

The Kernel-Up Polycentric Model

A Modular, Community-based Urban Development Framework

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ABSTRACT

The Kernel-Up Polycentric Model:
A Modular, Community-based Urban Development Framework

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Humanity will need to build homes and infrastructure for 5 billion people before the end of this century. Unfortunately, cities already face numerous challenges before factoring in decades of sustained, rapid growth. Building new cities from scratch would allow them to be rethought from first principles, with people and communities as the focus. Doing so could also enable new technologies to be incorporated and for outdated legacy systems to be eliminated.

This thesis presents a design-driven exploration of what such reimagined cities might look like and how they could be built. The argument is made for a nested polycentric layout, built from the bottom up out of small - approximately 100 resident - heterogeneous community units ("kernels"). The KUP (Kernel-Up Polycentric) Model is the result of arranging kernels around a common center to form larger communities, which in turn serve as subunits of yet larger community layers. Infinite differentiated forms can result while adhering to the same basic connectivity by simply adjusting kernel typologies, the number of community subunits per layer, the geometric arrangement of community subunits relative to their center, and the number of community layers.

The potential of this generalized, modular framework is explored in the context of historic urban models, recent ideas in the field of planning, and modern technological trends. Implications for transportation, work, retail, manufacturing, agriculture, utilities, the sharing economy, and governance are all discussed. Breadth is prioritized over depth in this thought experiment, in order to provide a holistic picture of the KUP Model. The potential to leverage this modular framework in the democratization of urban design is also touched on. Finally, the implications of this dramatically revised urban development approach are also discussed for cities, urban planning, and allied fields.

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EXECUTIVE SUMMARY

Humanity will need to build homes and infrastructure for 5 billion people before the end of this century. Unfortunately, cities already face numerous challenges before factoring in decades of sustained, rapid growth. Building new cities from scratch would allow them to be rethought from first principles, with people and communities as the focus. Doing so could also enable new technologies to be incorporated and for outdated legacy systems to be eliminated.

This thesis presents a comprehensive argument for constructing new cities that are characterized by a nested polycentric form. In contrast to existing urban environments, this model is defined from the bottom up: heterogeneous community units of approximately 100 residents ("kernels") are arranged around a common center to form larger communities, which in turn serve as subunits of larger community units. This simple, modular framework supports infinite variations by adjusting kernel typologies, the number of community subunits per layer, the geometric arrangement of community subunits relative to their center, and the number of community layers. Precedents for such urban forms throughout history and urban planning literature are discussed, in addition to parallels in nature.

This "Kernel-Up Polycentric" (KUP) model results in a novel street layout, which could better facilitate a transportation paradigm that consists of autonomous vehicles, micro mobility devices, bikes, and pedestrian travel. Additionally, having defined centers for each community scale allows for the strategic placement of suitable common spaces, shared resources, and businesses. The suitability of the KUP model for differentiated functions in these centers is discussed within the context of impactful trends like remote working, online shopping, supply chain localization, digitization of services, and decentralization of utilities. The potential for differentiated ownership and governance models is also touched on, as well as why the KUP model is better optimized for the sharing economy.

The modular form of the KUP model opens up the possibility of democratizing urban design through a collaborative world building platform. Aspirationally, future residents could co-create a virtual version of their ideal shared environment before eventually having it built. Finally, the implications of this dramatically revised urban development approach are also discussed for cities, urban planners, urban designers, architects, and real estate developers.

INTRODUCTION

The (Very Large) Problem

Over the coming decades, new housing and infrastructure will need to be constructed to accommodate at least 5 billion people across the world. The largest contributor to this demand will be the projected net increase in world population of approximately 3 billion humans by 2100.¹ This population increase will largely be concentrated in urban areas, but it will happen asymmetrically across the world, with some areas expected to experience a decrease in population while others increase substantially.² Additionally, there are more than 1 billion people living in informal settlements as a result of urbanization outstripping cities' abilities to expand.³ Ideally, proper homes and infrastructure would be constructed for these new urban residents as soon as possible. Another demand driver of urban development in the coming decades is that a large number of people will likely have to relocate as a result of climate change. For instance, sea level rise is expected to displace many people from coastal cities while more frequent fires, heat waves, hurricanes, and other natural disasters may also cause net emmigration from certain regions.⁴ Additionally, there are numerous people currently living in homes and relying on existing infrastructure that will reach the end of their useful life spans during this time period and need to be replaced.⁵ For example, the American Society of Civil Engineers projects that the United States will need to spend \$2.2 trillion more than is currently planned to replace and maintain the nation's aging water pipes over the next two decades.⁶

¹ United Nations, Department of Economic and Social Affairs, and Population Division. *World Population Prospects Highlights, 2019 Revision Highlights, 2019 Revision*, 2019.

² United Nations, 2019

³ United Nations. "SDG Indicators." Accessed January 29, 2022.
<https://unstats.un.org/sdgs/report/2019/Goal-11/>.

⁴ Palinkas, Lawrence A. *Global Climate Change, Population Displacement, and Public Health: The Next Wave of Migration*. Cham: Springer International Publishing AG, 2020.

⁵ Cindy Wallis-Lage, "Deferred Maintenance and Aging Infrastructure Threaten Water Sustainability, Reliability," *Journal AWWA* 109, no. 1 (2017): 53–57, <https://doi.org/10.5942/jawwa.2017.109.0005>.

⁶ American Society of Civil Engineers, "The Economic Benefits of Investing in Water Infrastructure: How a Failure to Act Would Affect the US Economic Recovery," *Value of Water Campaign/ASCE*, (2020), 12-13.

Unfortunately, most cities are already facing numerous other challenges and many of these are expected to get worse in the near future. Rapidly adapting to accommodate growing populations would likely make addressing these issues more difficult. Perhaps the most relevant challenge to note in the context of future housing demand is that many cities are already facing an acute lack of affordable housing.⁷ This is largely due to the fact that demand has outstripped supply, which has driven up costs.⁸ In the coming decades, cities will also need to make drastic changes to cut carbon emissions by facilitating the shift to electric vehicles, renewable energy, and more energy efficient buildings in order to meet the goals of the Paris Climate Accord.⁹ Besides air pollution, sustainable management of sewage and solid waste is still far from a solved matter in most places.¹⁰ Terrible traffic congestion and suboptimal transit systems are other major issues that plague many cities. On top of all of these challenges, many cities are operating with unsustainable budgets and ballooning debt.¹¹

While addressing these challenges, cities will need to adapt to a swiftly changing world. Nearly every industry is being disrupted by new technologies, from transportation to manufacturing and education to healthcare. Figuring out how to incorporate these advancements into urban environments is difficult due to the complex interdependencies of existing systems. For instance, the emergence of online shopping is creating uncertainty around the role of retail going forward¹² while the sudden, widespread implementation of remote work has brought into question the general need for so many offices or supporting

⁷ Steffen Wetzstein, "The Global Urban Housing Affordability Crisis," *Urban Studies* 54, no. 14 (2017): 3159–77.

⁸ Gregg Colburn, *Homelessness Is a Housing Problem: How Structural Factors Explain U.S. Patterns* (Oakland, California: University of California Press, 2022).

⁹ Socolow, Robert H. "Contending with Climate Change: The next 25 Years." *Bulletin of the Atomic Scientists* 76, no. 6 (November 1, 2020): 294–301. <https://doi.org/10.1080/00963402.2020.1846410>.

¹⁰ David C. Wilson and Costas A. Velis, "Waste Management – Still a Global Challenge in the 21st Century: An Evidence-Based Call for Action," *Waste Management & Research* 33, no. 12 (2015): 1049–51, <https://doi.org/10.1177/0734242X15616055>.

¹¹ Truth in Accounting, "Financial State of the Cities: An Annual Report by Truth in Accounting," (2022). Accessed January 31, 2022. <https://www.truthinaccounting.org/resources>.

¹² James Conca, "The Coronavirus Accelerates Online's Destruction Of Brick & Mortar Shopping," *Forbes*, accessed January 31, 2022, <https://www.forbes.com/sites/jamesconca/2020/08/21/the-coronavirus-accelerates-onlines-destruction-of-brick--mortar-shopping/>.

businesses in city centers.¹³ Despite the fact that so much change is underway and inevitable, the rigidity of existing regulations make it extremely difficult for cities to modify how they operate and develop over time.

Overall, it is fair to say that cities face a very tough road ahead without layering on decades of rapid and sustained growth. Regardless, the world's urban capacity will need to approximately double over the next 50 years. Given the context of the challenges noted above, urban planners need to step back and consider whether the current approach to urban development - continuously expanding existing cities radially and through infill - is best suited to meeting that demand.

Back to Basics

Before attempting to explore this question, it is worthwhile to step back and talk about what cities are. There are many dimensions that people tend to define them according to. One perspective is that they are large, dense populations that coexist and perform mutually interdependent functions in a set area. Cities are also defined by the large number of built structures that they contain: the buildings (residential, offices, warehouses, stores, etc.), roads, bridges, utility systems, and other physical resources (lights, bus stops, seating, etc.) that residents rely on. Additionally, each city is a legally defined administrative unit with powers and rights defined by the jurisdiction that it exists within.¹⁴

All of these and many other perspectives are valid. Some elements, however, are present in certain cities but not in others. Additionally, some are static while others change across time. Even trying to simply define cities as “large” human settlements doesn’t capture the reality that they span many orders of magnitude in terms of area as well as population: some cities have tens of thousands of residents while some have tens of millions; some cover just a handful of acres while others extend across thousands of square miles.

¹³ Shep Hyken, “The Impact Of The Remote Workforce,” Forbes, accessed January 31, 2022, <https://www.forbes.com/sites/shephyken/2021/02/28/the-impact-of-the-virtual-work-from-home-workforce/>.

¹⁴ Hans Blumenfeld, *The Modern Metropolis; Its Origins, Growth, Characteristics, and Planning. Selected Essays*. (Cambridge: Massachusetts Institute of Technology, 1967): 3-17

Rather than a standardized, rigid definition of a city, it is more accurate and useful to place human settlements along a spectrum from urban to rural.^{15,16} In my view, the primary criteria for assessing this is not size, but rather the density of built infrastructure as well as the resulting complexity of relationships among the people that rely on these systems. A large population is a necessary criteria for infrastructure densification to take place, but it is not what makes a settlement urban. Additionally, a large amount of land is neither necessary nor sufficient for an area to be called urban - even if 100 square miles were packed full with people standing shoulder to shoulder, it would not be a city. What makes an area more or less urban is the presence of purpose-built artificial structures and intentionally crafted spaces that facilitate mutually beneficial cohabitation by residents.

What I am primarily concerned with in this thesis is the emergent societal implications of “urban forms”, which can be thought of as the high level spatial arrangement of physical elements in urban areas, as well as the processes that result in them. It is important to remember that these morphological attributes of built environments are fundamentally inseparable from their sociological outcomes.¹⁷

“Urban forms are composed of houses, buildings, streets, parks, market farms, pipes and wires, railroads, highways, wharves, and airports. Any particular urban form reflects the complex interrelationships among social, economic, and political processes that brought it into being. New resources, new technologies, new ways of doing business, the migration of peoples, and shifts in politics and culture all have their part to play in the building and altering of urban form. Planning for a city’s future requires that such forces be discussed.”¹⁸

¹⁵ Anne Whiston, “Ecological Urbanism,” in *Companion to Urban Design* (Routledge, 2011), 614–24, <https://doi.org/10.4324/9780203844434>.

¹⁶ Emily Talen, “Help for Urban Planning: The Transect Strategy,” *Journal of Urban Design* 7, no. 3 (October 1, 2002): 293–312, <https://doi.org/10.1080/1357480022000039349>.

¹⁷ Henri Lefebvre, *The Urban Revolution* (University of Minnesota Press, 2014), <https://doi.org/10.5749/j.ctt5vkbkv>.

¹⁸ Sam Bass Warner and Andrew Whittemore, *American Urban Form: A Representative History*, Urban and Industrial Environments (Cambridge: The MIT Press, 2012), <https://doi.org/10.7551/mitpress/9183.001.0001>.

Human-Centric Design Goals

There is inevitably a tradeoff between artificial, human-made structures and natural landscapes in a given space, which is what defines a settlements position along the urban-rural spectrum. As a result, it is important to consider the advantages of building larger, denser agglomerations of artificial spaces and systems rather than simply constructing dispersed small villages or single family homes. Some of the benefits often ascribed to cities include more specialized labor markets, economies of scale, rich culture, and easier access to a wide variety of goods as well as services. For the most part, these advantages are the result of large, dense populations working together in a complex web of mutually supporting roles. Especially within the context of purpose built environments, our growing ability to coordinate complicated, interdependent functions should make it easy to satisfy at least the basic needs and desires of individual residents. I think it is plain to see, however, that cities are not currently living up to this unspoken ideal.

“Cities are full of places that are ill-adapted to the needs of their inhabitants. They are dysfunctional, contaminated, and vulnerable to natural hazards, exposing residents to discomfort, inconvenience, and even to danger.”¹⁹

What would an urban environment that is truly optimized for people look like though? In other words, what are the goals that human-centric urban development should strive for? Various authors have attempted to answer these questions in urban design manifestos.^{20,21,22} While there is a great deal of overlap between them, the truth is that these questions are fundamentally normative and everyone will likely have a somewhat different answer to them. Regardless, I have attempted to distill a set of parameters that are consistent with these

¹⁹ Anne Whiston Spirn, “Ecological Urbanism”: 614-24

²⁰ Allan Jacobs and Donald Appleyard, “Toward an Urban Design Manifesto,” in *The City Reader*, Frederic Stout and Richard T. LeGates, eds., (Routledge, 2016), 640–51, <https://doi.org/10.4324/9781315748504-80>.

²¹ Congress for the New Urbanism, “Charter of the New Urbanism,” *Bulletin of Science, Technology & Society* 20, no. 4 (2000): 339–41, <https://doi.org/10.1177/027046760002000417>.

²² Kevin Lynch, *A Theory of Good City Form* (Cambridge, Mass.: MIT Press, 1981).

previous proposals and are general enough to be agreeable to the majority of people. In my view, an ideal urban environment should:

1. Provide for all basic human needs - clean water, fresh air, food, clothing, shelter, sewage management
2. Provide access to modern functions that have become essential: electricity, internet connectivity, and solid waste disposal as well as recycling services
3. (Ideally) provide access to non-essential goods, amenities, and services that residents desire - this includes green, open spaces as well as restaurants and theaters
4. Take into account that every person has a unique set of needs and desires - in other words, they should enable rather than constrain diversity
5. Include employment and education opportunities - both for residents to contribute to the functioning of the systems they rely on and for them to derive a sense of purpose
6. Be designed to nurture and sustain community bonds, since humans are fundamentally social creatures
7. Have all resources* strategically located for convenient as well as efficient access by those who use them most frequently (this is an ideal to strive towards, but clearly it cannot be accomplished in full)
8. Be designed to adapt to do all of these things for people in the future as well
9. Include systems that enable residents to have a say in how the resources* they rely on operate and change over time, particularly for resources* in the areas where these residents live, work, or otherwise spend time
10. Be designed to sustainably co-exist with nearby and global ecologies since humans and nature are fundamentally interdependent

**Here and throughout this text, resources is used as the generic term for all physical systems that humans rely on: roads, street lights, parks, utility systems, stores, workplaces, etc.*

Clearly, meeting this full list of criteria is no easy task. Aside from the requirement to meet people's basic needs (which should honestly go without saying), the important design parameters to take away from this can be summarized as the need to enable: diversity, accessibility, community, sustainability, and public participation. Unsurprisingly, these are

exactly the ideals that the field of urban planning is most focused on. Beyond urban planners, most people in the general public will likely agree that these are good goals to strive for.

Overview

To return to the central problem this thesis addresses, we must double the global urban capacity in the coming decades. Furthermore, what we need to build for billions of people in the near future are artificial structures and systems that come together to form environments which meet the ten goals laid out above. Due to the sheer number of people and the advantages of scale and density, these new built environments will probably need to be closer to the urban end of the spectrum than the rural. Rather than adhering to a traditional conception of a city and making adjustments, I believe that the best way to accomplish this task is to rethink urban environments and development patterns from first principles, with people as the focus. Earnest Sternberg argued that an integrative theory of urban design “should not simply advocate one set of design approaches, but should rather reveal the principles that underlie several of them”.²³ Additionally, he argued that such a theoretical framework should also be actionable, human-oriented, and realistic.

In this thesis, I hope to contribute towards this important effort by presenting a generalized, yet powerful urban form and explaining why it may be better suited to achieving this goal than the spatial organization that characterizes cities currently. More specifically, what I describe is a nested polycentric model that is built from the bottom up out of small, heterogeneous community units. I dive into why this urban form could better enable more community owned and operated resources as well as some major trends that highlight why this is likely going to be increasingly important going forward. Additionally, I argue that this urban model could facilitate a modular, master planned development approach that is far superior to how cities grow currently.

First, I provide necessary context by reviewing how urban growth currently takes place, the issues associated with it, and the historical factors that have led to this being the norm. Next, I review the idea of polycentrism in urban planning and explore the benefits of employing this organizing principle at multiple scales. I then introduce my generalized urban

²³ Ernest Sternberg, “An Integrative Theory of Urban Design,” *Journal of the American Planning Association* 66, no. 3 (2000): 265–78, <https://doi.org/10.1080/01944360008976106>.

model and dive into some specific examples, leveraging diagrams and renders to help make it more tangible. Additionally, I discuss why this urban form is better suited to major shifts underway, such as remote work, online shopping, and the miniaturization, decentralization, and relocalization of various critical systems. Next, I describe ongoing meta trends in technology and society that make planning for more sharing economy resources sensible. Then, I explain why governance and ownership must be considered in conjunction with community owned and operated resources, as well as how this urban model is ideally suited to facilitating a feasible form of direct democracy. Finally, I conclude by discussing the practicalities as well as some of the implications that the widespread adoption of this model would have for urban planners, urban designers, real estate developers, and the broader public.

Audience

The intended audience for this document is not just the academic community or my thesis committee. I have made an effort to use as little planning jargon as possible so as to make it accessible to a broad range of potential readers. Furthermore, I have cited many sources from planning literature, but have intentionally avoided engaging with them as ongoing narratives, topics, and theories within the field whenever possible. Instead, I have attempted to extract fundamental ideas in the field and frame them in practical, tangible, and broadly relevant terms that stand on their own, rather than relying on a specific author for credibility. I apologize to the academics if this writing approach feels informal or nontraditional for a thesis at times, but that was intentional.

Disclaimers

There are a few disclaimers that I want to highlight before beginning. First of all, I will not be able to explore every relevant theory or practical consideration due to the broad scope of this topic and the limited size of a master's thesis. Instead, my hope is to paint a clear enough picture of a possible approach to future urban development to spark dialogue and further inquiry. To reiterate, this thesis is intended to be a rough sketch of a massive idea that serves as the beginning of a conversation - it is not a perfectly polished final product. Additionally, it would be more accurate to describe this document as a research informed, but design-focused exploration or thought experiment than a typical thesis. I do not attempt to

prove anything with data and analysis or use any particular methodology. Instead, I build up from first principles and weave many disparate facts into a vision of an alternate future for cities.

It is also worth acknowledging that the views and critiques expressed in this thesis are heavily influenced by my western perspective, even though I am attempting to address urban development patterns globally. This is just one of the innumerable limitations that I recognize are present within this document. In attempting to cover so many topics, I am certain that I made many other generalizations and failed to acknowledge valid alternate perspectives. I welcome any critical feedback on such issues or suggestions for how to improve my arguments. This is an idea that I have been developing since 2018 and plan to continue working on for many years to come.

Finally, I critique the field of urban design and planning regularly throughout this document, but do not mean it as an attack on the individuals who have dedicated their time and energy to these professions. I have found my fellow planners to be passionate, caring, and intelligent people that should be admired for their intentions and efforts. At the same time, however, I believe that the field would be in a better position to solve the issues that we all care so deeply about if there was generally more openness to radically different perspectives and approaches from the norm. Many of the ideas that I advocate for here are not currently prominent within urban planning, but they are also not new to the field. Comprehensively reimagining cities was all the rage in the beginning and middle of the twentieth century, but the pendulum has swung towards an emphasis on finer grained, incremental planning. As challenges have mounted in urban areas all across the world, however, I believe that the time has come for the pendulum to swing back.

CHAPTER 1: THE EVOLUTION OF URBAN DEVELOPMENT

This chapter provides an overview of how urban development currently takes place as well as a historical review of how these growth patterns have changed across time. The process of urban development, the environments that it results in, and the implications that both have for residents must be considered holistically. There are currently two main categories that urban development falls into: infill development and radial expansion out on the urban periphery. As

with urban versus rural and most other other dichotomies, this is an oversimplification. The specific attributes of either development pattern depend on how close to the center of a city they take place as well as how built up and dense the city already is. Regardless, the vast majority of development underway is closer to one extreme than the center so it is still a useful framing.

Current Growth Patterns: Infill

Infill development is the process whereby existing buildings or undeveloped plots of land in denser urban areas get (re)developed as residential, commercial, or mixed use buildings. Cities often catalyze this through upzoning²⁴ since they want to increase density in order to provide sufficient housing,²⁵ make transit or other municipal services more financially feasible,²⁶ and also increase tax revenue²⁷. The appeal of infill developments for residential renters and buyers are largely walkability, nearby amenities, proximity to friends or family, and reduced travel times generally.²⁸ For some businesses, setting up shop in denser areas may be a requirement to attract sufficient customers, while others choose them since a central location is most convenient, on average, for their employees.

²⁴ C. J. Gabbe, "Changing Residential Land Use Regulations to Address High Housing Prices," *Journal of the American Planning Association* 85, no. 2 (April 3, 2019): 152–68, <https://doi.org/10.1080/01944363.2018.1559078>.

²⁵ Jeongseob Kim and Kristin Larsen, "Can New Urbanism Infill Development Contribute to Social Sustainability? The Case of Orlando, Florida," *Urban Studies* 54, no. 16 (2017): 3843–62.

²⁶ Louis A. Merlin, "The Influence of Infill Development on Travel Behavior," *Research in Transportation Economics*, Transportation and land development in Australia and North American: Property values, the private sector, housing and travel behavior, 67 (May 1, 2018): 54–67, <https://doi.org/10.1016/j.retrec.2017.06.003>.

²⁷ Chicago Metropolitan Agency for Planning, "CMAP Regional Snapshot Series - Infill," (Fall 2009): 3, <https://www.cmap.illinois.gov/about/2040/supporting-materials/process-archive/cmap-regional-snapshots>.

²⁸ Matthew J. Nahlik and Mikhail V. Chester, "Transit-Oriented Smart Growth Can Reduce Life-Cycle Environmental Impacts and Household Costs in Los Angeles," *Transport Policy* 35 (September 1, 2014): 21–30, <https://doi.org/10.1016/j.tranpol.2014.05.004>.

Unfortunately, infill development is still often slow and expensive. This is largely due to permitting processes,²⁹ the need for underground garages to satisfy parking minimums,³⁰ and various challenges that result from building in a city that remains operational, such as closing off roads and digging them up to connect to utility systems. Another major issue is that these ever increasing construction expenses and timelines result in demand regularly outstripping supply. In combination with the increasing scarcity of developable inner city parcels of land, these factors conspire to continually drive up real estate values in growing cities, which in turn causes the displacement of many renters.^{31,32}

Besides many residents being priced out of their neighborhoods, others are unhappy with the changing character that infill development often results in and the fact that they have little to no say in how this happens.³³ Some cities have public participation processes, but these are usually ineffective since they are not able to incorporate meaningful input from more than a handful of residents and they typically happen too late in the process.³⁴

Another approach to infill development that enables densification without a major impact on neighborhood character is the construction of Accessory Dwelling Units (ADUs) on existing single family parcels. Only a handful of cities have embraced them, however, and there

²⁹ Jan Bröchner et al., "Accelerated Planning for Urban Housing Infills: Coordination Strategies," *European Planning Studies* 29, no. 6 (June 3, 2021): 1113–31, <https://doi.org/10.1080/09654313.2020.1817866>.

³⁰ Donald Shoup, "The High Cost of Minimum Parking Requirements," in *Parking Issues and Policies*, vol. 5 (Emerald Group Publishing Limited, 2014), 87–113, <https://doi.org/10.1108/S2044-994120140000005011>.

³¹ Meagan M. Ehlenz, Deirdre Pfeiffer, and Genevieve Pearthree, "Downtown Revitalization in the Era of Millennials: How Developer Perceptions of Millennial Market Demands Are Shaping Urban Landscapes," *Urban Geography* 41, no. 1 (January 2, 2020): 79–102, <https://doi.org/10.1080/02723638.2019.1647062>.

³² Justus Uitermark and Maarten Loopmans, "Urban Renewal without Displacement? Belgium's 'housing Contract Experiment' and the Risks of Gentrification," *Journal of Housing and the Built Environment* 28, no. 1 (2013): 157–66.

³³ Kate S. Shaw and Iris W. Hagemans, "'Gentrification Without Displacement' and the Consequent Loss of Place: The Effects of Class Transition on Low-Income Residents of Secure Housing in Gentrifying Areas," *International Journal of Urban and Regional Research* 39, no. 2 (2015): 323–41, <https://doi.org/10.1111/1468-2427.12164>.

³⁴ Archon Fung, "Varieties of Participation in Complex Governance," *Public Administration Review* 66, no. s1 (December 2006): 66–75, <https://doi.org/10.1111/j.1540-6210.2006.00667.x>.

are not enough plots appropriate for ADUs in most urban areas for this type of infill to play a substantial role in meeting future demand. ADUs are also typically rented for relatively high rates so they wouldn't contribute all that much to affordability. Furthermore, many residents are still unhappy with the addition of ADUs on neighboring parcels and these additions can increase parking demand in areas that are not well served by, or even suited to, transit.³⁵

Perhaps even more problematic than the minimal involvement that residents have in determining the future of their neighborhoods is the fact that city governments also have limited say in how these changes take place. While city planners can guide the growth process through (complex and often outdated) zoning regulations, incentives, and other tools, it is profit-seeking real estate developers that really determine what is built. When demand greatly outstrips supply, there is little incentive for them to optimize their projects for the best outcome for the residents of the buildings they develop, let alone the neighbors that previously lived in that area. Unsurprisingly, these groups tend to stick with tried and true approaches that they know will yield a sufficient return. Even if a developer wanted to put in the extra time and effort to plan their developments for the preferences of future residents, they typically have no idea who those residents will be. Together, these factors often lead to generic-feeling places that are optimized for no one.³⁶

While living in denser areas may reduce the average distance one has to travel to meet friends or family, ever increasing density is not particularly conducive to building or maintaining community.³⁷ Most people in urban areas don't know their immediate neighbors, let alone those that live a few houses or units away. This is perhaps attributable to the lack of common spaces or shared amenities in their apartment buildings or on their blocks, which could

³⁵ Thomas Davidoff, Andrey Pavlov, and Tsur Somerville, "Not in My Neighbour's Back Yard? Laneway Homes and Neighbours' Property Values," *Journal of Urban Economics* 128 (March 1, 2022): 103405, <https://doi.org/10.1016/j.jue.2021.103405>.

