (March 2011): 9, https://iopscience.iop.org/article/10.1088/1748-9326/6/1/014018.

26. Marcial H. Echenique et al., "Growing Cities Sustainably: Does Urban Form Really Matter?," *Journal of the American Planning Association* 78, no. 2 (May 2012): 121–37, https://www.tandfonline.com/doi/citedby/10.1080/01944363.2012.666731?scroll=top&needAccess=true.

27. Francesco Pomponi et al., "Decoupling Density from Tallness in Analysing the Life Cycle Greenhouse Gas Emissions of Cities," *Urban Sustainability* 1, no. 33 (July 5, 2021), https://www.nature.com/articles/s42949-021-00034-w.

28. Gina Zirkle, Rattan Lal, and Bruce Augustin, "Modeling Carbon Sequestration in Home Lawns," *American Society for Horticultural Science* 46, no. 5 (May 2011), https://journals.ashs.org/hortsci/view/journals/hortsci/46/5/article-p808.xml.

29. Pomponi et al., "Decoupling Density from Tallness in Analysing the Life Cycle Greenhouse Gas Emissions of Cities."

30. Pomponi et al., "Decoupling Density from Tallness in Analysing the Life Cycle Greenhouse Gas Emissions of Cities."

31. Ralph E. Heimlich et al., "Urbanizing Farmland: Dynamics of Land Use Change in Fast-Growth Counties: Concern over Farmland Loss," US Department of Agriculture, Economic Research Service, 1991, https://naldc.nal.usda.gov/catalog/CAT91960449; Edward L Glaeser and Matthew E. Kahn, "Sprawl and Urban Growth" (working paper, National Bureau of Economic Research, Cambridge, MA, May 2003), https://www.nber.org/papers/w9733; and V. Henderson and J. F. Thisse, *Handbook of Regional and Urban Economics* (Amsterdam, Netherlands: North Holland, 2004), 2481–527.

32. US Environmental Protection Agency, website, https://www.epa.gov.

33. Bureau of Vehicle Statistics, website, https://www.bts.gov; and US Department of Transportation, website, https://www.transportation.gov.

34. Matthew E. Kahn and Joel Schwartz, "Urban Air Pollution Progress Despite Sprawl: The 'Greening' of the Vehicle Fleet," *Journal of Urban Economics* 63, no. 3 (May 2008): 775–87, https://www.sciencedirect.com/science/article/abs/pii/S0094119007000617.

35. Michael L. McKinney, "Urbanization as a Major Cause of Biotic Homogenization," *Biological Conservation* 127, no. 3 (January 2006): 248, https://www.sciencedirect.com/science/article/abs/pii/S0006320705003563.

36. Ingo Kowarik, "Novel Urban Ecosystems, Biodiversity, and Conservation," *Environmental Pollution* 159, no. 8–9 (August–September 2011): 1974–83, https://www.sciencedirect.com/science/article/abs/pii/S0269749111000960; and Sébastien Bonthoux et al., "How Can Wastelands Promote Biodiversity in Cities? A Review," *Landscape and Urban Planning* 132 (2014): 79–88, https://www.researchgate.net/publication/265512639_How_can_wastelands_promote_biodiversity_in_cities_A_review.

37. Berger, Kotkin, and Guzman, *Infinite Suburbia*; Robert B. Blair and Elizabeth M. Johnson, "Suburban Habitats and Their Role for Birds in the Urban-Rural Habitat Network: Points of Local Invasion and Extinction?," *Landscape Ecology* 23, no. 10 (January 2008): 1167, https://www.researchgate.net/publication/227156751_Suburban_habitats_and_their_role_for_birds_in_the_urban-rural_habitat_network_Points_of_local_invasion_and_extinction; Sarah J. Hinners, Carol A. Kearns, and Carol A. Wessman, "Roles of Scale, Matrix, and Native Habitat in Supporting a Diverse Suburban Pollinator Assemblage," *Ecological Applications* 22, no. 7 (October 2012): 1923–35, https://pubmed.ncbi.nlm.nih.gov/23210309/; Robert B. Blair and Alan E. Launer, "Butterfly Diversity and Human Land Use: Species Assemblages Along an Urban Gradient," *Biological Conservation* 80, no. 1 (April 1997): 113–25, https://www.sciencedirect.com/science/article/abs/pii/S0006320796000560; Robert B. Blair et al., "Estimating Mammalian Species Diversity Across an Urban Gradient," *American Midland Naturalist* 68, no. 2 (2012): 315–32, https://www.researchgate.net/publication/259217159_Estimating_Mammalian_Species_Diversity_across_an_Urban_Gradient; Carla P. Catterall et al., "Long-Term Dynamics of Bird Diversity in Forest and Suburb: Decay, Turnover or Homogenization?," *Diversity and Distributions* 16, no. 4 (July 2010): 559–70, https://onlinelibrary.wiley.com/doi/full/10.1111/j.1472-4642.2010.00665.x; John M. Marzluff,

Welcome to Subirdia: Sharing Our Neighborhoods with Wrens, Robins, Woodpeckers, and Other Wildlife (New Haven, CT: Yale University Press, 2014); and John M. Marzluff, Reed Bowman, and Roarke Donnelly, eds., *Avian Ecology and Conservation in an Urbanizing World* (Boston, MA: Springer, 2001), 19–47.

38. William S. Currie et al., "MultiScale Heterogeneity in Vegetation and Soil Carbon in Exurban Residential Land of Southeastern Michigan, USA," *Ecological Applications* 26, no. 5 (July 2016): 1421–36, https://esajournals.onlinelibrary.wiley.com/doi/10.1890/15-0817.