³⁶ Rem Koolhaas, "The Generic City," *L'Architecture d'aujourd'hui* 304 (1996): 70–77.

³⁷ Peter Gordon and Harry W. Richardson, "Are Compact Cities a Desirable Planning Goal?," *Journal of the American Planning Association* 63, no. 1 (March 31, 1997): 95–106, <https://doi.org/10.1080/01944369708975727>.

facilitate chance encounters and community bonding.³⁸ In most cases, there is an abrupt transition from fully private to fully public as soon as an urban resident leaves their front door. A growing number of multi-family developments are including community spaces, but these are still very rare overall.

Accessibility is one of the major advantages of infill developments, compared with suburban developments and other peripheral urban expansion. Even though cities contain most things that residents may need or want, these resources are often clustered in locations that force urban dwellers that live in other areas to travel further than they should ideally have to. For instance, many city centers have no grocery stores or elementary schools despite being where many other resources and jobs are concentrated, as well as a substantial amount of housing. Additionally, many large cities do not provide sufficient access to open, natural spaces or fresh air.³⁹ These problems are partly due to the challenges that infill development itself creates: new pockets of demand are installed in exactly the areas where land is becoming increasingly scarce.

Current Growth Patterns: Peripheral Expansion

These issues with accessibility pale in comparison, however, to those faced by peripheral urban developments, such as suburbs and most informal settlements. Informal settlements, often referred to as slums, are where approximately 15% of the entire human population lives.⁴⁰ Some of these unsanctioned developments are technically better classified as infill since they occupy sloped or otherwise unattractive plots of land within a city, but the majority are on the outskirts of urban areas. These informal settlements are largely emerging due to urbanization outstripping cities' ability to plan, build, or pay for the creation of more

³⁸ Ray Oldenburg, *The Great Good Place: Cafés, Coffee Shops, Bookstores, Bars, Hair Salons, and Other Hangouts at the Heart of a Community* (New York : [Berkeley, Calif.]: Marlowe ; Distributed by Publishers Group West, 1999):

³⁹ Jennifer R. Wolch, Jason Byrne, and Joshua P. Newell, "Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'Just Green Enough,'" *Landscape and Urban Planning* 125 (May 1, 2014): 234–44, <https://doi.org/10.1016/j.landurbplan.2014.01.017>.

⁴⁰ United Nations. "SDG Indicators." Accessed January 29, 2022. <https://unstats.un.org/sdgs/report/2019/Goal-11/>.

housing and work opportunities.⁴¹ Especially in slums on the urban periphery, access to basic needs such as clean water and sewer systems are often, tragically, unavailable. Access to amenities that are less necessary is also lacking, but most residents of such areas are unable to afford them anyways.⁴²

Suburban development is characterized by primarily single family residential units that are built on relatively large lots near the urban periphery, where land is more plentiful and affordable. Many of the shops, jobs, and other things that suburban residents rely on are located further into the city, which necessitates regular long commutes as well as their accompanying stress, cost, and pollution. Even when suburbs have a good variety of shops and grocery stores nearby, they are not usually within walking distance due to the low density, which also makes transit impractical. Additionally, they often don't have sidewalks since they are designed for getting around by car and that would be prohibitively expensive. In fact, the cost of maintaining and upgrading dilute suburban infrastructure is another major failing of this development model that is not discussed as often as it perhaps should.⁴³ Aside from the cost and impracticality of maintaining public infrastructure in these environments, it is extremely expensive and inefficient for every home to own, store, and maintain everything that comes along with a suburban home, such as their own lawn mower for their own little lawn. Furthermore, these environments are not conducive to healthy, active lifestyles.⁴⁴

These are some of the costs that suburban residents pay for more privacy and independence. They do not have to worry as much about external forces pushing change on their neighborhood since these areas are often zoned as single family and the majority of suburban residents want it to stay that way. The clear delineation of property lines and absence

⁴¹ Kim Dovey and Ross King, "Forms of Informality: Morphology and Visibility of Informal Settlements," *Built Environment* 37, no. 1 (March 1, 2011): 11–29, <https://doi.org/10.2148/benv.37.1.11>.

⁴² Manish Chalana, "Urban Design and Informal Urbanism: Case Studies from Delhi and Mumbai," in *The New Companion to Urban Design*, 1st ed. (Routledge, 2019), 175–88, <https://doi.org/10.4324/9780203731932-18>.

⁴³ John B. Strait, *Sprawl City: Race, Politics, and Planning in Atlanta* (Washington, D.C.: Island Press, 2000).

⁴⁴ Harry Wiland, Dale Bell, and Beverly Baroff, *Designing Healthy Communities. Episode 1, Retrofitting Suburbia*, Academic Video Online: Premium (Santa Monica, CA: The Video Project, 2012), <http://www.aspresolver.com/aspresolver.asp?MARC:3394041>.

of public spaces, however, contributes to a systemic lack of community bonding or common identity.⁴⁵ Social isolation is a major issue among suburban residents, from children to the elderly.⁴⁶

Developers don't have to worry about any of these problems or the long term viability of this model, however. As in the case of infill development, they are simply seeking to make a profit and know that there is a market for suburban homes. This is why, despite building from scratch on undeveloped land, every suburb looks like the rest⁴⁷ - the term "cookie cutter" is frequently applied, for good reason. Informal urban development, by contrast, is still a bottom-up process that is driven by the residents of the spaces that are being built. Many authors even argue that the planning profession should actively study and implement lessons from these developments.⁴⁸

Despite this major difference between suburban and informal peripheral development patterns, it is fair to say that both are optimized for independence over accessibility - either by choice or by necessity. Informal developments better facilitate diversity and community than suburbs, but neither development pattern is particularly sustainable. By comparison, infill development scores better in terms of accessibility as well as perhaps diversity and sustainability, depending on how you define them. Neither development pattern comes close, however, to qualifying as successful approaches to creating optimal human environments.

Historical Growth Patterns

It is important to recognize that the scope and scale of urban development has changed drastically in the recent past and is truly unprecedented. This historical context is of critical importance to understand how cities ended up growing in the manner described above and how we might improve these development patterns going forward.

⁴⁵ James Howard Kunstler, *The Geography of Nowhere: The Rise and Decline of America's Man-Made Landscape* (Touchstone, 1994): 26-27.

⁴⁶ Wiland, Bell, and Baroff, *Designing Healthy Communities*.

⁴⁷ Kunstler, *The Geography of Nowhere*, 51.

⁴⁸ Raul P. Lejano and Corinna Del Bianco, "The Logic of Informality: Pattern and Process in a São Paulo Favela," *Geoforum* 91 (May 2018): 195–205, <https://doi.org/10.1016/j.geoforum.2018.03.005>.

Throughout the vast majority of humanity's existence, most people lived with their extended family, within the context of a local community that was mostly self-sufficient.⁴⁹ Typically there was some nucleation site that was a convenient location for residents of these nearby communities to congregate and trade. As more people, knowledge, and materials amassed in these trading centers over time, the value proposition of these trade networks increased. This created a feedback cycle in which an ever larger number of goods and services became available that nearby residents couldn't otherwise access. Naturally, more people came to rely on these primordial cities, which increased the opportunities for specialized work and led to their permanent populations increasing as well.⁵⁰

Across many centuries or even millennia, cities scaled in a gradual, organic way due to these feedback cycles. Populations grew, more homes were built, and infrastructure was developed to manage new challenges that emerged as density increased. There were setbacks from wars or natural disasters, but the general trend was incremental expansion and densification (Figure 1). The form this took was mostly defined by topography as well as a nearly universal urban evolutionary pattern characterized primarily by the emergence of multiple concentric city walls. The density within existing city walls would increase until some developments began to spill out around the walls, then after these peripheral developments grew large enough they were eventually encapsulated within another wall.⁵¹

⁴⁹ Yuval N. Harari, *Sapiens: A Brief History of Humankind*, First U.S. edition. (New York: Harper, 2015):356-362

⁵⁰ Hans Blumenfeld, *The Modern Metropolis*. 3-17.

⁵¹ Hans Blumenfeld, *The Modern Metropolis*. 3-17.

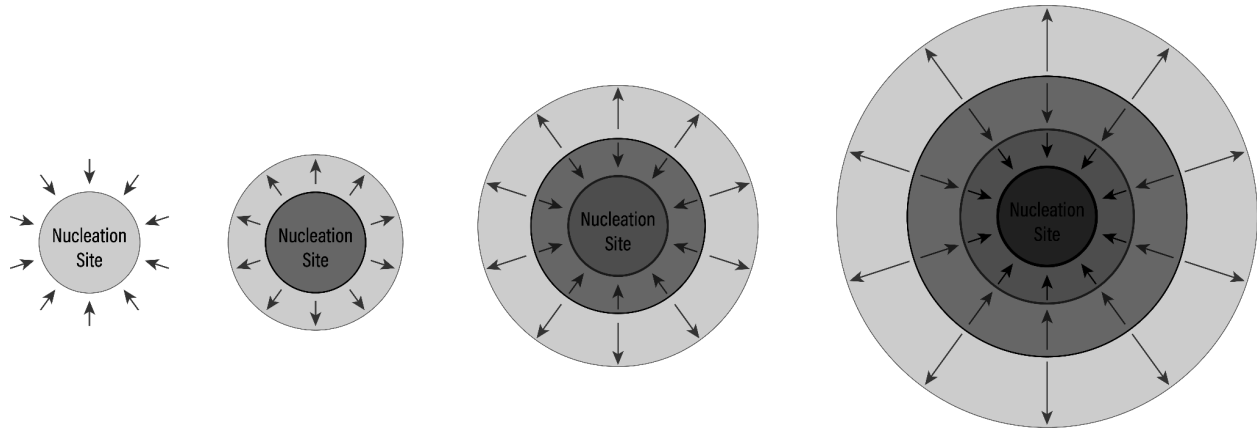


Figure 1. Historic urban growth pattern, defined by densification and radial expansion on the periphery.

The industrial revolution suddenly changed this development pattern and rate. Mechanization of various industries enabled economies of scale to be leveraged. Suddenly there was rapidly growing and insatiable demand for relatively unskilled workers in factories. This happened in sync with advancements in agriculture that reduced the demand for farm workers. In addition to pushing a large number of these rural residents towards the work opportunities in cities, improved agricultural yields in a given area enabled larger populations to be supported in nearby cities.⁵² Ever since then, urbanization has taken hold all across the planet and did not stop or slow when, in 2008, the world passed the mark of more than half of all people alive being city dwellers.⁵³

This is clearly an oversimplification of how things played out, but it captures the broad strokes of what happened. The key takeaway is that cities used to evolve slowly over time through a process of radial expansion and densification, but recently this accelerated and cities quickly grew to be much larger than they ever were previously. Both the pace of growth and the unprecend scale that cities achieved during this transition catalyzed numerous changes in the way that urban development takes place.

As the cumulative impacts of rapid, unplanned urban growth became more apparent, people began to start planning cities more directly and rationally. In reality, cities have always

⁵² Yuval N. Harari, *Sapiens: A Brief History of Humankind*, First U.S. edition. (New York: Harper, 2015): 247-375

⁵³ Neil Brenner and Christian Schmid, "The 'Urban Age' in Question," *International Journal of Urban and Regional Research* 38, no. 3 (2014): 731–55, <https://doi.org/10.1111/1468-2427.12115>.

developed according to a combination of planning and organic, bottom-up growth.⁵⁴ However, the accelerating rate of growth, as well as the unprecedented size and density that resulted from this, forced urban development patterns further towards the planned end of the organically-grown-versus-planned spectrum. Whereas urban development used to be shaped primarily by those who were impacted by these changes, the emergence of urban planners and implementation of top down guidelines created more of a disconnect between the shapers of human built environments and the residents. In more recent times, the rise of real estate developers as a specialized industry has similarly increased the separation between those who create urban spaces and those who occupy those spaces.

While these specialized roles and more intentional development patterns came to direct urban development, the degree to which cities could be planned largely depended on how developed they already were. For instance, few cities that were well established prior to the industrial revolution were organized according to a street grid. The concentric walls of most older cities were eventually converted to ring roads. Along with radial paths that extended away from the center in all directions (originally paths through gates in the walls), these ring roads defined a road network that is referred to as the radial-concentric pattern. This layout defines many cities that were well established prior to the industrial revolution, especially in Europe.⁵⁵

This type of urban form exists in stark contrast to that of American cities. Rather than an organic nucleation site that had expanded over time, the young settlements of the United States were quickly established and rationally divided up according to a gridiron plan. The parceling out of America's abundant land, in combination with strong private property rights and the fact that US cities were still relatively small, conspired together to prime them for domination by the automobile. Urban renewal and white flight to the suburbs played a critical

⁵⁴ Hans Blumenfeld, *The Modern Metropolis; Its Origins, Growth, Characteristics, and Planning. Selected Essays*. (Cambridge: Massachusetts Institute of Technology, 1967): 3-17

⁵⁵ Hans Blumenfeld, *The Modern Metropolis*, 246-269.

role as well, but American cities were particularly susceptible from the start due to these factors.^{56,57}

European cities, which were already much denser and defined by radial-concentric street networks, were not as easily modified to accommodate the automobile. Some cities underwent major renovations to accommodate vehicles while others, like Copenhagen, resisted.⁵⁸ Countries that have urbanized in recent decades, particularly in Asia, have favored hyper-dense cities, which have grown vertically and been planned around mass transit systems rather than the car.⁵⁹ Despite this, most have been arranged around a clear center and scaled radially outward from it according to a street network that is relatively rational, though often far less grid-like than those of many American cities.

It is interesting to note that, despite all that has changed in the scale and scope of cities (as well as who guides this process), their growth is still characterized by this same pattern that was happening prior to the industrial revolution: continuous, radial expansion out from a center and densification that is largely defined by previously laid down streets. American suburbs were arguably an attempt at a different model, as they are stand alone developments that are built in tandem with the curvilinear streets, which homes are arranged along. In reality, however, they just represent distant and dilute radial expansion around a dense center - plus their inefficient street networks will undoubtedly constrain urban development far into the future.

In fact, the urban form or “urban tissue” that streets define is arguably the hardest aspect of cities to change. Cities typically exist for centuries or even millennia, but the people in them don’t remain the same, nor do the roles they take on, the communities they make up, the way they get around, the foods they eat, or most other things people interact with on a

⁵⁶ Warner and Whittemore, *American Urban Form*.

⁵⁷ Michael P Conzen, “The Study of Urban Form in the United States,” *Urban Morphology*, no. 5(1) (2001): 3–14.

⁵⁸ Cedric Ferial, “The Revolution That Never Was? Pedestrianization in a Transnational Perspective, Europe and North America (1960S-1980S).,” *Journal of World History* 31, no. 4 (December 1, 2020): 761–84.

⁵⁹ Siman Tang and Hong K. Lo, “The Impact of Public Transport Policy on the Viability and Sustainability of Mass Railway Transit – The Hong Kong Experience,” *Transportation Research Part A: Policy and Practice* 42, no. 4 (May 1, 2008): 563–76, <https://doi.org/10.1016/j.tra.2008.01.022>.

daily basis. Individual buildings might be replaced and the character of neighborhoods may shift over time, but modifying the street layout in dense urban environments requires large-scale demolition. Occasionally fires or specific programs like Hausmann's renovation of Paris or Chicago's 1909 plan may bring this about, but it is difficult, painful, and uncommon.^{60,61} There are certainly some benefits to the durability of a city's urban tissue, such as in the case of European cities' incongruence with the automobile, but the constraints these extant forms present for future growth is important to acknowledge.

Continuous growth similarly presents challenges as well as benefits. Cities, by definition, can never reach a point of completion, but like living things, they can achieve a state of equilibrium. Adapting to changing technological, environmental, and other conditions is hard enough, but this is much more difficult when they are constantly growing. As explained above, infill developments that squeeze more people into a space eventually create a mismatch between residents and the utility system, road, transit, and parking capacity that is present. Additionally, it will tend to drive up rent for people who live there and anger the rest of the local community since people tend to be unhappy with change that is forced on them. Furthermore, new peripheral developments still typically rely on the same road network to get to a city's center and, therefore, inevitably exacerbate traffic congestion.

Despite these issues that result from continuous growth, the concentration of commonly needed, interdependent resources and work opportunities in larger centers tends to result in a self reinforcing dynamic - like a black hole drawing in more mass. This is partly attributable to the fact that their monopolization of regional growth stunts that of nearby cities, which could have otherwise been an attractive alternative for new businesses and residents.

Demand could be redirected from an existing center to a smaller one nearby - either with force or incentives - but this would require extreme forethought and a great deal of political will. Instead, market-driven urban development patterns often lead to smaller centers

⁶⁰ Yonah Freemark, A. Bliss, and Lawrence J. Vale, "Housing Haussmann's Paris: The Politics and Legacy of Second Empire Redevelopment," *Planning Perspectives* 0, no. 0 (June 8, 2021): 1–25, <https://doi.org/10.1080/02665433.2021.1937293>.

⁶¹ Samuel Kling, "Wide Boulevards, Narrow Visions: Burnham's Street System and the Chicago Plan Commission, 1909–1930," *Journal of Planning History* 12, no. 3 (August 1, 2013): 245–68, <https://doi.org/10.1177/1538513213476709>.

being incorporated into swelling metropolitan regions. Even if these smaller centers are not officially annexed, they tend to become subservient to the largest center in the growing urban agglomeration.

Creating a new center with comparable resources would, similarly, require a huge amount of coordination among a large number of people as well as a substantial amount of capital and time to build out. It is, thus, unsurprising that this does not happen often. Recently, however, the rate of urbanization has become so great that it is conceivable that we could fully plan it one chunk at a time, rather than simply directing private developers. At least theoretically, it should be much easier to comprehensively plan and even iterate on larger master-planned developments than trying to achieve similar outcomes using bureaucratic constraints to guide blind market forces.

Past Urban Models

Throughout the past two centuries of rapid urbanization, many people put forward visions of new and improved city models that sought to address some of the limitations discussed above. One of the most influential of these urban models is Ebenezer Howard's garden city, which was described as a hybrid of rural elements with urban ones. Each of these self-contained cities was intended to have everything their residents needed: a sufficiently large population to operate factories and ensure they had work opportunities while still providing enough natural open space, fresh air, and easily commutable distances. Inspired by the same obvious geometric sensibility that led to the natural emergence of the radial-concentric model, Howard planned to achieve this by organizing residential space in concentric circular bands around a central park, with radial boulevards that lead from this center to the outer edge of the circular city. This was where all agricultural and industrial functions were meant to be located (Figure 2, left). Howard proposed this idea largely as a reaction to the overcrowding, congestion, and pollution that were present in cities at the start of the 20th century, when the effects of unplanned urbanization had begun to become apparent.⁶²

⁶² Ebenezer Howard, *To-Morrow: A Peaceful Path to Real Reform*, Original ed. / with commentary by Peter Hall, Dennis Hardy & Colin Ward. (London; New York: Routledge, 2003).

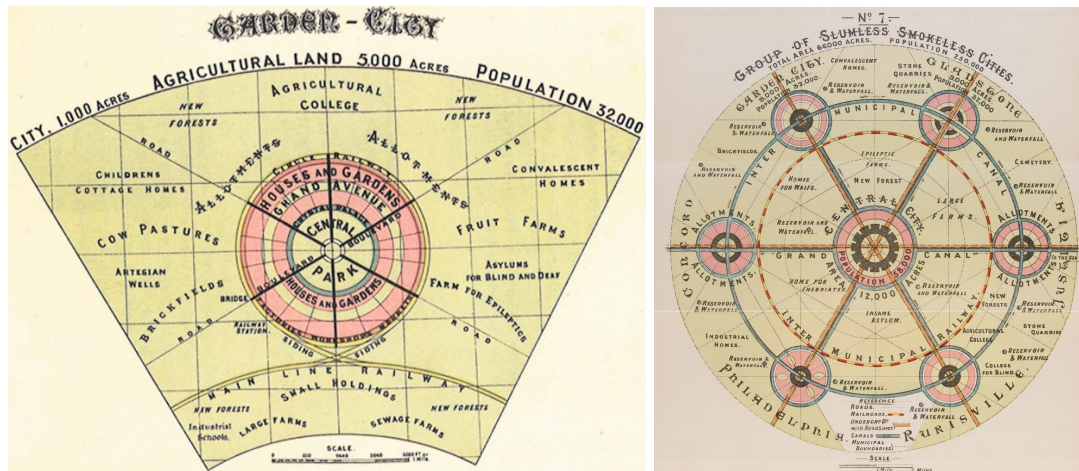


Figure 2. Diagram of Howard's garden city model and a group of networked garden cities.⁶³

His vision of the garden city went beyond the simple recognition that rapid urban development couldn't be left to its own devices, however. Howard suggested that cities be fully planned for a set population of 32,000 people prior to their construction in order to ensure appropriate housing, employment, and other resources for those residents was included from the start. Rather than growing these cities over time, additional regional demand for housing and work was supposed to be directed to the construction of neighboring garden cities that were to be networked together through linear connections between their centers as well as ring roads (Figure 2, right). They were meant to be laid out around a somewhat larger central city, resulting in an urban form that is essentially the radial-concentric urban form, but at two scales: within each garden city and across a group of them.⁶⁴ Interestingly, the sort of regional poly-nucleated urban network that this development pattern would have resulted in would be a more orderly version of what would have emerged if all human settlements had scaled in parallel, rather than the cannibalization of growth that urbanization actually resulted in.

The idea of spatially defined community units with resources appropriate for the local residents is found frequently in urban design and planning literature. Another historic example of this modular approach to city design is Clarence Perry's 1929 neighborhood unit model,

⁶³ Howard, *To-Morrow*.

⁶⁴ Ebenezer Howard, *Garden Cities of To-Morrow* /c by Ebenezer Howard; Edited, with a Preface, by F.J. Osborn; with an Introductory Essay by Lewis Mumford. (London: Faber and Faber Ltd, 1946).

which was characterized by the concentration of common amenities in a community center that was within walking distance of all of the residences (Figure 3). This self-contained unit was to be bordered by thoroughfares that connected it with other such neighborhood units and the city center that these units were arranged around.⁶⁵ While the scale Perry's model focused on was much smaller than in the garden city, the modular approach of planning and building defined community units is common to both.

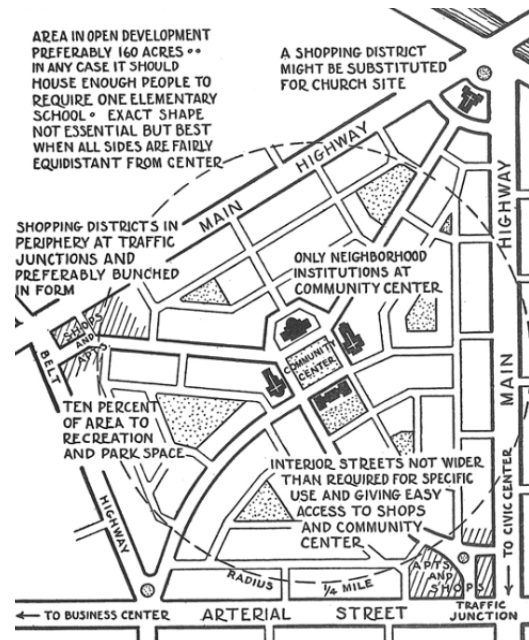


Figure 3. Diagram of Perry's neighborhood unit model.⁶⁶

These models are clearly far from perfect, however. For instance, they are often criticized for being too standardized and prescriptive - though both were really intended to be archetypal models to draw inspiration from.⁶⁷ Regardless, their standardized size and shape does make it hard for them to facilitate the diverse range of lifestyles and community dynamics that cities ideally would. This criticism would be less valid if these models had been presented

⁶⁵ Michael W. Mehaffy, Sergio Porta, and Ombretta Romice, "The 'Neighborhood Unit' on Trial: A Case Study in the Impacts of Urban Morphology," *Journal of Urbanism: International Research on Placemaking and Urban Sustainability* 8, no. 2 (April 3, 2015): 199–217, <https://doi.org/10.1080/17549175.2014.908786>.

⁶⁶ Mehaffy, et. al, "The 'Neighborhood Unit' on Trial", 199–217.

⁶⁷ Mehaffy, et. al, "The 'Neighborhood Unit' on Trial", 199–217.

as more of a framework rather than a specific form, as Ernest Sternberg argued is the correct approach.⁶⁸ Garden city-inspired developments are also often described as being more suburb than city, though this is because most did not fully implement Howard's model. Whereas Howard imagined garden cities being places where people both lived and worked - places that had most everything their residents needed on a regular basis - most garden city-inspired developments have just been residential.⁶⁹ Another reasonable criticism of these historic models is that they were designed around access to certain institutions, businesses, places of work, and technologies that were certain to become irrelevant with time. In their defense, however, designing for future conditions that do not yet exist is a very difficult task.

It is also worth noting that company towns in the late 19th and early 20th century were technically also fully planned communities with resources appropriate for their residents. While they had numerous similarities with Howard and Perry's modular approaches to urban development, the lack of agency that these employee-residents had often resulted in dystopian outcomes.⁷⁰ This highlights the need to consider ownership and governance as part of optimal urban environments, which is a topic that I explore in a later chapter.

Despite these issues, the idea of comprehensively planned community units that can be developed in a modular fashion is an intriguing alternative model for urban growth. It is conceivable that such an organizing principle could allow accessibility, community, and sustainability to be more easily optimized for. In the field of planning today, such master planned communities - from small residential clusters to mixed-use town centers - are referred to as planned unit developments.⁷¹ Due to spatial and financial constraints, as well as their incongruence with zoning, planned unit developments tend to unfortunately be few and far between. A generalized framework that could allow individually planned developments to be combined in a modular fashion, similar to Howard's proposal for assembling garden cities, is

⁶⁸ Sternberg, "An Integrative Theory of Urban Design," 265–78.

⁶⁹ Allan Jacobs and Donald Appleyard, "Toward an Urban Design Manifesto," 640–51.

⁷⁰ Hardy Green, *The Company Town: The Industrial Edens and Satanic Mills That Shaped the American Economy* (New York: Basic Books, 2012).

⁷¹ Daniel R. Mandelker, "New Perspectives On Planned Unit Developments," *Real Property, Trust and Estate Law Journal* 52, no. 2 (September 22, 2017): 229–229.

what I present in this thesis as the best urban development approach for achieving the human-centric design parameters set out above.

CHAPTER 2: CENTERS & SCALES

Polycentrism in Urban Planning

Planning areas with resources that match the needs of the surrounding population is such a simple and intuitive idea that, unsurprisingly, it has been reformulated by many urban theorists and practitioners in the recent past. One version of this idea that is currently popular amongst urban planners is the 15-minute city, which is really just the idea that strategically positioning as many commonly needed resources within a 15 minute walkshed of every home in urban areas will have many positive impacts.⁷² The expectation is that this approach would promote more pedestrian commuting, reduce unnecessary vehicle trips, and create more defined centers where people naturally congregate. All of these are core goals of modern urban design movements, such as New Urbanism.⁷³

While this is a good ideal to strive towards, a study of 5, 10, and 15-minute “community life circles” in Shanghai (analogous concepts to 15-minute cities in the west) found that it had not been implemented evenly: there was too much concentration of resources in the city center and not enough distribution of resources in the less central areas. The authors stressed that the selection and distribution of resources need to be optimized for a given community since all are different.⁷⁴ Before even factoring in diverse community needs and preferences, it is unsurprising that matching resources with demand will be difficult since varying density results in differing levels of demand in a given walkshed. This means that there are certain types of businesses and other resources that cannot be sustained in less dense areas due to the smaller addressable market. As noted above, this challenge of matching demand with resources is

⁷² Georgia Pozoukidou and Zoi Chatziyiannaki, “15-Minute City: Decomposing the New Urban Planning Eutopia,” *Sustainability* 13, no. 2 (January 2021): 928, <https://doi.org/10.3390/su13020928>.

⁷³ Allan Jacobs and Donald Appleyard, “Toward an Urban Design Manifesto,” 640–51.

⁷⁴ Haoyuan Wu et al., “Analysis and Optimization of 15-Minute Community Life Circle Based on Supply and Demand Matching: A Case Study of Shanghai,” *PloS One* 16, no. 8 (2021): e0256904–e0256904, <https://doi.org/10.1371/journal.pone.0256904>.

exacerbated in areas that are actively undergoing infill development since it means that demand is a moving target.

Another planning idea that is tightly interwoven with the 15-minute city concept is that of urban villages. Seattle, for example, has defined 27 urban villages that are meant to be the loci of higher density, mixed-use developments. The densest portion of these urban villages are meant to become small neighborhood centers that concentrate community activity and co-locate resources to increase accessibility, while also promoting pedestrian travel and serving as transit hubs. Whereas the 15-minute city concept is more focused on the sensible and equitable distribution of resources relative to residents, the designation and cultivation of urban villages are more of a strategy to achieve this. The growing recognition of the value of such an approach to resource distribution is highlighted by the fact that the city of Seattle describes its urban village strategy as the foundation of its comprehensive plan.⁷⁵

Rather than a simple gradient of density and urban-ness that decreases with distance from the city center, the inclusion of many subcenters provides a more varied urban morphology, which enables some of the benefits of a higher degree of urban-ness to be enjoyed locally. Lefebvre, a highly influential urban theorist, argued that centrality is what makes the urban urban; that it is not the content of a center, but rather the coming together of many different things and people, as well as the resulting juxtaposition of superimposed flows that makes cities a notable phenomenon.⁷⁶ Creating many of these small neighborhood centers throughout a city results in an urban form that should reasonably be called polycentric. In fact, Lefebvre even notes that the urban form tends towards either centrality or polycentricity.⁷⁷ In modern times, however, this term is typically reserved by planners to mean an urban form with multiple district centers at the city scale or true city centers on the metropolitan scale. Howard's proposal for a group of interlinked garden cities could be thought of as an early example of

⁷⁵ City of Seattle, "Seattle 2035 Comprehensive Plan: Managing Growth to Become an Equitable and Sustainable City," 2021, <https://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/SeattlesComprehensivePlan/ComprehensivePlanCouncilAdopted2021.pdf>.

⁷⁶ Henri Lefebvre, *The Urban Revolution* (Minneapolis: University of Minnesota Press, 2014).

⁷⁷ Henri Lefebvre, *The Urban Revolution*.

this type of city-scale polycentricity, though the forms described as polycentric today are rarely made up of subunits that are so distinct.⁷⁸

The authors of a recent paper reviewed the adoption of polycentrism in Chinese urban planning practice and contrasted it with western implementations of the idea. They argued that its use has actually guided urban development patterns in China, whereas it has mainly been used as a framework for studying the relationship among existing centers in the west. Shanghai's 1999 City Master Plan, which was the first formal introduction of polycentric planning in China, "proposed an urban spatial structure of 'multi-axis, multi-levels, multi-cores', which would be made up of the central city, new towns, central towns and market towns". Polycentrism has since been implemented in various other city master plans in China since then, such as Hangzhou's and Guangzhou's. Despite mentioning smaller scale intra-city centers and town centers on the urban periphery, these authors specifically restricted their definition of polycentric planning to three larger spatial scales - district centers within a city, the inter-urban scale, and inter-regional. In their review, however, the authors narrowed their scope even further and decided to focus only on the relationship among the largest centers in metropolitan regions with more than 10 million residents. This is emblematic of planner's common tendency to conceptualize and implement polycentric planning in a top down fashion that is more concerned with the largest centers.⁷⁹

The failure to acknowledge that polycentrism is a common organizing principle underlying both large and small scale urban planning ideas seems to be pervasive. This rigidity in conceptualizing polycentrism is exemplified by another article, in which the authors looked at Polish cities to develop a standardized method for measuring city regions' polycentricity that could then be used to study differences correlated with varying levels of polycentrism. The authors note that, while there is broad agreement in the value of polycentrism, there is no standard definition or way of measuring it. In fact, they go so far as to claim that the term "polycentric" has been used at so many spatial scales that it has largely lost its meaning. Similar to the previous article, however, these authors proceeded to arbitrarily define a

⁷⁸ Howard, *To-Morrow*.

⁷⁹ Hui Cheng and David Shaw, "Polycentric Development Practice in Master Planning: The Case of China," *International Planning Studies* 23, no. 2 (2018): 163–79, <https://doi.org/10.1080/13563475.2017.1361318>.

minimum scale for polycentric urban forms, which they set as an “elementary administrative unit”.⁸⁰ They somehow fail to see the irony in this despite their conclusion that the way polycentric urban development is measured may simply reflect pre-existing assumptions. It seems apparent that these authors’ unsuccessful attempt to standardize this concept and draw useful insights from their work is due to a fundamental failure to recognize that it is a generalized organizing principle which can exist at any scale.

Perhaps this misunderstanding is simply attributable to the fact that urban planners typically study a city as a whole, focus on its downtown, or oversee site-specific implementation of regulations. As a result, community-scale polycentricity seems to often emerge naturally, rather than through intentional planning efforts. For instance, a study in 2000 showed that suburban developments in Washington’s Puget Sound region have naturally nucleated and densified over time. After the initial wave of single family developments, small suburban clusters emerged containing many multi-family buildings alongside a small number of retail and other functions without the intentional implementation of any land use regulations to achieve that outcome. These clusters were not noticed initially since they lacked sufficient amounts of certain use cases, like office buildings, to meet the criteria that local planners used to define areas as mixed-use centers. The authors note that while this suggests there are natural pressures that lead to metropolitan regions becoming “multinucleated”, these centers are often poorly suited to scaling over time due to a lack of planning for that eventuality.⁸¹

Another notable example of naturally emerging polycentricity is the “agropolitan” Linpan landscape in China’s Chengdu plain. Small agricultural villages called Linpan, each made up of 30-90 households, are distributed across the plain and separated by agricultural land (Figure 4). Despite being highly productive agriculturally, this area has a density of 1,000 people/km². These dispersed villages doubled in size during the decades that urbanization was driving rapid growth in cities throughout China, even though they were already relatively dense

⁸⁰ Bartosz Bartosiewicz and Szymon Marcińczak, “Investigating Polycentric Urban Regions: Different Measures – Different Results,” *Cities* 105 (October 1, 2020): 102855, <https://doi.org/10.1016/j.cities.2020.102855>.

⁸¹ Anne Vernez Moudon and Paul Mitchell Hess, “Suburban Clusters: The Nucleation of Multifamily Housing in Suburban Areas of the Central Puget Sound,” *Journal of the American Planning Association* 66, no. 3 (September 30, 2000): 243–64, <https://doi.org/10.1080/01944360008976105>.

settlements. While not exactly what most think of as urban, this polycentric form emerged naturally and managed to scale symmetrically, unlike cities. Dan Abramson argues that recent adaptation by the Linpan “demonstrates that established forms of agropolitanism can persist and adapt, incorporating new forms of productive relations and values while maintaining function and identity.” Despite their resilience and adaptability, however, he notes that local planners tend to “view the scattered pattern of settlement as a hindrance to efficient infrastructure modernisation and farm consolidation”.⁸²



Figure 4. Drone photography of a Linpan (left) and Linpan Landscape (right).⁸³

It could also be argued that the adoption of superblocks in cities like Barcelona represent a planner-driven initiative to reintroduce community-scale polycentricity in urban areas. Superblocks are simply clusters of blocks that have their interior streets closed off to through traffic to create semi-public spaces for local residents to enjoy (Figure 5).⁸⁴

Interestingly, a similar sort of structure can be seen on a smaller scale, in the multi-family buildings of the blocks that Barcelona’s superblocks comprise. The large interior courtyards of these buildings, as well as those in other European cities like Copenhagen, provide a central

⁸² Daniel B Abramson, “Ancient and Current Resilience in the Chengdu Plain: Agropolitan Development Re-‘Revisited,’” *Urban Studies* 57, no. 7 (May 1, 2020): 1372–97, <https://doi.org/10.1177/0042098019843020>.

⁸³ Shuang Wu, Ning Wu, and Bo Zhong, “What Ecosystem Services Flowing from Linpan System—A Cultural Landscape in Chengdu Plain, Southwest China,” *Sustainability* 12, no. 10 (January 2020): 4122, <https://doi.org/10.3390/su12104122>.

⁸⁴ Nikola Babic, “Superblocks - The Future of Walkability in Cities?,” *Academia Letters*, March 20, 2021, <https://doi.org/10.20935/AL747>.

common space for their residents, thereby defining an additional layer of community units that are each oriented around a center.⁸⁵ There is a small initiative in the United States to merge private backyards and form “pocket neighborhoods”, which could be seen as a similar sort of block scale community unit that is anchored by a shared center.⁸⁶ While these smaller scale examples are defined by common open space in their center rather than the presence of concentrated businesses or resources, they still serve to define and unite these communities in a finer grained polycentricity.



Figure 5. Superblocks in Barcelona.⁸⁷

Nested Polycentrism

Regardless of whether urban forms are called polycentric or not, it seems clear that this type of multinucleated morphology is a common outcome of the natural or strategic placement

⁸⁵ “The Courtyards of Copenhagen,” *Sightline Institute* (blog), March 20, 2008, <https://www.sightline.org/2008/03/20/the-courtyards-of-copenhagen/>.

⁸⁶ Paul Downton, “Pocket Neighbourhoods,” *Sanctuary: Modern Green Homes*, no. 16 (2011): 60–62.

⁸⁷ Tomorrow.Mobility, “#Superblocks: Can #Barcelona Reduce #traffic by 21%?,” Tweet, March 14, 2018, <https://twitter.com/TomorrowMob/status/973921817965580289>.

of resources relative to those that need them. There is no reason why this simple, sensible organizing principle cannot be implemented at multiple scales simultaneously. Doing so would be helpful since the cost of certain resources, the space they take up, and the number of people that are needed to maintain or fully take advantage of them causes some to be suitable for smaller communities while others make sense for larger ones (Figure 6).

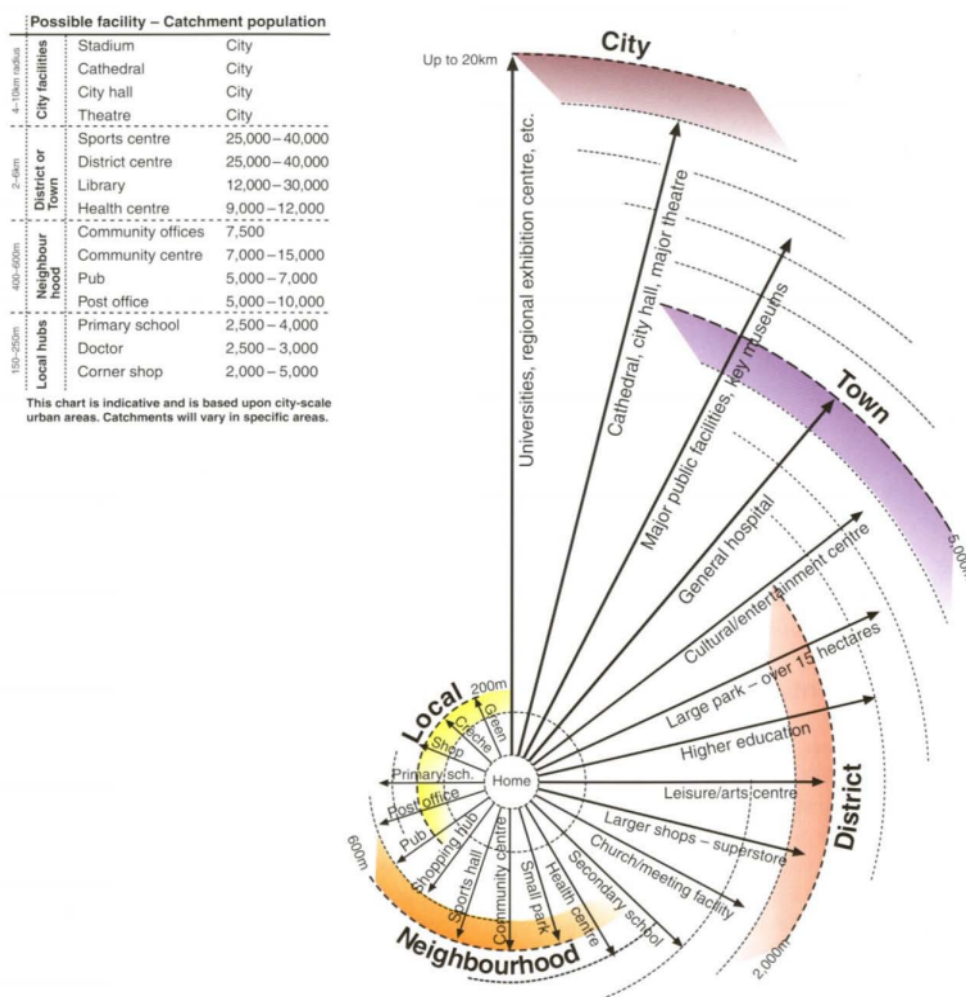


Figure 6. Common resources and how they fit within a framework of nested urban layers.⁸⁸

A nested or multi-tier polycentric urban morphology was one of the main recommendations put forward by the Urban Task Force in England, when they published the findings of their landmark 1999 study titled *Towards an Urban Renaissance*. The purpose of this

⁸⁸ Urban Task Force, *Towards an Urban Renaissance*, (London]: Spon, 1999): 7.

task force was to identify causes of urban decline in England and come up with recommendations for how to draw people back towards the country's denser areas. The pamphlet explored generally desirable goals for urban areas and suggested various strategies for meeting them, including the spatial organization of resources and residents around centers of differing scales.⁸⁹ Pasqual Maragall, the former mayor of Barcelona, wrote in the foreword that "it is by understanding human space as a network of centres of different size and density, that we will approach the goal of finding fitting solutions to real problems."⁹⁰

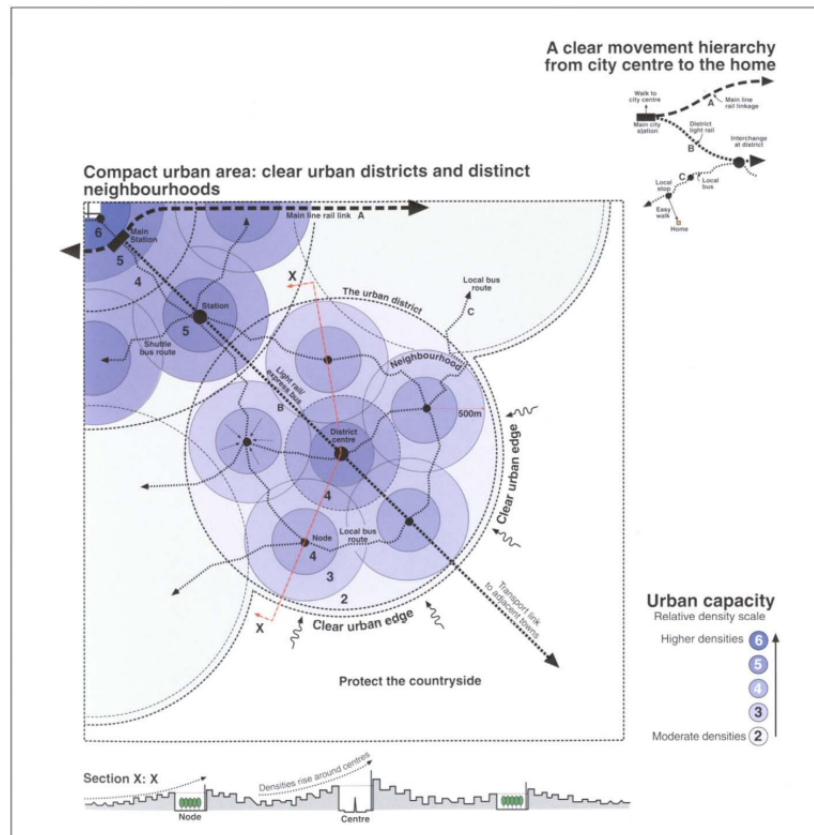


Figure 7. Diagram of compact urban forms with clearly defined districts and neighborhoods.⁹¹

The authors used diagrams to show this sort of nested polycentric layout (Figure 7), which they argue is the best form to organize these tiered community centers according to.

⁸⁹ Urban Task Force, *Towards an Urban Renaissance*, 25-27.

⁹⁰ Urban Task Force, *Towards an Urban Renaissance*, v.

⁹¹ Urban Task Force, *Towards an Urban Renaissance*, 26.

They suggest a structure with four layers - local, neighborhood, district, and city/town - that are each anchored by a center and arranged radially around the core of the next largest community layer. They also recommended a gradient of density that increases with proximity to a center, but an open, low density core at the center of each layer (Figure 7). The Urban Task Force included a similar diagram by Andrew Wright Associates (Figure 8) that defines these community units in terms of a walkshed from the center and an appropriate population range for that area.⁹² While the authors' primary goal was to help revitalize and direct the evolution of preexisting cities, they argued that this model was also appropriate for green field developments. Aside from the importance of this sort of organizational approach for easy access to various types of facilities and transportation hubs, the authors stress that concentrating development within clear boundaries helps to encourage more community engagement and the clear edge at the city layer protects the countryside from sprawling development.⁹³

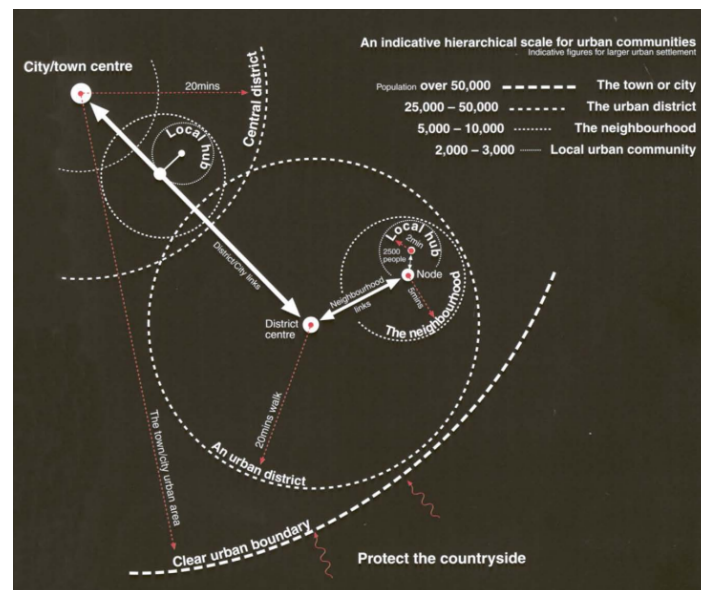


Figure 8. Older diagram of compact urban forms with clearly defined districts and neighborhoods.⁹⁴

⁹² Urban Task Force, *Towards an Urban Renaissance*, 27.

⁹³ Urban Task Force, *Towards an Urban Renaissance*.

⁹⁴ Urban Task Force, *Towards an Urban Renaissance*, 27.

While this sort of rational organizational framework seems sensible, not every urban theorist has such a positive view on it. Planning according to clearly defined, nested community layers is exactly what Christopher Alexander advocates against, in his famous 1966 article titled *A City is Not a Tree*. Alexander's argument leans heavily on the mathematical concept of a "tree" - the hierarchical composition of units made out of smaller units, with no overlap between the layers - as distinct from a "semi-lattice", in which some subunits are part of multiple non-discrete higher level units (Figure 9). The main argument of this paper is that planning cities according to a tree-like urban morphology creates numerous issues since the reality of the relationships among the people and other elements they contain is best described as a semi-lattice.⁹⁵

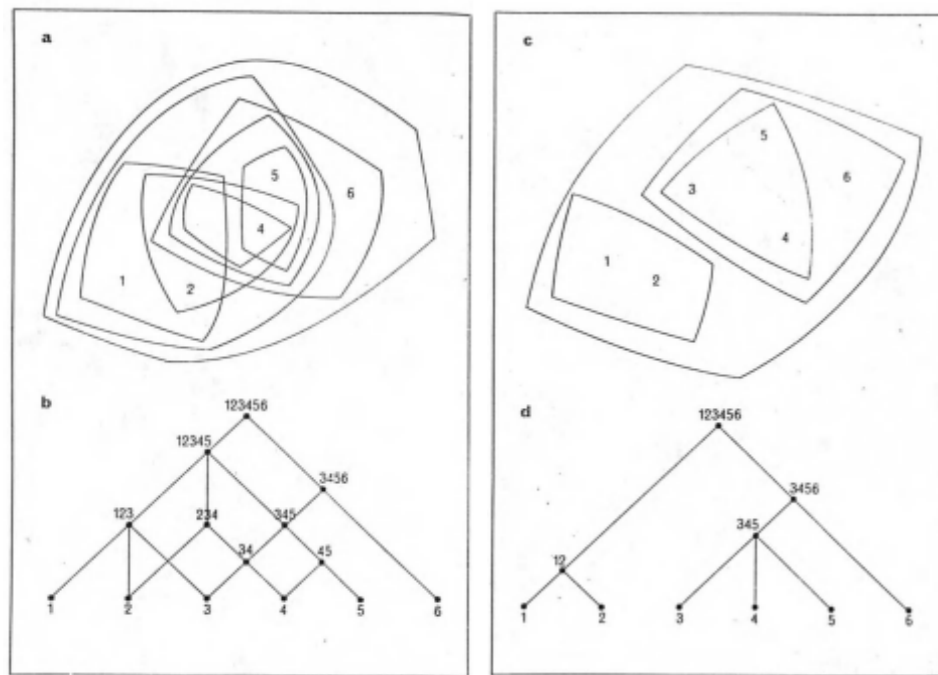


Figure 9. Diagrammatic representation of a semi-lattice (a & b) versus a tree (c & d).⁹⁶

While there is some kernel of truth to Alexander's argument, he talks in abstract terms and regularly conflates tree-like urban form with tree-like relationship dynamics. He stresses that very few people have entirely overlapping communities or are able to find work near their

⁹⁵ Christopher Alexander, "A City Is Not a Tree," *Design (London)*, no. 206 (1966).

⁹⁶ Christopher Alexander, "A City Is Not a Tree."

home in urban environments. Since there will inevitably be semi-lattice-type relationships that cut across community layers in a tree-like urban form, he argues that the boundaries which define them constrain the rich complexity of relationships that should characterize vibrant cities. This sounds somewhat reasonable initially, but Alexander admits that he is unable to depict or articulate qualities of urban forms that could optimally facilitate such overlapping semi-lattice-type relationships between arbitrary points in a city.⁹⁷

Complexity for complexity's sake is not a reasonable goal so we should not intentionally entrench the need for frequent long commutes just because of some abstract argument about facilitating complex, interwoven relationships. In reality, there is substantial value to co-locating residents with the resources and individuals that they are going to interact with most often. The simple fact that there are a lot of people in cities is not a good reason why neighbors need to be strangers and communities need to be dispersed. Perhaps the systemic lack of "communities of place" in cities is a serious problem and we should actually work to nurture or at least enable them, rather than planning for the opposite. Furthermore, it is entirely possible for a well designed road network in a tree-like urban form to support even better connectivity between - and thus relationships which span - distant points in a city (as I explain in Chapter 4).

In this article, Alexander also makes a strong case that people think of cities like trees due to humans' tendency to mentally categorize things this way for simplicity. He claims "when we think in terms of trees we are trading the humanity and richness of the living city for a conceptual simplicity which benefits only designers, planners, administrators and developers." I would argue, however, that many other people outside of these groups also talk about cities as if they were made of subunits like districts and neighborhoods, even though these areas are never truly defined spatially or functionally. Despite Alexander's recognition of the mismatch between our mental framework and reality, he concludes that the solution is to stop conceiving of them this way. An equally valid alternative, however, would be to actually organize cities like trees spatially.⁹⁸ All humans think this way, so why not organize our built environments according to this intuitive and natural mental map that is common to all?

⁹⁷ Christopher Alexander, "A City Is Not a Tree".

⁹⁸ Christopher Alexander, "A City Is Not a Tree".

Alexander's framing of this tendency as one of "putting things with the same name into the same basket" comes closer to the real problem that he should have been criticizing. It is not the subdivision of cities into a tree-like structure that is the issue, but rather what is included within the subunits of the different layers. Segregation by use, as has been the norm in much of modern planning efforts, or dividing communities up by age (which Alexander criticizes on multiple occasions) would be akin to some cells having mitochondria while others have only nuclei and yet others have only ribosomes. This obviously does not work; each cell needs to include all of the biological machinery for critical functions if any are to survive. It is the failure to understand this and design community units as complete entities, with resources needed for internal coherence, that often result in issues when "artificial cities" are planned from the top down according to a tree-like framework.

At the end of his article, Alexander emphasizes the importance of identifying the right type of overlap to create optimal semi-lattice urban forms. One could argue that a nested polycentric urban form in which the community units of a given layer share a common center are overlapping at that point and, thus, are technically semi-lattices. Indeed, most of the examples Alexander shows to critique tree-like cities lack a common center that unites the subunits of a given layer.⁹⁹ The absence of a center to unite adjacent communities is the type of obvious mistake that results from top down planning rather than a human-centric design approach. Instead of beginning with the need to design a city and then rationally subdividing it into smaller and smaller areas, a better outcome will always be achieved by starting with people and building from the bottom up to form larger and larger communities. It is the coming together of smaller units to create a whole that is greater than the sum of its parts which creates the complex and interesting cross layer dynamics Alexander is attempting to advocate for.

A final point regarding *A City is not a Tree* is that Alexander is correct to warn against excessive segmentation of community subunits from one another, but he fails to acknowledge that there is value to a delineation of interior versus exterior. At one point he states that "extreme compartmentalization and the dissociation of internal elements are the first signs of

⁹⁹ Christopher Alexander, "A City Is Not a Tree."

coming destruction."¹⁰⁰ While he is an accomplished mathematician, urban theorist, and designer, it is clear that Alexander is no biologist. It is precisely the segmentation of cells from their environment - as well as one another - by a membrane (or analogous structures that encapsulate organs, organelles, and organisms) that must be maintained for them to avoid dissociation and death. This boundary condition, semi-permeable though it may be, is what enables all of the rich complexity of life.