39. Adam Selhorst and Rattan Lal, "Net Carbon Sequestration Potential and Emissions in Home Lawn Turfgrasses of the United States," *Environmental Management* 51 (2013): 198–208, https://doi.org/10.1007/s00267-012-9967-6. These estimates are based on our approximate calculations using results from the literature extrapolated for total US turfgrass area, using the greenhouse gas equivalencies calculator from US Environmental Protection Agency, "Greenhouse Gas Equivalencies Calculator," https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator. See also US Energy Information Administration, website, https://www.eia.gov.

40. Joan Iverson Nassauer, "Greening Sprawl: Land Culture and Carbon Storage in the Suburban Landscape," in *Infinite Suburbia*, ed. Alan Berger, Joel Kotkin, and Celina Balderas Guzman (New York: Princeton Architectural Press, 2017).

41. Daniel Holland-Letz et al., "Mobility's Future: An Investment Reality Check," McKinsey & Company, April 14, 2021, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mobilitys-future-an-investment-reality-check.

42. Harvard University, Joint Center for Housing Studies, *Projections and Implications for Housing a Growing Population: Older Adults 2015–2035*, December 13, 2016, http://www.jchs.harvard.edu/housing-a-growing-population-older-adults.

43. McKinney Texas, "Population History—McKinney, Texas," https://www.mckinneytexas.org/DocumentCenter/View/27908/Population-History---by-Decade?bidId=.

44. US Census Bureau, "QuickFacts: McKinney City, Texas," https://www.census.gov/quickfacts/fact/table/mckinneycitytexas/PST045219.

45. Data USA, "McKinney, TX," https://datausa.io/profile/geo/mckinney-tx/#about; and US Department of Commerce, Census Bureau, "American Community Survey (ACS)," https://www.census.gov/programs-surveys/acs.

46. Walk Score, McKinney, Texas, https://www.walkscore.com/TX/McKinney. Walk Score measures the walkability of any address using a patented system. For each address, Walk Score analyzes hundreds of walking routes to nearby amenities. Points are awarded based on the distance to amenities in each category. Amenities within a five-minute walk (0.25 miles) are given maximum points. A decay function is used to give points to more distant amenities, with no points given after a 30-minute walk. Walk Score also measures pedestrian friendliness by analyzing population density and road metrics such as block length and intersection density. Data sources include Google, Factual, Great Schools, Open Street Map, the US Census, Localeze, and places added by the Walk Score user community.

47. US Department of Transportation, Bureau of Transportation Statistics, "Commuting Expenses: Disparity for the Working Poor," November 21, 2012, https://www.bts.

gov/archive/publications/special_reports_and_issue_briefs/issue_briefs/number_01/entire.

48. Trust for Public Land, website, https://www.tpl.org.

49. Todd Litman, "Quantifying Bicycling Benefits for Achieving TDM Objectives," Transportation Research Board, 1995.

50. City of McKinney, *McKinney Parks, Recreation, Open Space, Trails & Streetscape: 2017 Visioning Master Plan*, April 2017, https://www.mckinneytexas.org/DocumentCenter/View/12673/Executive-Summary.

51. Edward L. Glaeser and Joseph Gyourko, "The Impact of Building Restrictions on Housing Affordability," *Federal Reserve Bank of New York Economic Policy Review* (June 2003), https://www.newyorkfed.org/medialibrary/media/research/epr/03v09n2/0306glae.pdf.

52. Jeremy S. Hoffman, Vivek Shandas, and Nicholas Pendleton, "The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas," *Climate* 8, no. 1 (January 13, 2020): 12, https://doi.org/10.3390/cli8010012; and US Environmental Protection Agency, "Using Trees and Vegetation to Reduce Heat Islands," https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands.

53. Cecilia Rouse et al., "Exclusionary Zoning: Its Effect on Racial Discrimination in the Housing Market," White House, June 17, 2021, https://www.whitehouse.gov/cea/written-materials/2021/06/17/exclusionary-zoning-its-effect-on-racial-discrimination-in-the-housing-market; Marie Lynn Miranda et al., "Making the Environmental Justice Grade: The Relative Burden of Air Pollution Exposure in the United States," *International Journal of Environmental Research and Public Health* 8, no. 6 (June 2011): 1755–71, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3137995; Anthony Nardone et al., "Associations Between Historical Residential Redlining and Current Age-Adjusted Rates of Emergency Department Visits Due to Asthma Across Eight Cities in California: An Ecological Study," *Lancet* 4, no. 1 (January 2020): 24–31, https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(19)30241-4/fulltext; and Alana Semuels, "Good School, Rich School; Bad School, Poor School," *Atlantic*, August 25, 2016, https://www.theatlantic.com/business/archive/2016/08/property-taxes-and-unequal-schools/497333.

54. Nicole Friedman, "Millennials Are Supercharging the Housing Market," *Wall Street Journal*, December 14, 2021, https://www.wsj.com/articles/millennials-are-supercharging-the-housing-market-11639496815.

55. Susan Shaheen, Adam Cohen, and Mark Jaffee, "Innovative Mobility: Carsharing Outlook," University of California, Berkeley, Institute of Transportation Studies, 2018, https://escholarship.org/uc/item/1mw8n13h. Data depict July of each year, and numbers include round-trip and one-way car sharing.

56. Calculated using i-tree software, based on a typical single-family block zoned for one-fourth-acre lots.