Biology, Holons, and Complexity Theory

Biology, it turns out, is actually full of examples of analogous patterns: spatially-defined entities which have some set of concerted internal systems that simultaneously makeup and are made up of other such entities. For instance, cells are made of organelles, which are made of polymers, which are made of monomers, which are made of atoms, which are made of subatomic particles. Simultaneously, cells (in the case of multicellular organisms) make up tissues, which make up organs, which make up organisms, which make up communities, which, in turn, make up ecosystems. A similar sort of nested pattern can also be found in cosmology (subatomic particles - atoms - stars - galaxies - clusters - superclusters) and computers (subatomic particles - atoms - transistors - logic gates - chips - chipsets/entire computers - networks). Arthur Koestler introduced the term "holon" to describe entities that are simultaneously a whole in and of themselves and a part of a larger whole. Rather than hierarchies, which have a defined apex that lower levels are defined relative to, holons make up holarchies, which are defined by a more symmetric relational dynamic across nested layers.¹⁰¹

This sort of structure always seems to emerge in a bottom-up fashion, as smaller and simpler units combine to form a larger entity that has properties which are greater than the sum of their parts. The emergence of these higher level functions is mutually beneficial and thus creates a selective pressure for their constituent units to remain associated. Biocomplexity is the term for the study of such patterns of emergence in living things.

"Emergent complexity is a hallmark of life, from the organization of molecules into cellular machinery, through the organization of cells into tissues, to the organization of

¹⁰⁰ Christopher Alexander, "A City Is Not a Tree.

¹⁰¹ Arthur Koestler, *The Ghost in the Machine*, [1st American ed.]. (New York: Macmillan, 1968).

individuals into communities. The other key element of biocomplexity is the unavoidable presence of multiple scales.”¹⁰² - Indiana University, Institute of Biocomplexity

More broadly, this process of emergence is exactly what is postulated by complexity theory, a branch of systems theory.¹⁰³ Complexity theory, systems theory, and related ideas have not gone unnoticed by urban theorists. For instance Botequilha-Leitao, leverages them to argue that polycentric urban forms are more resilient and better able to operate in a sustainable manner.¹⁰⁴ In *The Well Tempered City*, Jonathan F. P. Rose explains how this natural process of emergence can be seen in human society:

“When the various individual agents in a system interact, they begin to self-organize into something larger: a community whose collective behavior allows it to function cohesively. This phenomenon, in which complex capabilities emerge from combining simple elements, is the basis for creating social clusters ... This happens when individuals become a family, families become neighbors, neighbors become a community, communities become a city, and cities become metropolitan regions. At each level, qualities emerge from the relational context that did not exist in the individual context.”¹⁰⁵

While this process of socio-spatial emergence (described in the previous chapter as well) is mostly historically accurate, urban tissue that clearly reflects these dynamics is lacking in many modern cities. This is arguably due to a combination of excessive rational planning getting in the way of organic agglomeration and the fact that whatever well defined

¹⁰² The Biocomplexity Institute - Indiana University, “What Is Biocomplexity?,” accessed February 16, 2022, <https://biocomplexity.indiana.edu/institute/biocomplexity.php>.

¹⁰³ Luigi Curini and Robert Franzese, *The SAGE Handbook of Research Methods in Political Science and International Relations*, vol. 2 (55 City Road: SAGE Publications Ltd, 2020), <https://doi.org/10.4135/9781526486387>, 166-167.

¹⁰⁴ André Botequilha-Leitão, “Eco-Polycentric Urban Systems: An Ecological Region Perspective for Network Cities,” *Challenges* 3, no. 1 (June 2012): 1–42, <https://doi.org/10.3390/challe3010001>.

¹⁰⁵ Jonathan F. P. Rose, *The Well-Tempered City: What Modern Science, Ancient Civilizations, and Human Nature Teach Us About the Future of Urban Life*, First edition. (New York, NY: Harper Wave, an imprint of HarperCollins Publishers, 2016).

communities existed in cities previously have become indistinct as infill development obscured their boundaries. This sort of negative outcome from uncontrolled growth can also be seen in biology. One obvious example is cancer, but another is the tendency for bacteria on a petri dish to multiply until they consume all of the available nutrition and starve themselves. I would argue that what humans are doing with infill development is analogous and we must implement self-imposed constraints on our growth patterns to avoid similarly starving ourselves of community, accessibility, or anything else.

If we are to take inspiration from biology in addressing this issue, a relevant fact here is that all cells maintain a relatively consistent size and replicate instead of growing larger over time. Even though organisms don't grow through the expansion of individual cells, these basic units of life remain highly dynamic internally and also in their relationship to one another. One of the main reasons that most cells remain a certain size rather than growing continuously is due to the importance of keeping all cellular functions within a certain proximity of the nucleus. Muscle cells are a noteworthy exception to this rule - they have multiple nuclei spread throughout their length since they must be larger (in one dimension) than most cells in order to perform their primary function.¹⁰⁶ This suggests that evolution also "understands" the value of strategically positioning appropriate resources in an accessible central location.

People in various fields have begun to look to biology for inspiration - an approach that has been termed biomimicry. A recent article notes that its impact in the field of planning has been limited thus far and suggests that organism-level biomimicry (as opposed to structural or material biomimicry) is a tool that should be explored for the development of novel, large-scale urban design concepts.¹⁰⁷ Doxiadis, an urban theorist and architect who proposed a science of human settlements that relied heavily on a multi-layer, nested framework, also argued that we should think of human settlements as "biological individuals of a higher order than cells or organisms".¹⁰⁸ In other words, various other people in the field have advocated for taking a

¹⁰⁶ Angelika Manhart et al., "Mechanical Positioning of Multiple Nuclei in Muscle Cells," *PLOS Computational Biology* 14, no. 6 (June 11, 2018): e1006208, <https://doi.org/10.1371/journal.pcbi.1006208>.

¹⁰⁷ Yuta Uchiyama, Eduardo Blanco, and Ryo Kohsaka, "Application of Biomimetics to Architectural and Urban Design: A Review across Scales," *Sustainability (Basel, Switzerland)* 12, no. 9813 (2020): 9813-, <https://doi.org/10.3390/su12239813>.

¹⁰⁸ Kōnstantinos Apostolou Doxiadēs, *Ekistics: An Introduction to the Science of Human Settlements* (London: Hutchinson, 1968): 41.

page out of nature's playbook in a similar way. While this may seem like a strange thing to include, the ubiquity of holarchies and bottom-up modular scaling in nature provides additional weight to the primary argument I seek to advance in this thesis: we should explore how to leverage nested polycentric urban forms for the massive amount of urban development that will take place in the coming decades.

CHAPTER 3: THE KERNEL-UP POLYCENTRIC (KUP) MODEL

While the value of these morphological patterns seems clear, it is not immediately apparent how to employ them in the design of new urban environments. In this chapter, I present a generalized framework for urban design that is informed by nested polycentric forms and the ten principles laid out in the introduction. I begin with an argument for why small heterogenous community units should be used as the basic building block before explaining how they could be assembled into infinite differentiated forms. Finally, I discuss the implications of the resulting differentiated typologies for community dynamics.

Community at the Core

As holarchies tend to develop through bottom-up emergence, it seems prudent to apply this insight to nested polycentric urban forms. It would also be more in line with human-centric design principles to start with small community units and use those as building blocks for larger and larger communities. This sort of modular, assembly-based design process requires that these small community building blocks be of approximately the same size. This limited degree of standardization at the base layer could also enable a more practical and universal urban design approach compared to starting at the scale of a city (which varies dramatically in population as well as area) and somehow subdividing it into nested community subunits. Additionally, assembling community units of roughly the same population would help to ensure this is mutually beneficial since their combined population would enable resources to be shared that each of the constituent community subunits could not fully utilize on their own. If one community unit were significantly larger than others it shared a center with, the overall

population would not be a significant enough increase relative to its own to make practical the inclusion of common spaces, resources, or businesses that it could not independently contain.

The primary question that then needs to be answered is how large these community units should be that will serve as the basic urban building blocks. Defining their size in population rather than area or any other metric is most appropriate for human-centric design, but how many people is the right size? Families have historically served this role, but this does not work quite as well today. Many more people now live alone or with only a partner, though there are still lots of larger family units living in urban areas as well.¹⁰⁹ In addition to the variability of household population, the homes that families occupy in cities come in many different shapes and sizes. Even if these issues were not present, it would still leave the question of what size of community unit should be next in the hierarchy after the family unit.

Research from various fields suggests that human brains are optimized for roughly 150 relationships. This maximum number of people with whom one can maintain stable social bonds is known as Dunbar's number, after the researcher who first described the relationship between neocortex size in primates and their average community sizes.¹¹⁰ While some groups have published evidence that the actual number is higher, lower, or more variable,¹¹¹ others have recently found strong support for 150 being at least in the middle of the accurate range. For instance, a recent paper showed evidence that Dunbar's number is supported by social connections among Twitter users¹¹² and another used phone call frequency to support this value.¹¹³

¹⁰⁹ US Census Bureau, "Tenure by Household Size, ACS 2019 Estimates," accessed March 2, 2022, <https://data.census.gov/cedsci/table?q=houshold%20size&t=Owner%2FRenter%20%28Householder%29%20Characteristics&y=2019&tid=ACSDT1Y2019.B25009>.

¹¹⁰ R. I. M. Dunbar, "Neocortex Size as a Constraint on Group Size in Primates," *Journal of Human Evolution* 22, no. 6 (June 1, 1992): 469–93, [https://doi.org/10.1016/0047-2484\(92\)90081-J](https://doi.org/10.1016/0047-2484(92)90081-J).

¹¹¹ Patrik Lindenfors, Andreas Wartel, and Johan Lind, "'Dunbar's Number' Deconstructed," *Biology Letters* 17, no. 5 (n.d.): 20210158, <https://doi.org/10.1098/rsbl.2021.0158>.

¹¹² Bruno Goncalves, Nicola Perra, and Alessandro Vespignani, "Modeling Users' Activity on Twitter Networks: Validation of Dunbar's Number," *PLoS ONE* 6, no. 8 (August 3, 2011): e22656–e22656, <https://doi.org/10.1371/journal.pone.0022656>.

¹¹³ P. Mac Carron, K. Kaski, and R. Dunbar, "Calling Dunbar's Numbers," *Social Networks* 47 (October 1, 2016): 151–55, <https://doi.org/10.1016/j.socnet.2016.06.003>.

Such a constraint on community scale is also reinforced by the operational experience of teams in engineering, design, and various other industries. According to famed microprocessor architect Jim Keller, “we’re really good in teams of 10 ... up to teams of 100 they can know each other. Beyond that you need organizational boundaries.”¹¹⁴ History also suggests that around 50-150 is a good population size for these basic community units since this is approximately how large most of the smallest scale tribal communities have been throughout time.¹¹⁵

People will also want to have many close relationships with others that don’t live in their local community so, if the human brain is indeed optimized for 150 relationships, the ideal size for basic community units is likely somewhere around 100. This size should allow many more shared systems and spaces to be feasible than would be the case for a single home while still being small enough that everyone in the community can know one another.

As recently as the early 1900’s, neighborhoods were commonly thought of as almost ecological units (even referred to as “ethnic enclaves”).¹¹⁶ While this segmentation was largely due to racial prejudice, these communities were, as a result of their common heritage, bound together by some shared beliefs, norms, and routines that made them internally cohesive and distinct relative to other communities. Obviously, we should not strive for people to be confined to or barred from certain communities based on their race or other factors like sexual orientation. There is, however, a clear benefit to community members being united by some values and lifestyle preferences: trust, identity, and stronger bonds generally. By definition, this does mean that such communities would be internally uniform or homogeneous in some dimension, which many would argue runs counter to diversity. To the contrary, I argue that diversity amongst communities is also important and this can only be achieved if they are allowed to be distinct and internally cohesive in some way. Just as cells of a certain type cluster

¹¹⁴ Lex Fridman, *Jim Keller: Moore’s Law, Microprocessors, and First Principles* / Lex Fridman Podcast #70, 2020, <https://www.youtube.com/watch?v=Nb2tebYAaOA>,

¹¹⁵ Julia Lehmann, Phyllis Lee, and R.I.M. Dunbar, “Unravelling the Function of Community-Level Organization,” in *Lucy to Language* (Oxford: Oxford University Press, 2014), <https://doi.org/10.1093/acprof:osobl/9780199652594.003.0011>.

¹¹⁶ Martin Ruef and Angelina Grigoryeva, “Jim Crow, Ethnic Enclaves, and Status Attainment: Occupational Mobility among U.S. Blacks, 1880–1940,” *American Journal of Sociology* 124, no. 3 (November 2018): 814–59, <https://doi.org/10.1086/701020>.

together to make up distinct tissues, some degree of diversity must be sacrificed at the base layer for diversity to be possible at higher levels in a holarchy.

Whatever distinct lifestyle preferences, community dynamics, or other factors define one of these 100 person community units will translate into distinct spatial forms that are optimal for them. Similar to how cells come in myriad forms with varying organelle combinations, these basic community units should therefore come in countless shapes, densities, and layouts. I call these heterogeneous 100 person community units “kernels” since they serve as the smallest and most essential urban elements, which have distinct properties that together define the larger urban communities they combine to form. Before diving into how varied kernels could be and the implications for built environments, I want to discuss a general framework for how they could come together to form nested polycentric urban forms.

Scale of Societal Layers

“The compact, many-centred city of mixed uses which favours walking, cycling and public transport, is the most sustainable urban form. While different places will be able to appropriate this model to differing degrees, in every case it is the neighbourhood which forms the basic building block of the town and the city. The way in which we define relationships within a neighbourhood, and between neighbourhoods, determines whether or not the city functions efficiently and harmoniously.” - Urban Task Force¹¹⁷

There is a wide range of urban forms which could adhere to a multi-tier polycentric layout that is built from kernels. Variables to consider include which type of kernels they comprise, how many community subunits there are per layer, how many layers they are assembled into, how the community subunits in each layer are arranged relative to one another, and the degree to which these factors can vary within as well as across layers. As with kernels, variability is critical in order to facilitate the diverse range of lifestyle and community dynamic preferences that residents may have. However, I address the impact of the other three factors on how kernels can be assembled first, and then return to the matter of variability.

¹¹⁷ Urban Task Force, *Towards an Urban Renaissance*, 7.

In order to determine the optimal number of kernels that should be combined to form second layer communities, as well as how many of these (or larger community units) should be combined to form subsequent layers, it is important to consider the tradeoffs this decision entails. For a fixed overall population size, fewer community units per layer means that there will be more layers - and vice versa. The primary purpose of combining these communities into larger ones is for them to include infrastructure, spaces, and services that would not be financially or logistically suitable for a smaller population. As a result, there needs to be a significant enough increase in population between community layers for that benefit to take effect. Furthermore, having too many layers would lead to unnecessary complexity (geometrically, functionally, and psychologically). On the other hand, too drastic of an increase from one community scale to the next would also necessarily mean that the center is further away from some community members than is really necessary or optimal. Additionally, if there is too great of a population increase from one community layer to the next, that next layer will likely feel more like the broader public than a community to which the smaller community subunits belong.

As a result of these factors, I propose that roughly an order of magnitude population increase would be a good compromise. In other words, approximately 10 community subunits should be combined to form the next tier in the polycentric form - though perhaps a range is more appropriate than a fixed number. This initial proposal is not based on any empirical evidence, however, and I fully acknowledge that this could be wrong. Others have suggested different numbers of community subunits per layer in the past, though also without strong evidence. For instance, Dioxides believed that seven was the right choice (entirely for geometric simplicity)¹¹⁸ while the diagrams created by the British Urban Task force suggest five community units per layer.¹¹⁹ Dunbar and colleagues have also made the case that communities historically tended to organize into nested communities of 50, 150, 500, and 1,500 people each - suggesting a natural increase by a factor of three.¹²⁰

¹¹⁸ Kōnstantinos Apostolou Doxiadēs, *Ekistics: An Introduction to the Science of Human Settlements* (London: Hutchinson, 1968): 41.

¹¹⁹ Urban Task Force, *Towards an Urban Renaissance*, 26.

¹²⁰ Lehmann et. al, "Unravelling the Function of Community-Level Organization"

There is also precedent for a base-10 polycentric scaling across community layers. Most notably, Victor Gruen suggested such an arrangement (Figure 10) in his book *The Heart of Our Cities*, which apparently was a major factor that inspired Walt Disney's design for EPCOT (The Experimental Prototype Community of Tomorrow).

"Gruen believed that there was an underlying cellular nature to a properly built community. If the basic unit of life is a cell, and millions of cells can come together to create an organism, he reasoned that an urban structure based on cells (clusters of mixed-use development) would be the healthiest system. The benefit of a cellular urban organization is that it can be scaled as small as a home or as large as the size of a metropolis."¹²¹

Returning to the matter of how many community subunits there should be per layer, research will need to determine whether roughly ten is the correct choice. For now, I will assume that 8-12 community subunits per layer is appropriate. Regardless of whether this value is revised, however, the model I present in the following pages will remain largely unchanged.

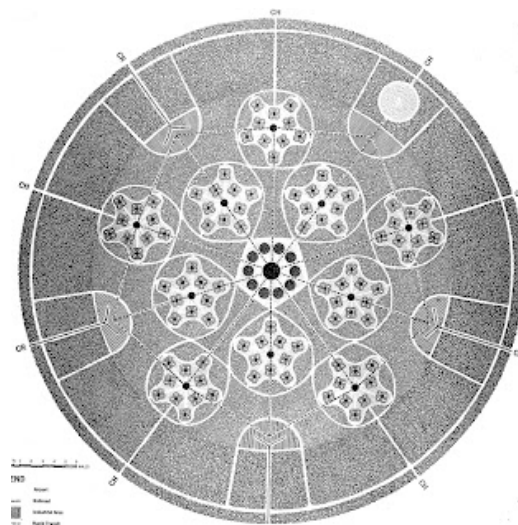


Figure 10. Victor Gruen's diagram from *The Heart of our Cities*.¹²²

¹²¹ Sam Gannaway, "The Original E.P.C.O.T - E.P.C.O.T and The Heart of Our Cities," accessed June 5, 2022, <https://sites.google.com/site/theoriginalepcot/essays/epcot-and-the-heart-of-our-cities>.

¹²² Sam Gannaway, "The Original E.P.C.O.T - E.P.C.O.T and The Heart of Our Cities".

The next question to address is how many layers there should be in a city overall. As Gruen notes, this model can scale indefinitely since communities could continue to be arranged around larger and larger centers. At some point, however, the benefits of scale begin to dwindle and other constraints such as topography would inevitably make these settlements less cohesive. Really the question comes down, once again, to what an appropriate population would be for the types of resources that a city needs to include.

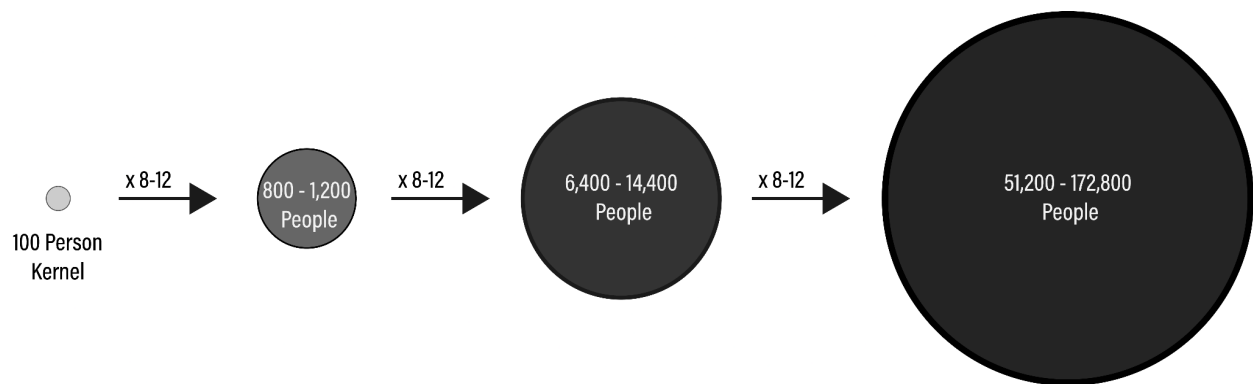


Figure 11. Population of base-8 through base-12, four-layer, kernel-based cities.

With kernels of approximately 100 people as the building blocks and between eight and twelve communities making up each subsequent layer, the population of the fourth layer would be between roughly 50,000 and 200,000 people (Figure 11). The majority of cities in the United States already have populations in this range: of the 792 cities with more than 50,000 residents in 2019, 60% had populations below 100,000 people and only 15% had populations greater than 200,000.¹²³ While urban planning as a field tends to focus disproportionately on the largest cities, with half of a million to many millions of residents, most do not fit this definition. Regardless, many have culturally rich, lively downtowns with ample amenities and work opportunities.

Considering this, even the lower end of this proposed range should be sufficient to support a decent selection of restaurants, bars, cafes, and shops as well as a couple of venues or flexible event spaces, a hospital, some office buildings, and various other uses that are expected in downtowns. City centers of this scale could be superior to their extant equals if

¹²³ US Census Bureau, "Annual Estimates of the Resident Population for Incorporated Places of 50,000 or More, Ranked by July 1, 2019 Population: April 1, 2010 to July 1, 2019," accessed February 26, 2022, <https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-cities-and-towns.html>.

they are well designed for a set population from the start, prioritize the pedestrian experience, and take advantage of various technological trends. In the next two chapters, I discuss why many urban elements - such as surface parking, parking garages, banks, many types of retail, and most office towers - can likely be eliminated. Together, these refinements should enable city centers to be more walkable, aesthetically pleasing, and vibrant, despite being smaller.

I believe that the urban framework I have briefly described above is distinct enough from current cities that it requires some new terminology. I have chosen the terms *group* and *cluster* for the second and third community layers, respectively (drawing inspiration from the Local Group and Laniakea Supercluster that our Galaxy belongs to). While *groups* could be compared to urban villages or neighborhoods and *clusters* could be compared to towns or districts, these community units I have proposed would be much more clearly defined, both spatially and in terms of identity. This rebranding is important to emphasize that they are different from existing urban subunits that people already have certain associations with the terms for. Overall, I will be referring to this urban model as the Kernel-Up Polycentric model, or the KUP model, for reasons that should be apparent as well as the fact that the acronym sounds like the word for a roughly circular vessel (cup).

Due to the fact that the center of the fourth layer in this KUP model would be large enough to be called a city center, I will simply refer to this layer as a city. Similar to the constituent community layers, each city could be just one of many subunits that are organized around, rely upon, and contribute to a larger metropolitan-scale urban center that anchors a fifth layer - in which case it would similarly make sense to recycle the term metropolis. As I argue later, however, it would likely make more sense for these fifth layer centers to be industrial: where materials processing, manufacturing, and other functions that require scale and are best separated from residential areas could be concentrated (in which case the term metropolis does not seem as appropriate). As a result, there is not a fifth layer in my proposed KUP model so much as a sort of regional tissue that is made from a network of interlinked cities and strategically placed industrial centers.

Differentiated Structure

Above, I have presented my rationale for the ideal values for kernel population, number of subunits per layer, number of layers, and population needed to support a vibrant city center. While further research and experimentation will be needed to determine if they really are optimal, some degree of variability must be facilitated for each - they are meant to be the mean of an optimal range rather than a rigid constraint. In addition to these factors, differentiated layouts of community subunits in a given layer is critical. Figure 12 shows the urban form that would result if kernels were a standard size and arranged perfectly symmetrically around a common center in groups of 10 community subunits per layer.

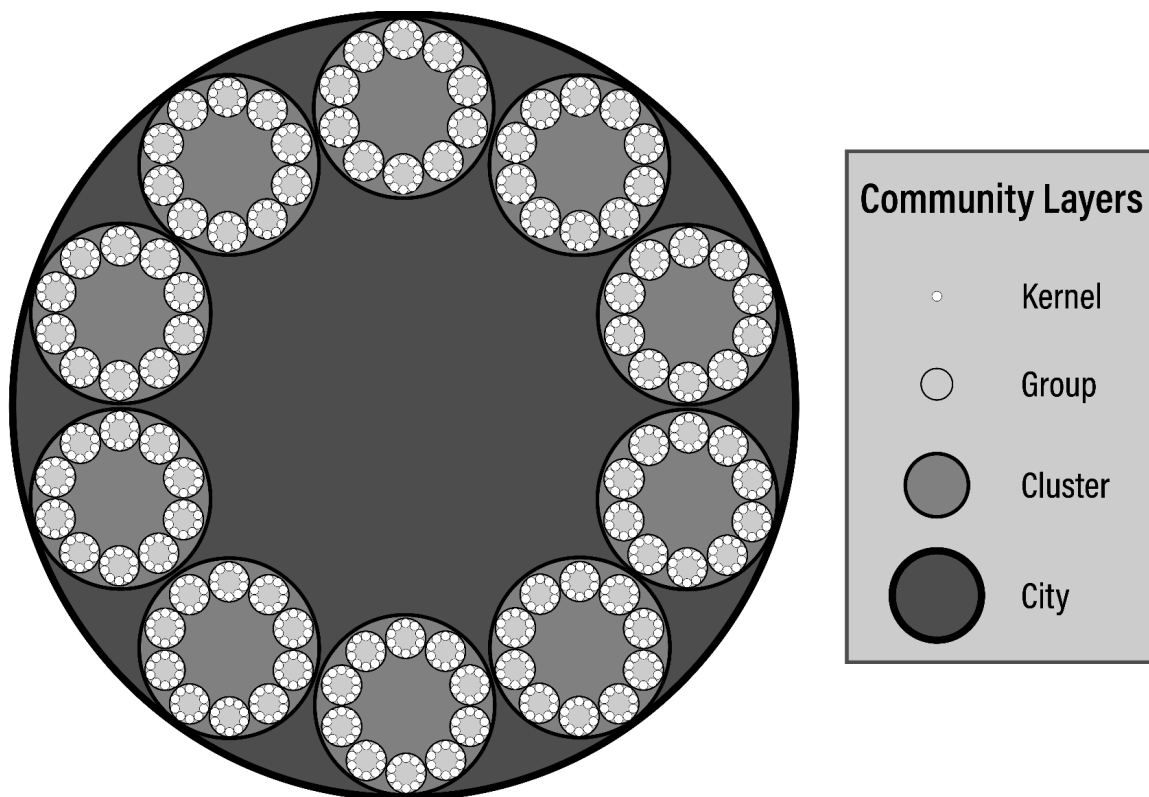


Figure 12. Undifferentiated kernel-based, multi-tier polycentric urban form.

Even this perfectly symmetric base-10 KUP model results in some functional differentiation among kernels due to variability in their distance from the city and cluster centers, but many issues clearly result from this level of standardization. First of all, it does not allow for variable kernel sizes and densities, which would be required to facilitate the diverse

array of lifestyles and community dynamics that residents may desire. The radial arrangement of ten identical, circular community subunits also results in a center that is much larger than those subunits. Despite providing equal access to the surrounding communities, this is not ideal since it would result in an excessively high ratio of space in each center relative to the community subunits that are meant to share that center. Additionally, there is lots of empty space between subunits and the boundary of the community layer they make up. Besides being inefficient in terms of space, this dilute layout would also increase the average travel time. Finally, it is worth noting that having no residential space anywhere near the enormous city center may also result in issues such as a lack of “eyes on the street”, as Jane Jacobs famously advocated for.

It is possible to overcome these issues while still adhering to the KUP model and having 10 communities per layer. For instance, the subunits of a given layer could vary in size, vary in number, be arranged in a non-radial arrangement around the center of that layer, be non-circular in shape themselves, or a combination of all of these. In reality, these types of differentiation would necessarily emerge from the use of heterogeneous kernels as the basic building blocks. Figure 13 shows an archetypal urban form that leverages most of these changes, though the kernels it is made from are still shown as circular for diagrammatic simplicity and there are still 10 subunits per layer.

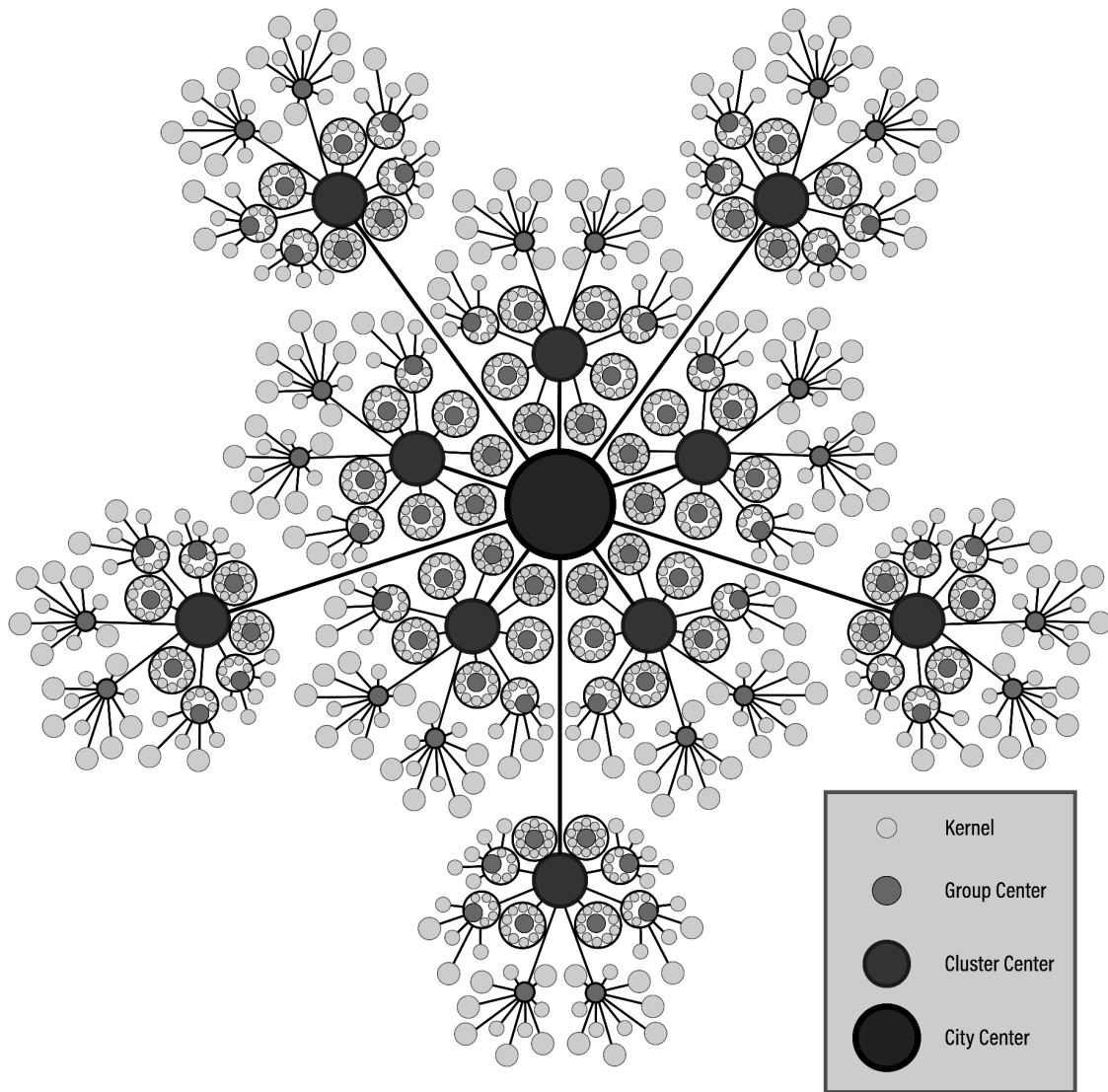


Figure 13. Differentiated kernel-based, multi-tier polycentric urban form.

There are a number of notable takeaways from this differentiated form. First of all, smaller community subunits are arranged towards the center of the next largest layer, which results in a gradient of density that decreases with distance from the center. Additionally, having only a portion of the ten community units (that are also the smaller ones) clustered around a center enables it to be more appropriately sized relative to the surrounding population. Spatially it also makes the most sense to put smaller community units close to the

center of the next layer up the hierarchy and more dilute community units opposite of that center. Put another way, larger kernels are best positioned on the side of a group that is furthest from the cluster center to which the group belongs and, similarly, larger groups fit best on the opposite side of their cluster from the city center. Due to these factors, the groups and clusters that kernels make up are not circular even though, in this diagram, the kernels they're made from are.

Figure 10 shows that a small degree of differentiation among the kernels at the base layer can result in a complex emergent form that is arguably much more organic and natural looking than most modern cities, despite still being a relatively standardized archetype. This is, however, just one example of an infinite number of multi-tier polycentric urban forms that could adhere to the KUP model. To reiterate, this is meant to serve as a generalized organizing principle for how heterogeneous communities could be assembled into cities, rather than some rigid, prescriptive framework. The diagram above also highlights how the KUP model is perhaps better thought of in terms of the connectivity between centers of different scales, rather than as boundary defined community units that are combined in a lego-like modular way. Additionally, the road network that this naturally results in is defined by linear connections between centers and ring roads around those centers. The details and implications of this novel road system is explored further in the following chapter.

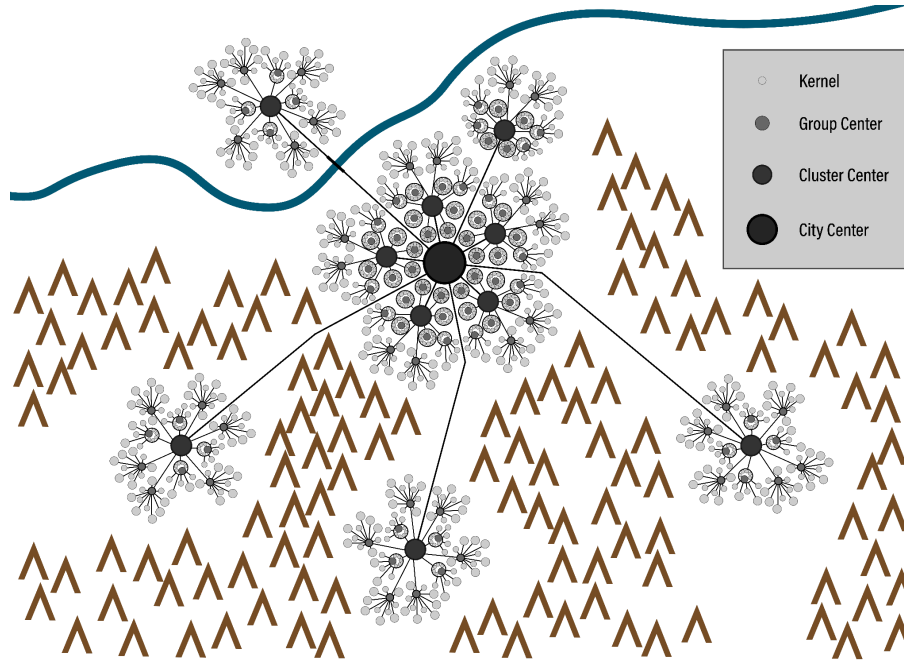


Figure 14. Differentiated kernel-based, multi-tier polycentric urban form adapted to varied topography.

Simply being defined by the connectivity between differentiated community building blocks to form larger and larger community layers can result in much more spatially efficient forms that can also adapt to topographical variation or constraints like bodies of water. These factors would vary more across larger areas so that even rough radial symmetry around a city center would be very rare. Figures 14 and 15 show other examples that still adhere to this urban form but have been adapted to locations among hills and along a coast line, respectively.

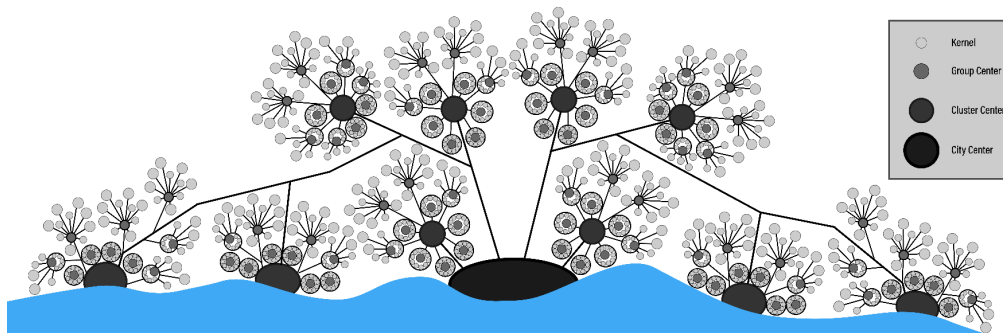


Figure 15. Differentiated kernel-based, multi-tier polycentric urban form adapted to coastal constraints.

Form-Defined Community Dynamics

Just as the internal layout of rooms and common spaces of a home shape our relationship with those we live with, the dynamics among neighbors are also defined by the arrangement of their homes, the common spaces they share, and the transition zones between them. Differentiation among kernels and the larger community units they make up in terms of size, density, shape, and distance for the nearest center makes each better suited to the unique preferences of some individuals than others. In this section, I use rendered models and diagrams of differentiated kernel varieties as well as their composite community units (groups, clusters, cities) to explain the implications of these variables.

Generally speaking, the density and typologies of homes in a kernel will be the largest determinant of community dynamics. There is a tradeoff between privacy and high levels of community involvement, with the former being better facilitated by a dilute arrangement of buildings and the latter being more suited to higher density. Similarly, greater affordability and efficiency can be achieved by sharing more spaces and resources, but this does impact individual autonomy and require higher levels of coordination. With greater density, it also becomes increasingly sensible and necessary to consolidate residential units into fewer buildings and increase their height. Doing so does not necessarily require that there be more common spaces or higher levels of community involvement, but it does make it easier and more efficient for such shared spaces to be included.

While kernels are simply defined as (approximately) 100 person community units and could come in near infinite forms, I present a selection of archetypes here to highlight the likely spectrum of qualities they may have. These are shown in an abstract cylindrical style to emphasize that they are not what kernels would actually look like. In reality, it would make more sense for buildings to be a more standard shape and define space, rather than sitting in it. Ignoring minor details like specific layout or architectural styles, the primary factors defining kernels will be density (land area they occupy), the amount of common space they include, the presence or absence of internal roads, and whether (as well as the degree to which) they are segmented into (multi-household) sub-kernel community units.



Figure 15. Tower kernel shown in an abstract cylindrical style.

At one end of the density spectrum, a kernel could be a tall apartment building. How tall and wide they might be could vary greatly, but they could only be so large with just 100 residents. Shown below in Figure 15, these “tower kernels” could have common space on the first floor, the roof, both, or none at all. Their density certainly makes the inclusion of shared resources and spaces easy, when maximizing rentable space to improve profit margins is not the goal. It is true though, that the segmentation of communities into floors necessarily creates some degree of fragmentation into sub-kernels communities. As a result, each floor-defined community could also share common space in place of or in addition to the kernel-wide shared spaces on the first floor or roof. Another possibility for tower kernels is to be mixed use buildings with commercial or community functions included in their first floor since it will always be sensible to position these buildings close to group, cluster, or city centers.

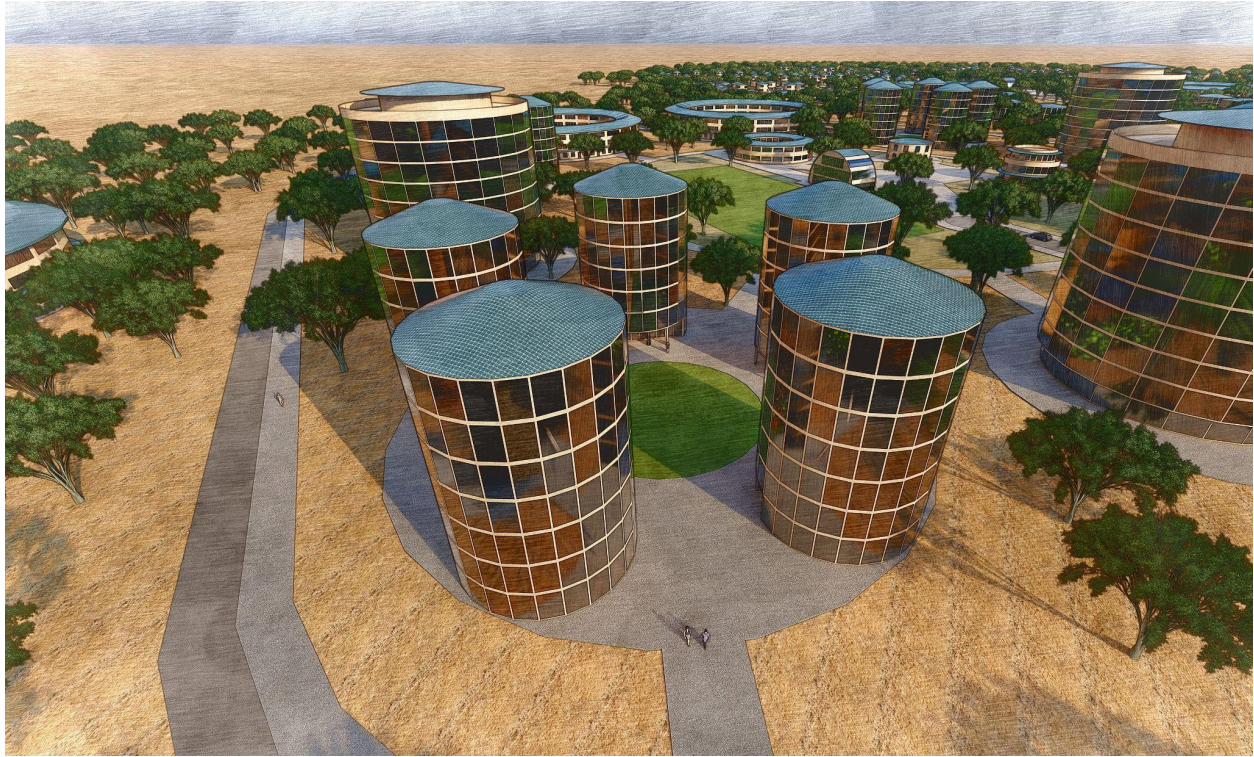


Figure 16. Pillar kernel shown in an abstract cylindrical style.

Slightly less tall and dense, a “pillar kernel” (Figure 16) would essentially be a group of two or more apartment buildings that share a common space in between them. The communities inside each of the constituent buildings could have additional common space and would likely be an even more tightly knit community, thereby introducing another degree of sub-kernel segmentation across buildings.



Figure 17. Courtyard kernel shown in an abstract cylindrical style.

A “courtyard kernel” (Figure 17) would be a single large apartment building that has many adjacent ground access units and a common courtyard in the middle. These are very similar to European multifamily buildings with an inner courtyard or the traditional Chinese “Tulou”.¹²⁴ While not as dense as tower or pillar kernels, it may actually encourage more community bonding due to the fact that all residents would live on the same plane and have a clearly defined common area.

¹²⁴ Lei Hua et al., “3D Documentation on Chinese Hakka Tulou and Internet-Based Virtual Experience for Cultural Tourism: A Case Study of Yongding County, Fujian,” *Journal of Cultural Heritage* 29 (January 1, 2018): 173–79, <https://doi.org/10.1016/j.culher.2017.08.008>.



Figure 18. Composite kernel shown in an abstract cylindrical style.

"Composite kernels" (Figure 18) would be made of a number of small multi-family buildings like, duplexes or fourplexes. Many different types of shared resources or common buildings could be included in the area between these buildings, or they could just share some landscaped open space in the center. Regardless, this form would create another community layer between kernels and households. While not as spatially efficient as taller apartment buildings, these options are still moderately dense and may facilitate more community engagement and sharing potential.



Figure 19. Clustered kernel shown in an abstract cylindrical style.

Similar to composite kernels, “clustered kernels” (Figure 19) would be made of groups of households, but they would each have their own home rather than sharing a multi-family building. These clusters of households could each have a common building, a single common building shared by all of the clusters of homes, both, or neither. While not particularly dense, the clustering of homes does increase spatial efficiency to some degree, in addition to defining residents as a community.



Figure 20. Campus kernel shown in an abstract cylindrical style.

As with clustered kernels, “campus kernels” (Figure 20) would have a road that leads to their center and pedestrian paths from there to each residence, rather than roads. These dispersed, yet moderately dense pedestrian-oriented kernels could be made of homes that vary in size from small ADU-like buildings to larger single family homes. While this would provide substantial privacy for each household and enable more independence, these communities could still have a common building in their center.



Figure 21. Cul-de-sac kernel shown in an abstract cylindrical style.

Suburban-style “cul-de-sac kernels” (Figure 21) would be made of single family homes that are arranged along a road and cul-de-sac. This form encourages some degree of community engagement, despite each household having its own private space and essentially no real common space. Due to their larger size, cul-de-sac kernels would need to be further from their group center and thus having a road through the community is more important than something like a campus kernel.



Figure 22. Dispersed kernel shown in an abstract cylindrical style.

At the most dilute end of the spectrum, more rural-style “dispersed kernels” (Figure 22) would be made of dilute single family homes that all have their own private driveway branching off a larger road. This is the most inefficient use of space, roads, and resources generally, but there will likely always be some subset of people that want to have as much space and little interaction with others as possible. While most urban planners would prefer that this option not even be considered, the takeaway is that the definition of kernels can extend from this to tall multi-family apartment towers and the KUP model can incorporate them all.

To reiterate, these examples are just meant to provide some insight into the range of kernels that could be designed as community modules which assemble according to the KUP model. Below are some diagrams that show the variability of second layer “groups” that could be built from these modular urban building blocks. The size and density of each group would primarily be the result of the types of kernels that it is built from. In addition to their size, I have differentiated these groups based on whether the ring road goes around the group center (“unbound groups”), some portion of the constituent kernels as well as the center (“hybrid groups”), or all of the kernels that the group is made of (“enclosed groups”). Generally, it would make sense for smaller groups to be enclosed (Figure 23), medium sized ones to be

hybrid (Figure 24), and larger ones to be unbound (Figure 25), but I have shown all nine varieties below in Figure 26 to demonstrate the spectrum of typologies.

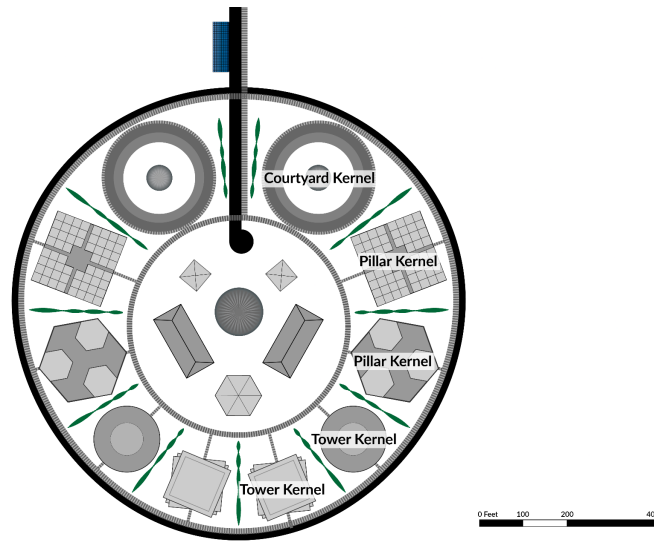


Figure 23. Small enclosed group made of archetypal kernels (labeled), with roads shown in black.

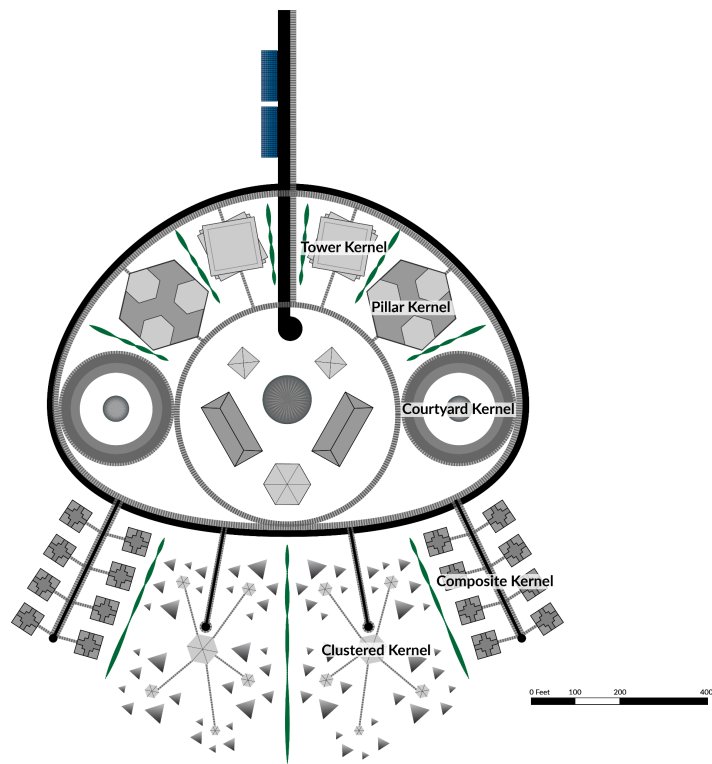


Figure 24. Medium hybrid group made of archetypal kernels (labeled), with roads shown in black.

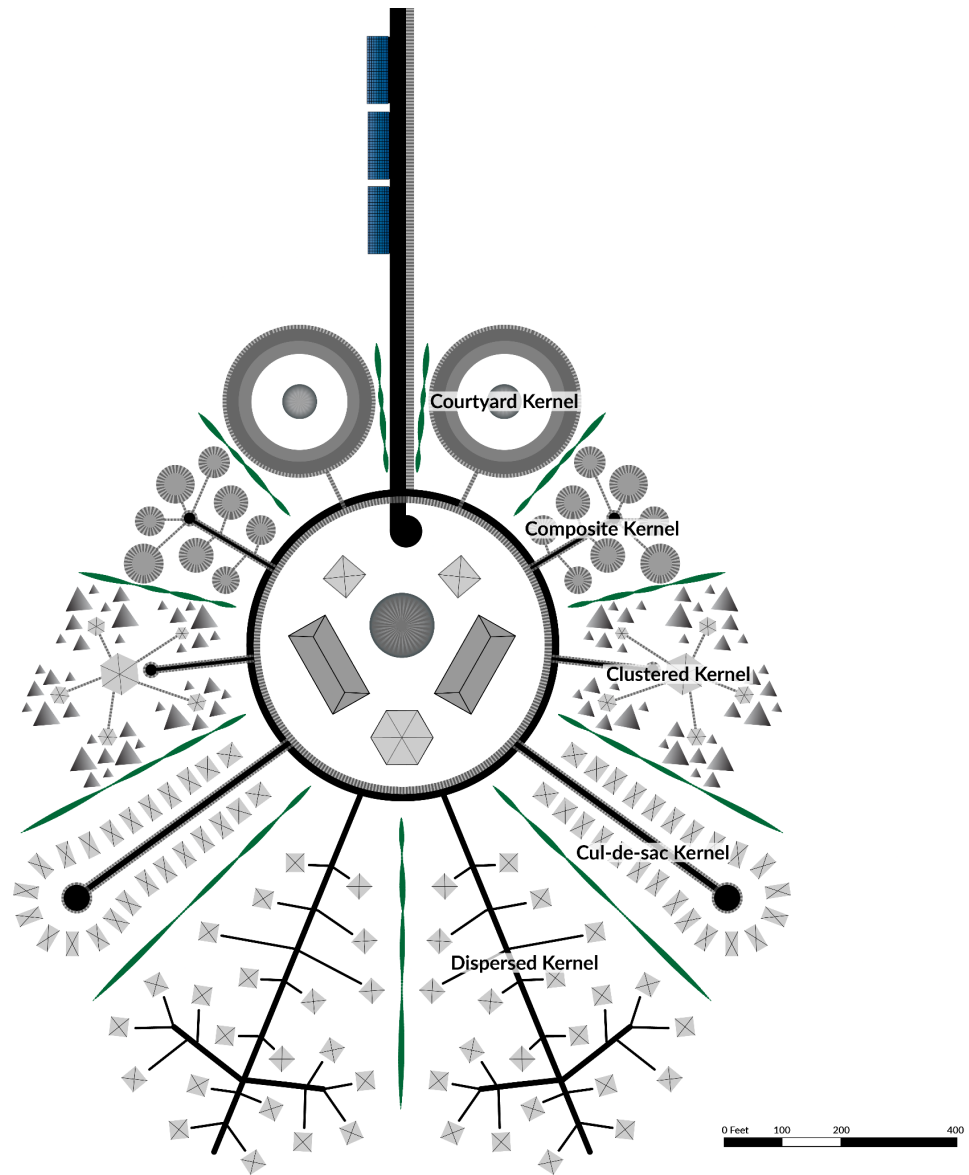


Figure 25. Large unbound group made of archetypal kernels (labeled), with roads shown in black.

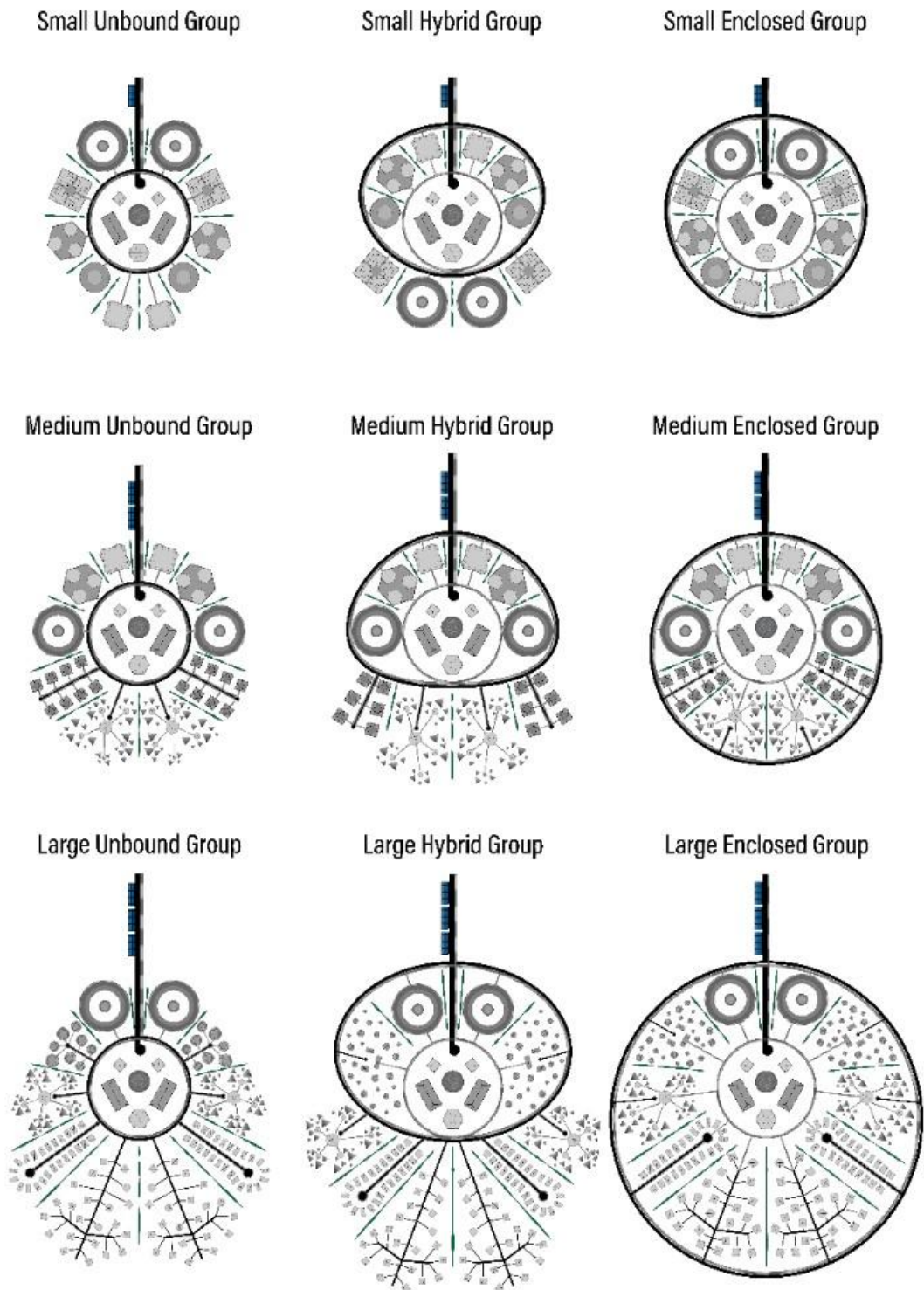


Figure 26. Archetypes of second layer community unit "groups" that are each composed of ten kernels.



Figure 27. Small unbound group (above) and small enclosed group (below), shown in an abstract cylindrical style.



Figure 28. Medium unbound group (above) and large unbound group (below), shown in an abstract cylindrical style.

As noted in the previous section, kernels that are larger and more dilute must be further from the group center, with the largest typically opposite the group center from the road towards the cluster center. The inner and outer cluster archetypes in Figure 29 below show that this geometric sensibility also holds true for groups: larger ones fit best further from the cluster center and opposite the road that leads from it to the city center (Figure 32). It is not particularly problematic that less dense communities would have to be located further from the center since people who value privacy and autonomy over affordability and community engagement would also likely spend more time in their kernel and make fewer trips to larger centers, on average. Additionally, the further distance to larger centers as well as the higher land costs of these more dilute communities serve as disincentives for excessive sprawl. It is worth noting that there is probably a third cluster archetype that is not shown here. Perhaps called remote or distant clusters, these would be more radially symmetric satellite communities that are not adjacent to their city due to topography or some other constraint.

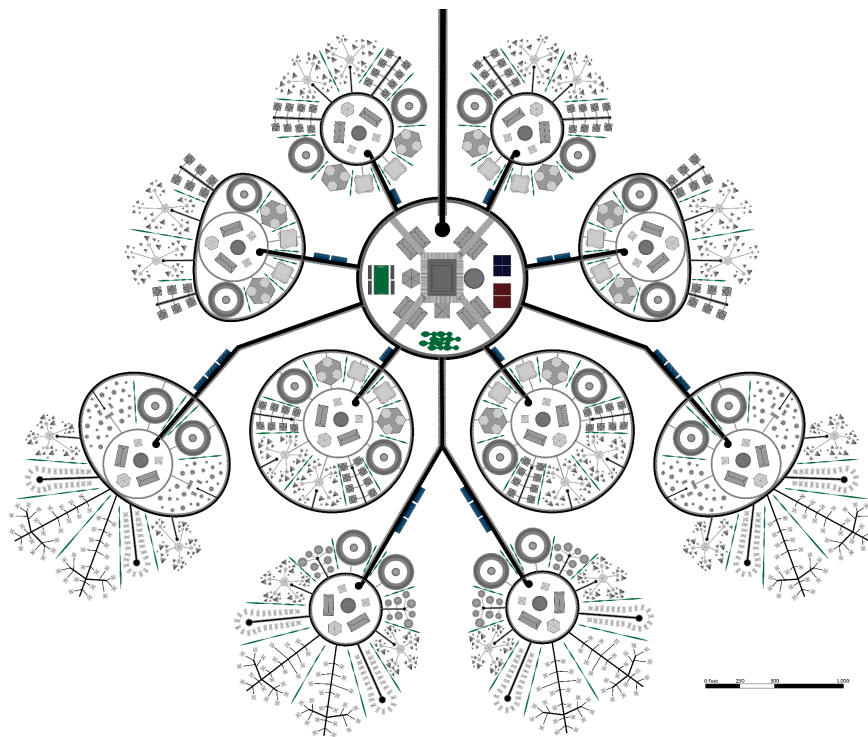
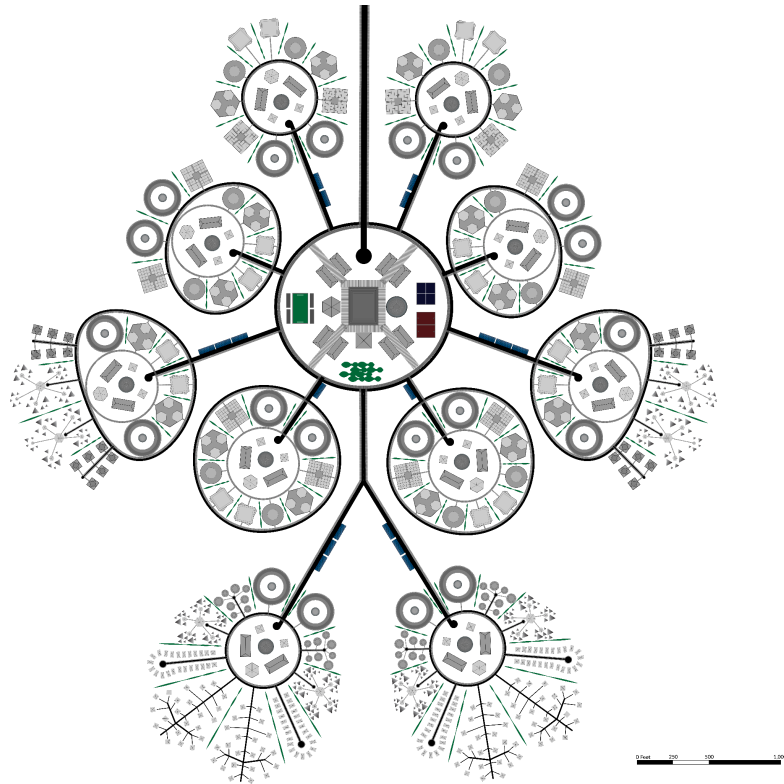


Figure 29. Examples of inner (above) and outer clusters (below).



Figure 30. Render of inner cluster archetype in plan (above) and perspective (below), shown in an abstract cylindrical style.



Figure 31. Render of inner cluster archetype (above) and one possible - probably significantly oversized - cluster center (below), shown in an abstract cylindrical style.

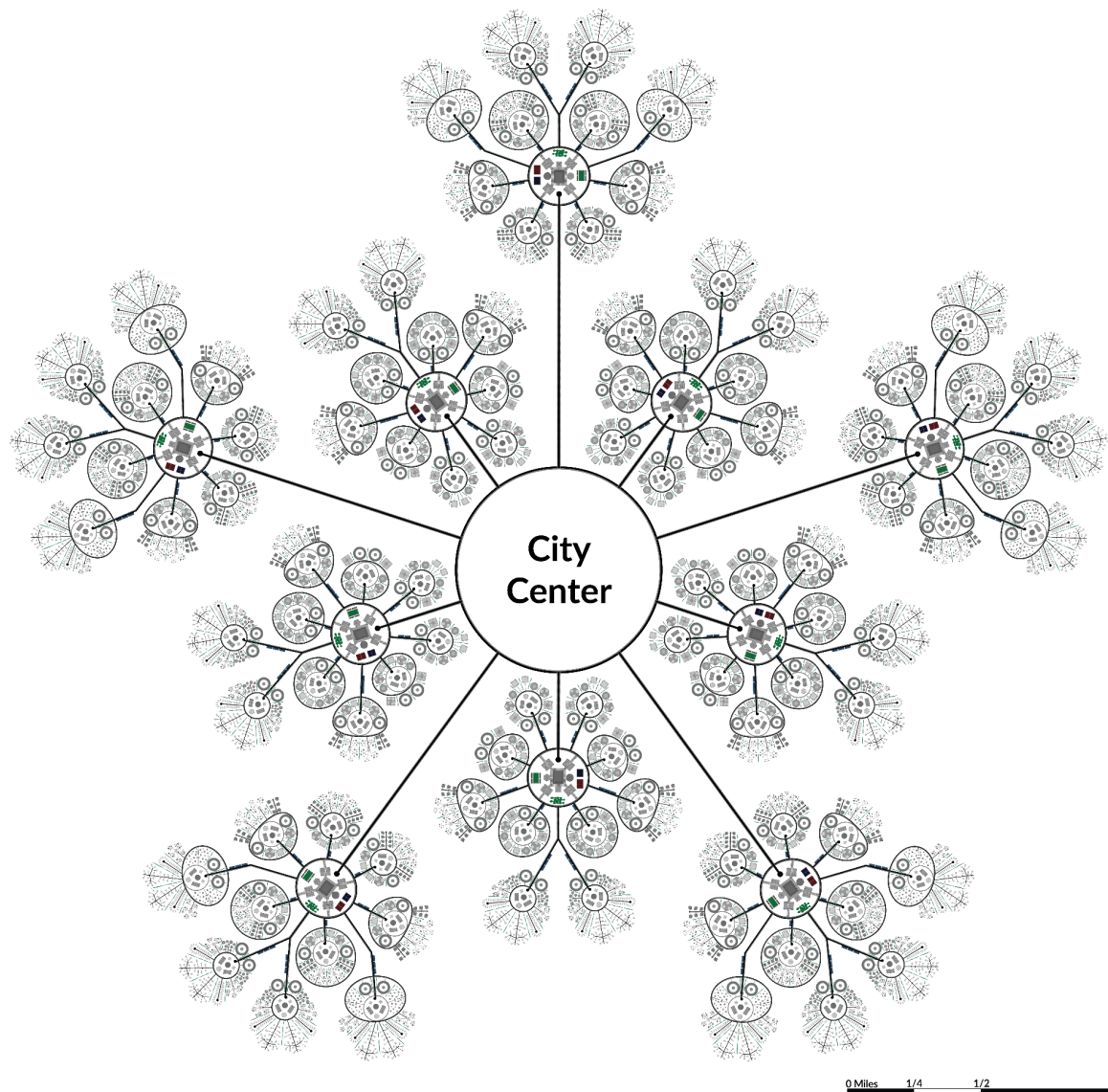


Figure 32. Archetypal city based on the KUP model that is built from differentiated kernels, groups, and clusters.

Just as the size and shape of kernels, groups, or clusters inform (to some degree) which others they are best suited to be assembled with and the form of the resulting community units, a similar dynamic would define other aspects of these composite entities. For instance, whatever differentiated social or cultural dimensions defined the constituent community units would determine how suited they are to hybridization and the sociocultural flavor of their common center as well as overall identity. Additionally, differences in the types of resources

and infrastructure systems that communities contain would make some better suited to sharing a center than others, since commonalities in the internal capabilities of each should also translate to common unmet needs. More tangible examples of these types of shared resources and infrastructure are explored in the following chapters, but the important takeaway here is that differentiation across various dimensions at multiple scales makes the KUP model extremely flexible. Rather than defining urban areas by use, as has historically been done in urban planning, defining them by a sort of lifestyle or community dynamic (and the supporting physical attributes) allows the full range of preference to be facilitated, while also providing a sensible framework for how to construct cities out of communities.

CHAPTER 4: MOBILIZING A NEW PARADIGM

Taking a step back, it is worth reiterating that I have introduced this KUP model as an alternate framework that could be leveraged in the substantial amount of urban development that must occur in the coming decades. In order to assess its advantages over the status quo, we must consider how it could address not only existing urban challenges, but also how well it could take advantage of emerging opportunities. To have such a conversation, it is important to recognize that the world is in the midst of a period of sustained, rapid technological innovation that is transforming nearly every industry. While it is impossible to predict what the outcome will be from all of these changes, it is worth reviewing them to look for major trends that are likely to continue for some time. Doing so should enable us to assess how well the KUP model could adapt to, or even benefit from, them in ways that existing cities cannot.

In this chapter, I discuss major trends that are underway in the transportation industry. While doing so and exploring their implications for urban design, I dive deeper into some of the more tangible and functional aspects of the KUP model. In the following two chapters, I continue this exploration of technological advancements and their implications for kernel-based urban developments - first within the context of employment, logistics, and production then for the sharing economy, ownership, and governance.

An Alternative to Gridiron

The fact that transportation is set to be majorly disrupted in the near future is fantastic since how people move around cities is a part of nearly every residents' daily experience, yet it is perhaps the aspect of urban environments with the most obvious issues. Unfortunately, however, the existing road networks in cities are not well suited to adopting these recent and impending advancements, such as ride hailing, on-demand micro mobility, and autonomous vehicles. Furthermore, an ever growing number of people want to commute by biking or walking, due to a combination of environmental concerns, lifestyle preferences, and health implications.

Before diving into these new technologies and how the KUP model can better integrate them into a comprehensively reimagined transport ecosystem, it is worth reviewing some of the major complaints with the current situation. Approaches to urban transportation today largely fall into three buckets: non-motorized transport, public transit, and private vehicles.

The non-motorized category, which mostly comprises pedestrian and bicycle travel, is often impractical or unsafe as a regular method of commuting in most cities around the world. In the case of pedestrian travel, American cities are worse than most since they are so spread out and the majority of things people want to access are further than is practical to go by foot. This issue is exacerbated by the fact that they often don't have contiguous sidewalks, especially in suburbs. Besides a handful of notable European cities, commuting by bike is similarly problematic since bike lanes, when they are present at all, are often squeezed into roadways as an afterthought. As a result, biking is (understandably) regarded as too dangerous in most places to be a suitable alternative to driving.¹²⁵

Public transit networks are often hailed as the ideal alternative to single passenger vehicles in urban areas, but they have some notable issues as well. First of all, they are

¹²⁵ Sara Daraei et al. "A data-driven approach for assessing biking safety in cities." *EPJ Data Science* 10, no. 1 (2021): NA. *Gale Academic OneFile* (accessed April 2, 2022). https://link.gale.com/apps/doc/A653662208/AONE?u=wash_main&sid=bookmark-AONE&xid=cf30f02f

perceived to be inconvenient and unsafe by users - not without reason.¹²⁶ The limited routes and schedules of public transit also make them substantially less inconvenient than point-to-point, on-demand transportation methods like private vehicles. Additionally, transit systems are extremely expensive for cities to build and operate. The fares that are charged serve as a psychological and logistical barrier to would-be passengers while also funding just a small portion of the actual cost.¹²⁷ Overall, what cities get for the expense is not great outside of a few well designed systems in hyper dense cities like Tokyo¹²⁸ and Hong Kong.¹²⁹ Achieving sufficient density to make public transit work well is not a practical solution for most cities though.

Considering these issues, it is unsurprising that private vehicle travel is as widespread as it is. Of course, it has its own substantial drawbacks, perhaps most notably traffic. When you have a large number of people trying to get to or from work at roughly the same time in vehicles that mostly have a single occupant, congestion is inevitable. Expanding major thoroughfares and freeways only helps so much and providing parking space for all of these cars is also a major challenge. Including more space for vehicles to travel and park spreads everything further out, which makes travel by foot or bike less feasible and further encourages the use of cars. Aside from the associated costs, the ever growing need for paved surfaces that this transportation paradigm demands contributes to flooding as well as the urban heat island effect. Lastly, the health and environmental impacts of all of these ICE (internal combustion engine) vehicles must also be recognized.

¹²⁶ Vania Ceccato and Anastasia Loukaitou-Sideris, "Fear of Sexual Harassment and Its Impact on Safety Perceptions in Transit Environments: A Global Perspective," *Violence Against Women* 28, no. 1 (January 1, 2022): 26–48, <https://doi.org/10.1177/1077801221992874>.

¹²⁷ Owen Bull, Juan Carlos Muñoz, and Hugo E. Silva, "The Impact of Fare-Free Public Transport on Travel Behavior: Evidence from a Randomized Controlled Trial," *Regional Science and Urban Economics* 86 (January 1, 2021): 103616, <https://doi.org/10.1016/j.regsciurbeco.2020.103616>.

¹²⁸ Marcelo Altieri, Cecília Silva, and Shintaro Terabe, "Keep Pushing! Analysing Public Transit and Car Competitiveness in Tokyo," *Case Studies on Transport Policy* 9, no. 2 (June 1, 2021): 457–65, <https://doi.org/10.1016/j.cstp.2021.02.001>.

¹²⁹ Natacha Aveline-Dubach and Guillaume Blandeau, "The Political Economy of Transit Value Capture: The Changing Business Model of the MTRC in Hong Kong," *Urban Studies* 56, no. 16 (December 1, 2019): 3415–31, <https://doi.org/10.1177/0042098018821519>.

Pedestrian and bicycle travel are healthier, environmentally friendly, and more efficient options in terms of space as well as cost. Increasing the utilization of these options, however, requires that more of the places that people go are within a mode-appropriate distance and there are suitable paths that lead to them. Even within the context of the current transport paradigm, this is one of the areas where the KUP model offers some substantial improvements since strategic placement residents most common destinations in nearby centers should reduce the average trip length. Furthermore, the relatively small size of these kernel-based cities reduces the barrier to non-motorized trips, even if they are from an outer community into the city center. The most notable advantage of the KUP model within this context is that dedicated space for non-motorized transport modalities, such as contiguous sidewalks and protected bike lanes, can be designed in from the start.

The street network that the KUP model naturally results in consists of ring roads around centers and radial lines between them. This is a substantial departure from gridiron or historical radial-concentric layouts, though it could be described as nested radial-concentric. As discussed in a previous chapter, the layout of road networks is also one of the most impactful and permanent features of urban form so it is critical to consider all of the implications carefully. Whereas the grid makes few assumptions about common routes that will be taken and connects each point to every other in multiple ways, this alternate design links each center to the next largest in the hierarchy. Such an approach to connectivity drastically reduces the possible routes between any two points, but it also reduces the overall paved surface area - this has implications for cost, stormwater management, and the urban heat island effect.

In addition to being more spatially efficient, this model should greatly improve traffic flow by almost entirely eliminating intersections. This would be achieved by making the ring road around group centers (and perhaps also cluster centers) one directional, which would result in the entire road system becoming a series of traffic circles with tributary feeds from and outlets toward other centers. The city center, as well as possibly cluster centers, would need multiple concentric ring roads, in which case the outer ones would function better as bidirectional paths (Figure 33). Along the outside of the ring roads would be a wide path for bikes and pedestrians (or two separate paths) that allow for travel in either direction. By allowing for bidirectional flows along these paths, non-motorized transport would be prioritized and encouraged. Vehicles would have to cross these bike and pedestrian routes before

entering a ring road so they would simply need to yield - again, prioritizing travel on foot or bike. Given that these would be the only “intersections” that vehicles would have to stop at, this model still allows for more freely flowing traffic generally than in gridded road networks (even if it does require less direct routes to be taken).

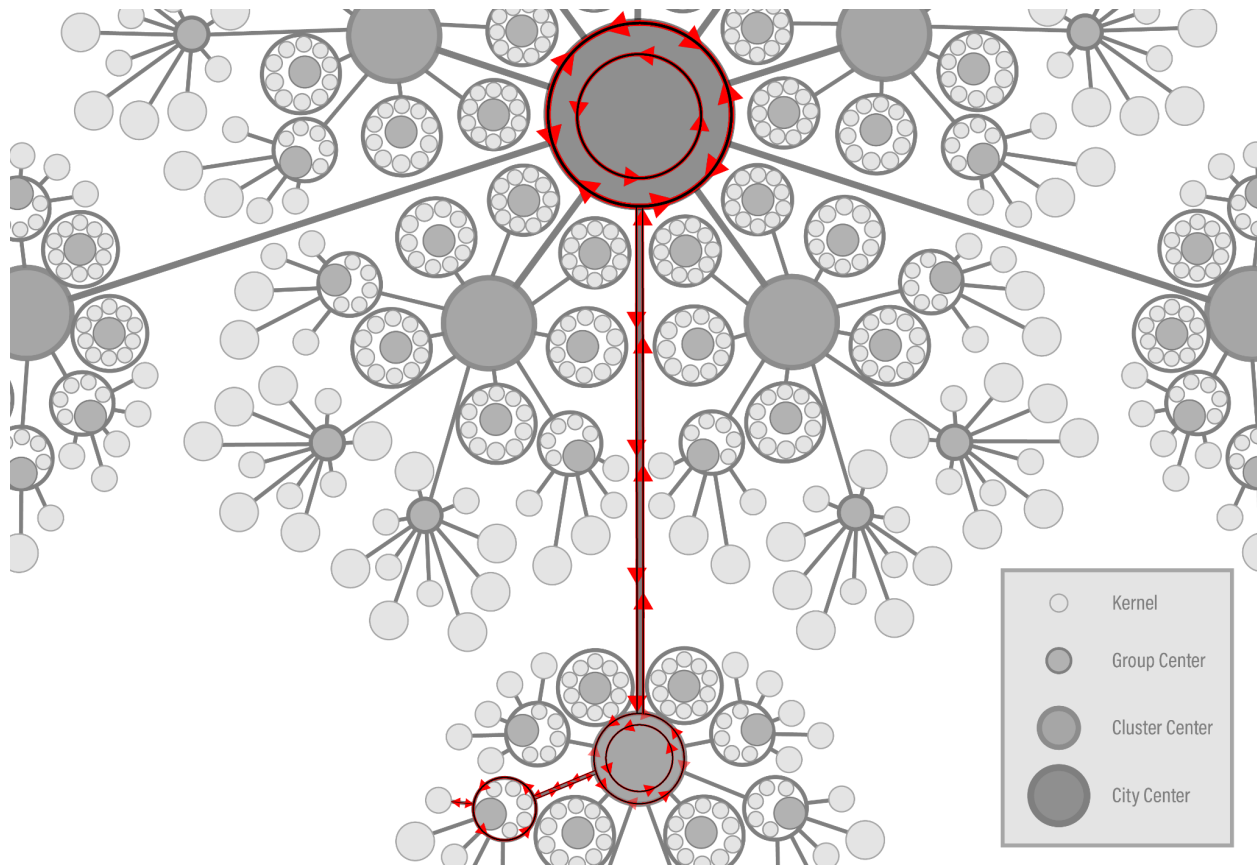


Figure 33. Traffic flow patterns along radial lines and ring roads.

Of course, this whole model is predicated on the assumption that most of the trips residents will take are from their kernel to their group, cluster, or city center and then back. If resources were randomly distributed throughout the various centers rather than being strategically located nearby those that rely on them, this road layout would not be ideal. This model still allows vehicles to travel between any two points, but their path may be inefficient if, for instance, someone is trying to get from one kernel to a nearby kernel that is part of an adjacent cluster. This is because they would have to travel first to their group center, their cluster center, and the city center ring road in order to access the radial line back to the

neighboring cluster, where they would then make the inverse trip down the holarchy: from that cluster's ring road to the group center of their destination kernel before finally arriving at it (Figure 34).

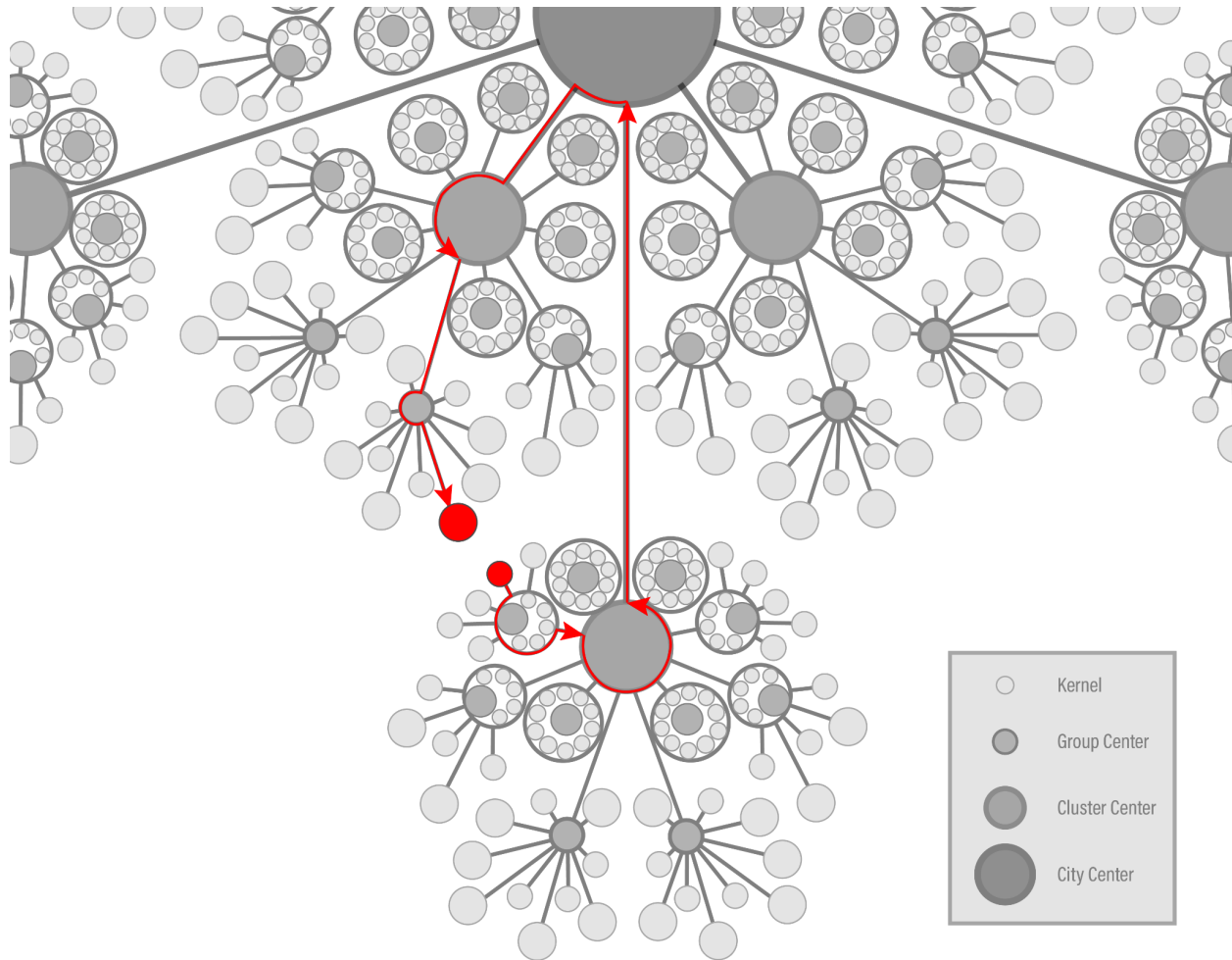


Figure 34. Example vehicular trip between adjacent kernels in neighboring clusters.

While this may seem like an unreasonable constraint, more direct routes can be provided by non-vehicular paths. For instance, a green belt could weave between inner and outer clusters, serving as a natural buffer between adjacent communities as well as a pedestrian path (Figure 35). Connections to groups that are near this non-vehicular ring road would provide more direct routes to many other communities than going into the city center first, but without the disruption and spatial demands of vehicles. In short, this road network incentivises

people to get around via more efficient modes of transport than cars while still facilitating their use.

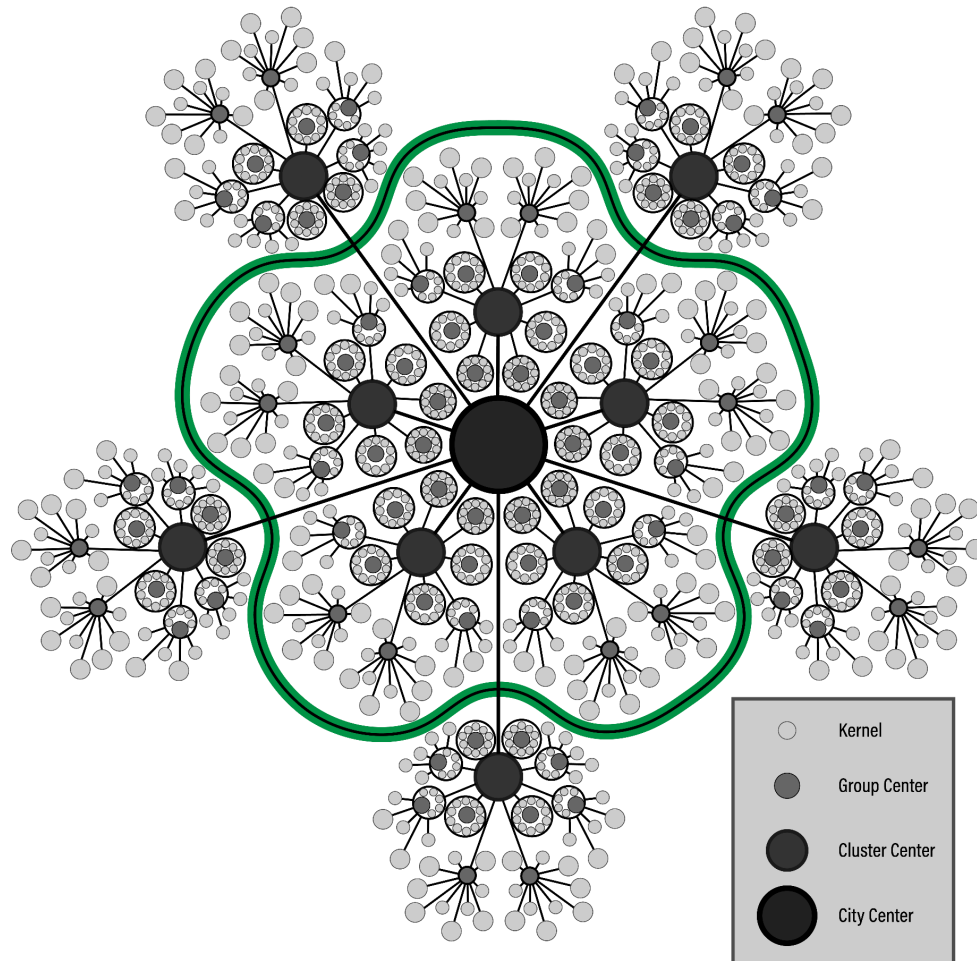


Figure 35. Archetypal city based on the KUP model that shows a green belt/pedestrian ring road weaving between the inner and outer clusters.

Despite being a radical departure from the norm, this approach to street design has many of the qualities that urban planners advocate for. In addition to locating resources in the centers of different community layers, orienting the road system so that all paths converge on them encourages the concentration of pedestrian activity. As any urban designer will tell you, this is what leads to areas feeling rich and vibrant. In their report, the British Urban Task Force noted that “pedestrian routes need to respond to ‘desire lines’ and connect the places where

people want to go in a direct and convenient way.”¹³⁰ The road layout presented here achieves this since linear paths always lead directly to a larger center, creating a visual draw and providing a high degree of legibility, as Kevin Lynch defined it. According to his criteria, a “legible” environment is defined by clear paths, nodes, edges, landmarks, and districts. All of these are central to the KUP model besides possibly landmarks, though centers would generally have buildings or other features that serve as landmarks.¹³¹

New Ways Forward

The advantages of this transport paradigm are already somewhat apparent, but there are three major technological advancements that this model is better positioned to take advantage of. The most notable and impactful of these is, without a doubt, the maturation of autonomous vehicles (AVs). Driven by ever more affordable computing power and advancements in machine learning, as well as data collection and labeling advancements, autonomous driving software is advancing rapidly. The investment of more than \$250 billion on this technology between 2018 and 2021 certainly suggests that companies expect it will be commercially viable soon.¹³²

There are many advantages that autonomous vehicles have over humans. First of all, software never gets distracted, computers have much quicker reaction times than people, and AVs can have many “eyes” looking in different directions at the same time. Once their ability to interpret the 3D world and respond appropriately to that information is sufficiently mature, experts expect these vehicles to be much safer than human drivers.¹³³ The importance of this cannot be understated since 41,000 people died in car accidents in just the United States in 2019.¹³⁴ In addition to safety, fully autonomous driving will free up countless hours of time,

¹³⁰ Urban Task Force, *Towards an Urban Renaissance*, (London]: Spon, 1999): 61.

¹³¹ Kevin Lynch, *The Image of the City*, Publication of the Joint Center for Urban Studies (Cambridge, Mass.: MITPress, 1965).

¹³² Steve Schwatz, “Are Self-Driving Cars Really Safer Than Human Drivers?,” The Gradient, June 13, 2021, <https://thegradient.pub/are-self-driving-cars-really-safer-than-human-drivers/>.

¹³³ Steve Schwatz, “Are Self-Driving Cars Really Safer Than Human Drivers?”.

¹³⁴ Centers for Disease Control, “Accidents or Unintentional Injuries,” January 24, 2022, <https://www.cdc.gov/nchs/fastats/accidental-injury.htm>.

eliminate the stress of driving, and free up people's attention for work or entertainment while commuting.



Figure 36. Toyota's woven city is designed with three types of roads that weave through it: those for AVs, those for pedestrians, and those for bikes or other micro mobility solutions.¹³⁵

This technology is advancing rapidly, but one of the largest sources of difficulty for AVs is sharing the road with unpredictable humans. Even with humans on the roads, Tesla vehicles were 9 times less likely to get in an accident when they had autopilot engaged (though these are the statistics from 2020 and there has been substantial improvement since then).¹³⁶ Regardless, people add a large amount of complexity and uncertainty. This is why multiple groups are planning the construction of entire cities where no human drivers are allowed - only AVs. For example, Toyota is building "Woven City"¹³⁷ (Figure 36) and a group in the United

¹³⁵ River Davis, "A City Tailor-Made for Self-Driving Cars? Toyota Is Building One," *Bloomberg.Com*, April 26, 2021, <https://www.bloomberg.com/news/articles/2021-04-26/a-city-tailor-made-for-self-driving-cars-toyota-is-building-one>.

¹³⁶ Tesla, "2020 Impact Report," Tesla, accessed April 2, 2022, <https://www.tesla.com/impact-report/2020>.

¹³⁷ River Davis, "A City Tailor-Made for Self-Driving Cars? Toyota Is Building One".

states is building the city of Telosa. The latter is designed as a place where people will want to live, rather than a destination city. In that aim, Telosa has been designed with super blocks that are optimized for pedestrians and AVs, with all common resources strategically located within 15 minutes of every resident (Figure 37).¹³⁸ These are just a few examples of the various groups planning whole new cities around AVs, micromobility, and a sustainable, pedestrian oriented transportation ecosystem - others include Saudi Arabia's "Neom" and¹³⁹ Bill Gates' proposed city in Arizona called Belmont.¹⁴⁰



Figure 37. Render of a street in the city of Telosa.¹⁴¹

The road system in the KUP model is optimal for AVs for a number of reasons. First of all, the fact that any kernel-based city would have to be constructed from scratch makes it possible to design roads specifically for their capabilities, without any of the aspects that the

¹³⁸ Telosa, "Telosa | City of the Future," Telosa, accessed March 16, 2022, <https://cityoftelosa.com/>.

¹³⁹ Neom, "The Future of Mobility," accessed April 2, 2022, <https://neom.com/en-us/sectors/mobility>.

¹⁴⁰ Chris Weller, "Bill Gates Is Building a Smart City in Arizona," World Economic Forum, accessed April 2, 2022, <https://www.weforum.org/agenda/2017/11/bill-gates-is-building-a-smart-city-in-arizona/>.

¹⁴¹ Telosa, "Telosa | City of the Future", Telosa, accessed June 8, 2022, <https://cityoftelosa.com/press/>.

technology is still having a hard time with. The elimination of human drivers from the road and most intersections is a great start, but if all of the vehicles on the road are connected to one another, in addition to being autonomous and in a well-mapped area, they could actively coordinate for maximum efficiency and safety. As a result of these changes, everything from lane markings to signs and stop lights could be redesigned or replaced with alternatives that the AVs understand better. In the process of reimagining these features, these new alternatives could be made more aesthetically pleasing as well or they could be eliminated altogether.

Another major opportunity that AVs present within the context of the KUP model is directly related to the two other major advancements that are underway in the transportation industry: electrification and ride hailing. Nearly every autonomous vehicle will be fully electric as well since both transitions are underway at the same time and there are certain synergies in the underlying technology.¹⁴² Out of concern for the environment, due to demand projections, or simply to appease investors, every major auto manufacturer has announced plans to fully electrify their offerings over the next few decades.¹⁴³ While the initial cost of an electric vehicle (EV) is still a slight premium over an ICE equivalent, this will continue to fall along with battery costs and the total cost of ownership for EVs is already lower.¹⁴⁴

Designing for electric vehicles rather than ICE vehicles has a few implications besides improved sustainability, reduced air pollution, and less noise. Most notably, there is no need for gas stations, but conveniently placed charging locations are required. The time required to charge an EV is continuing to fall, but it still takes substantially longer than filling up a gas tank for now.¹⁴⁵ One idea that autonomy makes feasible is that cars can drop their passengers off and then go park somewhere else where they can charge. This would eliminate the need for garages and street parking near residences while still providing the convenience of being able

¹⁴² Aniruddh Mohan et al., "Trade-Offs between Automation and Light Vehicle Electrification," *Nature Energy* 5, no. 7 (July 2020): 543–49, <https://doi.org/10.1038/s41560-020-0644-3>.

¹⁴³ Jim Motavalli, "Every Automaker's EV Plans Through 2035 And Beyond," *Forbes Wheels*, July 27, 2021, <https://www.forbes.com/wheels/news/automaker-ev-plans/>.

¹⁴⁴ Zhe Liu et al., "Comparing Total Cost of Ownership of Battery Electric Vehicles and Internal Combustion Engine Vehicles," *Energy Policy* 158 (November 1, 2021): 112564, <https://doi.org/10.1016/j.enpol.2021.112564>.

¹⁴⁵ K. c Colwell, "How Long Does It Take to Charge an Electric Vehicle?," *Car and Driver*, May 22, 2020, <https://www.caranddriver.com/shopping-advice/a32600212/ev-charging-time/>.

to be dropped off closer to or picked up near one's home. The road network described above provides an optimal location for these carports, which double as charging stations: along the radial lines that connect group centers to cluster centers (Figure 38).



Figure 38. Solar covered carport for AEVs, located along the radial line between a group center and its cluster center.

Of course, this is not a required feature, but it would save a substantial amount of space and cost, while further limiting the impervious and heat absorbing surfaces. Additionally, this carport charging approach would also solve the commonly cited issue of people who do not have a garage being unable to plug in their EVs at home. Further out kernels, which tend to be less spatially efficient and appeal to those that prioritize autonomy, would likely be the ones that opt out of this arrangement and charge vehicles at home.

To fully leverage AVs auto parking and summoning capacity to eliminate the need for parking space in kernels, as well as group and cluster centers, it would make sense for them to include an inlet road with a round-a-bout for pick up and drop off (Figure 39). This sort of infold that provides access without cutting through - a feature that biology has employed liberally in

cells and tissues - ensures that centers are as pedestrian oriented as possible. The internal paths of any center could still be capable of supporting infrequent car travel for moving heavy objects, emergencies, or other occasional needs - similar to the interior roads of superblocks or Dutch "woonerf".



Figure 39. Group center drop-off inlet, shown in an abstract cylindrical style.

There are far more design variations and implications that result from the combination of new mobility solutions and the KUP model's novel road system. While I cannot feasibly explore all of the possibilities, one more aspect that could be particularly impactful is mobility-as-a-service or "ride hailing". Services like Uber and Lyft are well known at this point, but the implications of autonomy for these types of platforms are not as well recognized by the general public yet. The research arm of Ark Investment Management recently published a report that suggests that trips in a "robotaxi" will likely be less than half of the cost of personal car ownership today and less than 10% of the cost of human-driven taxi services - at only \$0.26/mile. A large portion of the expected cost reduction is a result of higher utilization of vehicles in ride hailing fleets compared with private ownership, which also means that fewer

vehicles would be needed in a city to provide the same number of trips.¹⁴⁶ Having substantially lower cost, in addition to the convenience benefits of not having to drive, park, fill up with gas, pay for insurance, or deal with maintenance would likely convince many urban residents to give up car ownership for this alternate model.

Shared trips in these vehicles could easily be coordinated by the software, just like ride hailing apps offer today. Due to the road layout, those who would be leaving from close enough locations for a shared ride to be sensible would be community members. This should make people more willing to do so and it could even be seen as a good way to bond with neighbors. Taking this one step further, an even more intriguing possibility is that these autonomous vehicles could be shared fleets that are owned by kernel or group communities rather than some large corporation. A community could purchase the number of vehicles required for their needs, store them in the nearby carport, and get sufficient utilization via sharing that they would still be much more affordable and efficient than each individual or family having their own.¹⁴⁷ Furthermore, vehicles in a community fleet would probably be treated much better since all riders would be owners and they would not have to worry about strangers leaving a mess or causing damage. This model could, however, conceivably work for privately owned vehicles, community owned vehicles, or company owned fleets, perhaps even all coexisting so long as they are fully autonomous.

This approach of selling locally owned and operated fleets has recently been adopted by micro mobility companies like Bird, which pioneered the on-demand scooter rental idea.¹⁴⁸ There were many issues that resulted from the sudden deployment of large numbers of e-scooters to cities that were not designed for such micro mobility devices, including blocked

¹⁴⁶ Ark Invest, "ARK Contributes Its Financial Autonomous Taxi Model to GitHub," ARK Invest, March 29, 2019, <https://ark-invest.com/articles/analyst-research/autonomous-taxi-model/>.

¹⁴⁷ Neda Masoud and R. Jayakrishnan, "Autonomous or Driver-Less Vehicles: Implementation Strategies and Operational Concerns," *Transportation Research Part E: Logistics and Transportation Review* 108 (December 2017): 179–94, <https://doi.org/10.1016/j.tre.2017.10.011>.

¹⁴⁸ Wes Schlagenhauf, "Bird Will Allow Entrepreneurs to Manage Their Own Fleet of Bird Scooters," *The Hustle*, November 29, 2018, <https://thehustle.co/bird-entrepreneurs-scooters-amazon/>.

sidewalks, accidents with other vehicles, and vandalism of the scooters by the public.¹⁴⁹ Many of these issues could be overcome if they were locally owned and more fully integrated into the local transport ecosystem. The recent proliferation of different electrified form factors - e-scooters, e-bikes, e-mopeds, hoverboards, monocycles, etc. - offers great potential since they are cheap, sustainable, spatially efficient, and faster than non-motorized options. The KUP model, once again, provides an ideal framework for this since these devices could be owned and managed by a group or cluster, docking stations with charging could be located in every center (out of the pedestrian right-of-way), and they would likely be treated better by users who are also owners. A dedicated lane could be included in the roadway for users or they could share the bike and pedestrian path.

Real world examples that are similar to this vision are beginning to appear. For instance, Culdesac is a car-free community under development in Tempe, Arizona that is designed to be a pedestrian paradise. To discourage car use, the developers partnered with various companies to provide shared micro mobility and encourage ride hailing for trips outside of the 761 unit neighborhood.¹⁵⁰ Though it is still early, Culdesac and the cities mentioned above are evidence of the growing recognition of the potential to entirely rethink our transportation ecosystem around these new technologies.

The Long Haul

Transit advocates may argue that relying on lower capacity AVs rather than buses or light rail will cause congestion, but there are a few factors that can counter this concern. First of all, it is worth pointing out that half of the argument for transit comes from sustainability concerns and these would all be electric vehicles. With regard to the traffic half of the equation, however, the software coordinating trip plans could recognize excessive usage and encourage ride sharing if the vehicles are community owned or incentivize ride sharing with lower rates if not. Another factor worth considering is that the time when people go into and leave from the city center is likely to become more variable in addition to these trips becoming less frequent.

¹⁴⁹ Alberica Domitilla Bozzi and Anne Aguilera, "Shared E-Scooters: A Review of Uses, Health and Environmental Impacts, and Policy Implications of a New Micro-Mobility Service," *Sustainability* 13, no. 16 (January 2021): 8676, <https://doi.org/10.3390/su13168676>.

¹⁵⁰ Culdesac, "Cities For People Not Cars," Culdesac, accessed April 3, 2022, <https://culdesac.com/>.

This is discussed more thoroughly in the following chapter, but it is important to mention here since this should reduce the peak demand on the road system and thus limit the amount of traffic that results from single occupancy vehicles. Finally, the opportunities to make other modes of transit - bikes, walking, and electrified micro mobility - more safe and efficient will also reduce the overall strain.

While these factors may eliminate the need for higher capacity transit options, the KUP model could certainly facilitate them. The linear connections between city centers and cluster centers are ideal locations for simple light rails or streetcars since they could go directly between the two stops without any complexity. Depending on the distance between the centers being served and the level of demand, there may not even be the need for multiple cars or tracks since one train could quickly shuttle riders back and forth. Linear rail solutions could coexist with AVs on these higher capacity routes, but they probably would not make sense for connections between group and cluster centers. This presents many hybrid trip options for individuals going into the city center since they could first travel to the light rail stop in their cluster center via another mode of transportation and then take the train for the last, longest leg of the commute.

Buses could possibly be incorporated into the ecosystem as well, but medium capacity autonomous shuttles would likely make more sense. First of all, it would be easier for them to navigate the numerous drop off/pick up inlet roads that provide access to group, cluster, and city centers. Aside from being more suited to turning around in these small round-a-bouts, the nonlinear nature of routes simply make the average bus trip even slower than in today's cities. Rather than waiting for a certain stop along a route, riders would have to wait through a great deal of backtracking to the ring road after each stop.

As these road networks would need to be built from scratch, it would be much more cost effective than in existing cities to elevate or underground portions, such as the light rail routes between city and cluster centers. To accommodate higher volume of traffic flows to and from the city center, linear connections to cluster centers could also be made relatively wide (in terms of lane number) and the overall paved surface in the road network would still be far less than today's cities. Due to the larger scale and capacity demands of the city center, it would likely need to have multiple concentric ring roads that are bidirectional, which would require

intersection management systems like stop lights or whatever the AV-optimal alternative is. These ring roads would feed into many AV drop off/pick up locations to accommodate the absence of parking in this paradigm. Rather than driving all of the way back to the carport of their home group, it would make sense to have similar solar covered parking and charging locations (or even structured parking) along the cluster center-city center roads. This would allow AVs to remain more accessible while their owners are in the city center and eliminate trip redundancy - without clogging up the downtown with parking spaces and garages or necessitating expensive underground parking.

Clearly, many of these details will need to be critiqued and refined prior to implementation. They should, however, provide a glimpse into a dramatically different transportation paradigm that is theoretically possible and better facilitated by the KUP model than gridded cities. What I have described above is optimized for a relatively small scale, but there are various other transportation advancements on the horizon that could be leveraged to interconnect such cities with others. Obviously major freeways can be used to link neighboring cities and facilitate longer distance travel, but better options may include hyperloops and electric vertical takeoff and landing (eVTOL) vehicles. The latter is expected to become a commercially viable option for transporting small numbers of individuals over moderate distances once batteries' energy density and charging rate improves slightly.¹⁵¹ Hyperloops are like train cars propelled in vacuum tubes at airplane speeds. Due to their cost and other constraints, they make the most sense along linear routes with high volume flows, but they can have branching arms that individual pods enter and exit via at lower speeds.¹⁵² This would work extremely well as the circulatory system of regional groups of kernel-based cities since linear routes between industrial centers could facilitate the high capacity flow of goods, materials, and workers between these manufacturing hubs as well as cities along these main routes (Figure 40).

¹⁵¹ Xiao-Guang Yang et al., "Challenges and Key Requirements of Batteries for Electric Vertical Takeoff and Landing Aircraft," *Joule* 5, no. 7 (July 21, 2021): 1644–59, <https://doi.org/10.1016/j.joule.2021.05.001>.

¹⁵² Lambros Mitropoulos et al., "The Hyperloop System and Stakeholders: A Review and Future Directions," *Sustainability* 13, no. 15 (January 2021): 8430, <https://doi.org/10.3390/su13158430>.

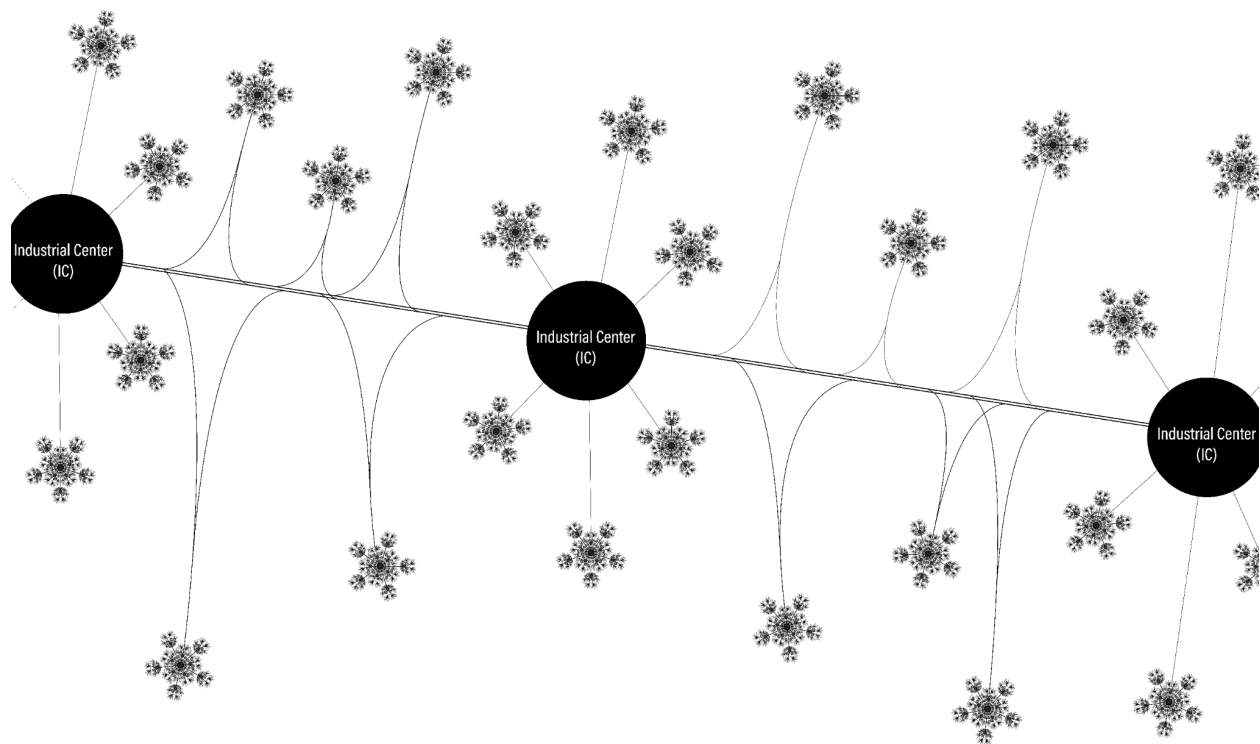


Figure 40. A regional network of industrial centers and cities, linked via hyperloop.

In a recent paper, Glazebrook and Newman advocate for almost exactly the model I have presented above, primarily from a sustainability perspective. Their paper argues that ‘the City of the Future will need to be built around a different transport and urban paradigm’ and that ‘new model will be a polycentric city linked by fast electric rail, with local access based on autonomous “community”-owned electric cars and buses supplemented by bicycles, electric bikes and scooters, with all electricity generated from renewables.’¹⁵³ In addition to sustainability improvements, this new paradigm should encourage physical activity, reduce the average trip length, eliminate traffic, and generally improve the experience of getting around. All of this should be possible by leveraging these (and other) technological advancements and designing from scratch, for a set population.

¹⁵³ Garry Glazebrook and Peter Newman, “The City of the Future,” *Urban Planning* 3, no. 2 (June 1, 2018): 1–21, <https://doi.org/10.17645/up.v3i2.1247>.

CHAPTER 5: A FUTURE OF THE CITY

A major determinant of quality, human-oriented urban design that I have focused on in this thesis is access. In addition to considering how people will get around in the KUP model, it is important to dive deeper into how it could facilitate the sensible placement of goods, services, amenities, workplaces, and other resources that people would need access regularly. In this chapter, I attempt to provide a brief overview of numerous trends that are actively reshaping these critical urban functions and describe how the KUP model is better suited to facilitating the new normal that they seem to be taking us towards. Many of the trends I highlight are in their early stages and how they will change over time is highly speculative. Regardless, it is absolutely necessary to consider the potential impact of possible paradigm shifts when planning developments that will be around for many decades, if not centuries. My aim here is not to provide proof that these trends will continue, but rather sufficient evidence that they might and discuss their implications within the context of the KUP model

The Evolution of Work

There was no such thing as a dedicated workplace throughout the majority of humanity's existence, but when our ancestors left the nomadic hunter gatherer lifestyle behind, most work became anchored to the area around their homes.¹⁵⁴ As cities developed, their primary function was as labor markets, which became larger and more specialized over time. In the recent past, this accelerated and an ever greater number of jobs have been squeezed into large urban centers - first in factories and then increasingly in office buildings. While many urban residents today view the twice-daily mass migration to and from a central workplace as a normal part of life, there is good reason to believe that this was a temporary phenomenon.

A growing number of people now expect the adoption and evolution of online collaboration tools to radically transform where and how work happens. In 1975, before the term telecommuting was ever used, Jack Nilles published a paper arguing that "telecommunications-augmented decentralization" of work would likely increase over time and

¹⁵⁴Clark Spencer Larsen et al., "Bioarchaeology of Neolithic Çatalhöyük Reveals Fundamental Transitions in Health, Mobility, and Lifestyle in Early Farmers," *Proceedings of the National Academy of Sciences* 116, no. 26 (June 25, 2019): 12615–23, <https://doi.org/10.1073/pnas.1904345116>.

have profound implications for labor, transportation, and land use policies. He argued that this inevitable decentralization of work would be driven by “the ability of new telecommunications and computer technologies to maintain or increase productivity for routine clerical and management functions”, in addition to the availability and shrinking costs of these technologies relative to transportation.¹⁵⁵

Many people echoed this viewpoint over the years, but most remained skeptical until Covid-19 transformed the way that work was done almost overnight. If the virus had appeared just a few years earlier, it is likely that the technology would not have been mature enough to facilitate the rapid transition that followed. As it happened, however, a large portion of urban work and nearly all education was able to effectively convert from in person to digital operations overnight. Immediately, the number of Microsoft Teams meetings more than doubled and their length increased¹⁵⁶ while the number of daily Zoom meeting participants increased from 10 million in December 2019 to 300 million in April 2020.¹⁵⁷

Two years on from the start of the pandemic, the consensus viewpoint is that remote work, in some capacity, is here to stay. There are many common frustrations that people have expressed with remote work and school, but this period made it clear that it is feasible and that there are many benefits as well. According to a large survey of US employees, half of all office employees expect to work from home part time going forward - on average, 2 days per week. This report also argued that this will be the new normal due to five main factors: better than expected experiences with working remotely, new investments that facilitate it, technological innovations that support it, reduced stigma associated with it, and persistent concerns about germ exposure in crowded settings.¹⁵⁸ Multiple large surveys have found that the majority of

¹⁵⁵ J. Nilles, “Telecommunications and Organizational Decentralization,” *IEEE Transactions on Communications* 23, no. 10 (October 1975): 1142–47, <https://doi.org/10.1109/TCOM.1975.1092687>.

¹⁵⁶ Microsoft, “The Next Great Disruption Is Hybrid Work—Are We Ready?,” accessed March 12, 2022, <https://www.microsoft.com/en-us/worklab/work-trend-index/hybrid-work>.

¹⁵⁷ Tom Warren, “Zoom Grows to 300 Million Meeting Participants despite Security Backlash,” *The Verge*, April 23, 2020, <https://www.theverge.com/2020/4/23/21232401/zoom-300-million-users-growth-coronavirus-pandemic-security-privacy-concerns-response>.

¹⁵⁸ Jose Maria Barrero, Nicholas Bloom, and Steven J Davis, “Why Working From Home Will Stick,” n.d., 69.

office workers around the world prefer hybrid work schedules in the future since they want to be able to come into the office, but also have the flexibility to work from home part time.^{159,160}

One of the largest advocates of the transition to hybrid work has been Microsoft, which has 180,000 employees and is the second most valuable company in the world). In a 2021 report, they note the benefits of flexible working conditions that workers have come to expect during the last two years, but also claim that employees at their company and elsewhere are experiencing “digital exhaustion” from fully remote work.¹⁶¹ Microsoft as well as Apple, Google, Amazon, IBM, Uber, Twitter, and Salesforce are among the large companies transitioning to a hybrid work model, while others like Facebook and Coinbase are offering to let employees work entirely remotely. Most, however, fear that going fully remote would have a negative impact on company culture and productivity.¹⁶²

There is a confluence of factors that is likely to supercharge the transition to remote or hybrid work, now that it is under way. One factor to consider is that the lines between work and education are increasingly blurring since jobs require employees to constantly be learning new information to keep up with a rapidly changing world. On demand, context dependent learning will primarily be supported by online resources and is, therefore, one more work-related task that is well suited to being done remotely. Additionally, the growing number of roles that can be done remotely enables companies to draw on a wider pool of talent and find employees that are happy to work for less since they live in more affordable locations. This is a win for workers as well as companies: “people no longer have to leave their desk, house or community to expand their career, and it will have profound impacts on the talent landscape.”¹⁶³

¹⁵⁹ Janet McLaurin, “4 Emerging Patterns About Hybrid Work and the Future of the Office,” Wisp, September 13, 2021, <https://wisp.gensler.com/4-emerging-patterns-about-hybrid-work-and-the-future-of-the-office-2/>.

¹⁶⁰ JLL, “Reimagining Human Experience: How to Embrace the New Work-Life Priorities and Expectations of a Liquid Workforce,” November 2020, 21.

¹⁶¹ Microsoft, “The Next Great Disruption Is Hybrid Work—Are We Ready?”.

¹⁶² Mark Sullivan, “How 15+ Tech Companies Are Transitioning Back to the Office (or Not),” Fast Company, July 26, 2021, <https://www.fastcompany.com/90653268/tech-companies-hybrid-office-remote-work-policies>.

¹⁶³ Microsoft, “The Next Great Disruption Is Hybrid Work—Are We Ready?”

Another major catalyzing force is the improvement of systems that make remote collaboration possible. From cloud-based whiteboard applications to real-time design programs and video conferencing, the tools for virtual collaboration are both evolving and growing in number. Many believe that spatial computing, enabled by virtual and augmented reality (AR and VR) headsets, will bring a powerful new set of capabilities and accelerate this further. For instance, AR and VR headsets enable virtual meetings to be more engaging and provide a sense of “presence” despite physical distance.¹⁶⁴ Additionally, “spatial audio” makes it possible for there to be side conversations between those who are “next to” one another in a virtual space without disrupting another conversation - something that video conferencing does not allow.^{165,166} While this may sound like science fiction to some, 2021 saw significant momentum towards widespread adoption of these technologies. For instance, 26 million VR headsets were sold compared with 19 million in 2020 and this rapid rate of growth is expected to continue.¹⁶⁷ There are also multiple virtual meeting applications that are already available, such as Spatial,¹⁶⁸ Meta’s Horizon Workrooms,¹⁶⁹ and even Microsoft Teams, which will have the company’s mixed reality platform (Mesh) incorporated into the widely used app.¹⁷⁰ Many tech

¹⁶⁴ Michael Wilkinson, Sean Brantley, and Jing Feng, “A Mini Review of Presence and Immersion in Virtual Reality,” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 65, no. 1 (September 1, 2021): 1099–1103, <https://doi.org/10.1177/1071181321651148>.

¹⁶⁵ Jim Poore, “Spatial Audio – A Game Changer in Conferencing,” *Immersitech* (blog), April 27, 2021, <https://immersitech.io/spatial-audio-conferencing/>.

¹⁶⁶ Jing Yang et al., “The Effects of Spatial Auditory and Visual Cues on Mixed Reality Remote Collaboration,” *Journal on Multimodal User Interfaces* 14, no. 4 (2020): 337–52, <https://doi.org/10.1007/s12193-020-00331-1>.

¹⁶⁷ Omdia, “Omdia Research Reveals 12.5m Consumer VR Headsets Sold in 2021 with Content Spend Exceeding \$2bn,” Omdia, accessed April 19, 2022, <https://omdia.tech.informa.com/pr/2021-dec/omdia-research-reveals-12m-consumer-vr-headsets-sold-in-2021-with-content-spend-exceeding-2bn>.

¹⁶⁸ Spatial, “Create Your Avatar: Build Your Metaverse Presence,” accessed March 13, 2022, <https://spatial.io/create-an-avatar>.

¹⁶⁹ Meta, “Horizon Workrooms for VR Remote Collaboration,” *Meta* (blog), August 19, 2021, <https://about.fb.com/news/2021/08/introducing-horizon-workrooms-remote-collaboration-reimagined/>.

¹⁷⁰ Tom Warren, “Microsoft Teams Enters the Metaverse Race with 3D Avatars and Immersive Meetings,” *The Verge*, November 2, 2021, <https://www.theverge.com/2021/11/2/22758974/microsoft-teams-metaverse-mesh-3d-avatars-meetings-features>.

companies besides Meta¹⁷¹ and Microsoft,¹⁷² such as Apple,¹⁷³ ByteDance,¹⁷⁴ and Google,¹⁷⁵ are investing heavily in this area since it has become clear that the enabling hardware and software are approaching commercial viability.

As a result of these and other changes that help to overcome the challenges of remote collaboration, the types of meetings that require a trip into a central office will decrease, on the margin. Many companies - 66% according to Microsoft - are redesigning their spaces to facilitate collaboration and meetings since this will increasingly be the main function of central offices, rather than independent work.¹⁷⁶ These changes often include a transition from dedicated work spaces to open seating arrangements, which translates to less space requirements when employees aren't coming in each day (and, by extension, lower costs). In explaining IBM's rationale for downsizing and remodeling their offices, the company's CEO stated plainly that "solitary work will likely be done from home" going forward.¹⁷⁷

Working from home has become the default term for remote work, but in reality home environments are often not ideal for productivity due to noise, distractions, and other factors.

¹⁷¹ Kevin Carbotte, "Meta Now Holds 60% of the SteamVR Market Share and 36% Is Quest 2," TweakTown, December 2, 2021, <https://www.tweaktown.com/news/83121/meta-now-holds-60-of-the-steamvr-market-share-and-36-is-quest-2/index.html>.

¹⁷² Ronan Jenkins, "Microsoft HoloLens 2 and Mixed Reality Bridge Physical Reality and Digital Experiences," Microsoft Dynamics 365 Blog, February 23, 2022, <https://cloudblogs.microsoft.com/dynamics365/bdm/2022/02/23/microsoft-hololens-2-and-mixed-reality-bridge-physical-reality-and-digital-experiences/>.

¹⁷³ Hector Hamish and Axel Metz, "Apple MR Headset News, Leaks and What We Want to See," TechRadar, February 10, 2022, <https://www.techradar.com/news/apple-vr-headset>.

¹⁷⁴ Rita Liao, "ByteDance-Owned VR Startup Pico Strengthens Ties with Qualcomm," *TechCrunch* (blog), accessed March 13, 2022, <https://social.techcrunch.com/2022/03/01/bytedance-vr-pico-qualcomm/>.

¹⁷⁵ Mike Wheatly, "Report: Google Acquires MicroLED Startup Raxium to Aid AR Headset Ambitions," SiliconANGLE (blog), March 16, 2022, <https://siliconangle.com/2022/03/16/report-google-acquires-microled-startup-raxium-aid-ar-headset-ambitions/>.

¹⁷⁶ Microsoft, "The Next Great Disruption Is Hybrid Work—Are We Ready?"

¹⁷⁷ Brody Ford and Emily Chang, "IBM Sees 80% of Employees Working in Hybrid Roles After Pandemic," Bloomberg.Com, March 31, 2021, <https://www.bloomberg.com/news/articles/2021-03-31/ibm-expects-80-of-its-employees-to-work-hybrid-post-pandemic>.

As a result, many people prefer to go to cafes or coworking spaces when they work remotely, regardless of whether they do so every day or as part of a hybrid schedule. Even prior to the pandemic, coworking spaces were seeing massive adoption since they offer flexible, on-demand work spaces as well as other benefits and solutions to the limitations of remote work. For instance, studies have found that strong communities and culture often emerge in such environments, plus they facilitate networking and the cross pollination of ideas.^{178,179}

In addition to reconfiguring and often downsizing their central offices, some organizations are establishing multiple satellite offices in the surrounding metropolitan area. As Microsoft frames it, “rather than returning to one mega-office when the lockdown ends, workers may be spending more time in coworking spots closer to home or in satellite facilities built along a hub-and-spoke model.”¹⁸⁰ Like coworking spaces, these conveniently located small offices provide a dedicated work space away from the distractions of home life and a culture of productivity without the need to go all of the way downtown each day. The main benefits of satellite offices over coworking spaces are that they are free to use, can provide dedicated workstations (that facilitate workers’ preferred ergonomic or aesthetic desk setup), and are only occupied by one’s co-workers (though this could be seen as a drawback as well). Such satellite locations could provide a nice complement to small central offices that primarily contain flexible, multipurpose rooms for meetings and some open, unassigned workspace for the days when people do come in.

Regardless of whether remote workers come to prefer cafes, commercial coworking spaces, or official satellite offices operated by employers, it seems likely that cities will need more of these conveniently located micro work hubs and less central office space going forward. This shift would be well facilitated by the KUP model since the different scale centers provide optimal locations for a spectrum of workplace typologies. It would most likely make

¹⁷⁸ Lyndon E. Garrett, Gretchen M. Spreitzer, and Peter A. Bacevice, “Co-Constructing a Sense of Community at Work: The Emergence of Community in Coworking Spaces,” *Organization Studies* 38, no. 6 (June 1, 2017): 821–42, <https://doi.org/10.1177/0170840616685354>.

¹⁷⁹ Blagoy Blagoev, Jana Costas, and Dan Kärreman, “‘We Are All Herd Animals’: Community and Organizationality in Coworking Spaces,” *Organization* 26, no. 6 (November 1, 2019): 894–916, <https://doi.org/10.1177/1350508418821008>.

¹⁸⁰ Microsoft, “How to Reimagine Work Spaces for the Hybrid Era”. Accessed March 12, 2022. <https://www.microsoft.com/en-us/worklab/reimagine-work-spaces-for-the-hybrid-era>.

sense to locate satellite offices and other dedicated work spaces in cluster centers that the employees live around. Group centers, on the other hand, would be more appropriate for flexible, unspecialized coworking space that community members can use on-demand. Such coworking spaces are ideal candidates for sharable community resources, which will be discussed in the following chapter. Furthermore, this approach to workplace differentiation and distribution would also be very in line with the central design philosophy I have advocated for of locating resources as close as is practical to those who rely on them. Having fewer people in the city center for work each day would also mean a reduced need for supporting roles and businesses there. By extension, this should translate to a more compact and pedestrian friendly layout in the city center, reduced traffic demands on the roads that radiate out from it, as well as more activity in the smaller scale cluster and group centers.

Besides true “office” work, there are many other jobs that will become more amenable to this model of small, distributed workplaces over time and many that are already well suited to it (consumer facing jobs that provide access to goods and services - grocery stores, banks, medical clinics, etc. - will be discussed in the following sections). For instance, all sorts of research, design, and development work will require fewer and fewer people due to a confluence of factors. These include: a growing suite of software tools, increasingly affordable robotics for the automation of tasks, access to ever improving knowledge bases online, powerful data modeling and simulation tools, improved equipment and techniques for various types of research, digital fabrication tools for rapid prototyping, and many more.

Together, these types of advancements are enabling smaller teams to accomplish what used to take many more people and much more specialized equipment. Assuming the underlying technologies continue to improve and leverage one another, it is reasonable to expect that this will reinforce the shift towards smaller distributed workspaces. Even with offices or labs in different parts of the world, team members that need to be physically together on a daily basis can be colocated without the inconvenience of commuting, but still remain linked with other teams digitally. This level of differentiation between intra-team and inter-team collaboration meshes well with the KUP model, though workplaces with specialized equipment like research labs will probably make more sense to be located in city centers or at least cluster centers, rather than in group centers.

While these trends suggest that many industries will transition to being done in a hybrid or fully remote manner, it is important to acknowledge that most jobs in the world today are still location dependent. The vast majority of these are, however, lower skilled ones that are more likely candidates for automation or simply becoming irrelevant in the near future. By some estimates, up to 50% of all existing tasks could be automated over the coming decade¹⁸¹ - a very short time horizon relative to city planning and construction. There has been a great deal of anxiety and fear of job loss due to automation many times in the past. Every time that a new tool was created that replaced some role, however, new jobs have always emerged for this newly free workforce and experts expect this will be the case once again.¹⁸² The new roles that emerge this time around are far more likely to be online, creative, or knowledge-based jobs that can be done remotely at least part time. Due to the factors discussed above, these new jobs could be better supported by the differentiated workplaces in the centers of a nested polycentric urban form than within a traditional city.

Distributed Demand

It was not only the work opportunities which cities offered that drew people to them, but also the value that they provided in the form of differentiated goods and services. Over time, trade networks grew and larger portions of the goods that people relied on were grown or produced elsewhere. As with many things, this accelerated in the recent past and now most people rely on global trade networks to acquire the crops, clothes, devices, and just about everything else they purchase. The rise of e-commerce has even begun to disrupt stores as the link between consumers and these supply chains. Similarly, there has been a proliferation of services that people rely on, many of which are now being digitized. These trends in how urban residents access goods and services have significant implications for the optimal amount, as well as the optimal location, of supporting facilities in future cities. In this section, I briefly touch

¹⁸¹McKinsey, "What the Future of Work Will Mean for Jobs, Skills, and Wages: Jobs Lost, Jobs Gained," accessed April 19, 2022, <https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages>.

¹⁸² David R. Henderson, "Aye, Robot: Yes, the Robots Are Coming, but Not for Our Jobs. Automation Will Bring New Kinds of Work, and New Chances to Create Wealth," *Hoover Digest*, no. 1 (January 1, 2018): 16–22.

on how various consumer-facing businesses appear to be changing and explain how the KUP model is well suited to facilitate this.

Beginning with services, the banking industry is undergoing a dramatic paradigm shift, as financial services are increasingly digitized. Many parts of the world, particularly the less developed nations, have seen a rapid adoption of digital wallets and payment methods due to the lack of traditional banking services and financial rails.¹⁸³ Many researchers expect this adoption to accelerate globally due to the ubiquity of mobile devices, the improved convenience for users that digital wallets provide, as well as the reduction in cost for financial service providers of both operations and customer acquisition.¹⁸⁴ Furthermore, many of the backend accounting and routine administrative roles in the broader financial services industry (which is a sector that accounts for nearly 9 million employees in the US alone)¹⁸⁵ will likely be replaced with software. This will largely be facilitated by distributed ledger technology - also known as blockchain - since it provides a common substrate for cross party transactions in addition to automation of numerous common functions that banks have taken care of manually until now.^{186,187} In other words, this is also another example of how automation could free up workers to take on more creative and collaborative roles, which are well suited to hybrid work schedules. The implications for the KUP model of this transition would be that few (if any) physical bank branches will be needed while there will be less demand for central office space and more demand for small coworking spaces or satellite offices.

¹⁸³ Ajimon George and Prajod Sunny, "Developing a Research Model for Mobile Wallet Adoption and Usage," *IIM Kozhikode Society & Management Review* 10, no. 1 (January 1, 2021): 82–98, <https://doi.org/10.1177/2277975220965354>.

¹⁸⁴ Ark Invest, "Big Ideas 2021" (Ark Investment Management, January 6, 2021), https://research.ark-invest.com/hubfs/1_Download_Files_ARK-Invest/White_Papers/ARK%E2%80%93Invest_BigIdeas_2021.pdf: 28–36.

¹⁸⁵ U.S. Bureau of Labor Statistics, "Industries at a Glance: Financial Activities," April 22, 2022, <https://www.bls.gov/iag/tgs/iag50.htm#workforce>.

¹⁸⁶ Kurt Kunselman, "Council Post: The Future Of Blockchain In Accountancy," *Forbes*, accessed April 22, 2022, <https://www.forbes.com/sites/forbesfinancecouncil/2021/01/29/the-future-of-blockchain-in-accountancy/>

¹⁸⁷ Nicolai Andersen, "Blockchain Technology: A Game-Changer in Accounting?" (Deloitte, 2016), https://www2.deloitte.com/content/dam/Deloitte/de/Documents/Innovation/Blockchain_A%20game-changer%20in%20accounting.pdf.

Healthcare is another major category of services that is integral to modern cities. There are regular advancements in the medical industry that are certain to continue in the coming decades, but most will be new procedures and treatments that do not impact the essential role that medical facilities play in cities. There are, however, certain advancements - like home diagnostics, wearable devices, and telehealth appointments for simple check-ins - that should increase the quality of health coverage while decreasing the number of trips patients need to make to their doctor's office. Similarly, the dental industry is experiencing some disruption in the form of at-home teeth impression kits, mail-delivered 3D printed retainers, and image-based digital check-ins.¹⁸⁸ These advancements decrease the cost for treatment and democratize access, but are also unlikely to substantially change the demand profile for dental offices in urban areas. Fortunately, the sort of small offices that many doctors, as well as most dentists, counselors, and physical therapists, tend to practice out of are a very appropriate scale for a cluster center, where they would serve the surrounding population of roughly 10,000 people. In order to serve the less frequent needs of the larger surrounding population, a central hospital with specialists and specialized equipment would be a sensible resource to include in the city center. Clearly, this differentiation of functions and associated facilities across scales is very similar to the hub and spoke model for offices - exactly what the KUP model supports best.

Sports are a huge part of many people's lives and fitness facilities are another common service-oriented resource in urban areas. Unlike many other industries, technological advancement is more likely to increase the amount of urban area dedicated to fitness (at least, that is my hope personally). As automation frees up more people to do knowledge work, remaining physically active will become increasingly important for focus and productivity, but also increasingly necessary to dedicate time to since these jobs are more sedentary on average. The KUP model encourages daily activity since commuting by foot or bike is more feasible, but dedicated facilities are still needed as well as some supporting roles. Standard gyms with cardio equipment and weights probably make the most sense in group centers or even within individual kernels, where they could be a shared community resource that is more practical than home gyms. Similarly, unspecialized fields and flexible, multi-purpose fitness

¹⁸⁸ Kim Acosta, "SmileDirectClub: Review," Forbes Health, August 9, 2021, <https://www.forbes.com/health/body/smiledirectclub-review/>.

studios (for yoga, dance, and other classes) may make sense in group centers, but dedicated sports fields and courts or larger facilities like pools would be more suitable to cluster centers. Some of the more specialized or least commonly used facilities (like climbing gyms, hockey rinks, and stadiums with substantial seating) are probably best suited to city centers.

The transition to autonomous and electric vehicles will have major effects on various common urban businesses, in addition to the implications it has for road systems and transit. As discussed in the previous chapter, gas stations and parking garages can be eliminated while new charging stalls must be added. Besides these businesses, there will be very little need for mechanic shops since EVs require almost no maintenance compared to ICE cars and AVs will be far less likely to get in accidents. With regard to dealerships, the industry is already transitioning to a direct-to-consumer sales model¹⁸⁹ as most new EV manufacturers - Tesla, Lucid, Rivian, etc. - are abandoning the old model.¹⁹⁰ Traditional auto OEMs are having a harder time moving away from dealerships due to how intertwined their businesses have become, but even Ford recently decided to adopt a direct-to-consumer model for its electric models.¹⁹¹ The rise of ride hailing fleets, regardless of whether they are community owned or not, will make dealerships even less practical since the increased utilization rates of AV's mean fewer cars will be needed in a given area.¹⁹² Similarly, used vehicle sales are increasingly done online rather than through dealerships and resale will become less practical for AVs as they have shorter lifespans due to their increased utilization.¹⁹³ Overall, it is reasonable to expect that there will not be any car dealerships in cities that are planned for AEVs, though there may

¹⁸⁹ Marina Lao, Debbie Feinstein, and Francine Lafontaine, "Direct-to-Consumer Auto Sales: It's Not Just about Tesla," Federal Trade Commission, May 11, 2015, <http://www.ftc.gov/enforcement/competition-matters/2015/05/direct-consumer-auto-sales-its-not-just-about-tesla>.

¹⁹⁰ Aria Alamalhodaie, "EV Rivals Tesla, Rivian Unite to Target Direct Sales Legislation," *TechCrunch* (blog), accessed April 23, 2022, <https://social.techcrunch.com/2021/03/03/ev-rivals-tesla-rivian-unite-to-target-direct-sales-legislation/>.

¹⁹¹ Steven Loveday, "Ford's EV And ICE Reorganization Will Have Huge Impact On Dealers," *InsideEVs*, accessed April 23, 2022, <https://insideevs.com/news/571959/ford-dealerships-impacted-ev-ice-split/>.

¹⁹² Ark Invest, "ARK Contributes Its Financial Autonomous Taxi Model to GitHub".

¹⁹³ Sarwant Singh, "New Digital Retailing Business Models In Used Car Market Take Center Stage With Covid," *Forbes*, accessed April 23, 2022, <https://www.forbes.com/sites/sarwantsingh/2020/07/21/new-digital-retailing-business-models-in-used-car-market-take-center-stage-with-covid/>.

be smaller showrooms that would be suitable for city centers. This is really fantastic news for urban design because of how much space, especially in American cities, is dedicated to dealerships that are also somewhat of an eyesore.

Similar to car dealerships, restaurants straddle the line between goods and service. Until recently, that was the extent of the similarities between these businesses, but the recent push towards digitization of sales and subsequent delivery is also rapidly transforming the food services industry.¹⁹⁴ Most people will have noticed, if not directly partaken of, the ever-expanding options provided by food delivery services like DoorDash and Uber Eats in recent years. Many more businesses adopted online delivery platforms, among other adaptations, to survive the Covid-19 pandemic.¹⁹⁵ To facilitate this rapidly expanding demand, “shadow kitchen” or “cloud kitchen” companies have begun to emerge that function as online only restaurants with no brick and mortar, customer-facing location.¹⁹⁶ This adoption of online food orders could be seen as a logical continuation of the trend towards convenience that fast food represented as well as microwave dinners before them. There are many fair arguments to be made about potential negative impacts this could have on traditional restaurants, people’s lifestyles, or society’s already outrageous level of waste production.^{197,198} Regardless, the recent past has shown that there is substantial demand for delivery food and this trend will likely continue.

¹⁹⁴ Kabir Ahuja et al., “Ordering in: The Rapid Evolution of Food Delivery | McKinsey,” accessed April 24, 2022, <https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ordering-in-the-rapid-evolution-of-food-delivery>.

¹⁹⁵ Thaiza Serrano Pinheiro de Souza et al., “Food Services in Times of Uncertainty: Remodeling Operations, Changing Trends, and Looking into Perspectives after the COVID-19 Pandemic,” *Trends in Food Science & Technology* 120 (February 1, 2022): 301–7, <https://doi.org/10.1016/j.tifs.2022.01.005>.

¹⁹⁶ Adam Chandler, “How a Shadow Army of Ghost Kitchens Took Over America’s Restaurants,” *Marker* (blog), February 10, 2021, <https://marker.medium.com/how-a-shadow-army-of-ghost-kitchens-took-over-americas-restaurants-b7ac1a099c8c>

¹⁹⁷ Gengyuan Liu et al., “Environmental Impacts Characterization of Packaging Waste Generated by Urban Food Delivery Services. A Big-Data Analysis in Jing-Jin-Ji Region (China),” *Waste Management* 117 (November 1, 2020): 157–69, <https://doi.org/10.1016/j.wasman.2020.07.028>.

¹⁹⁸ Charlene Li et al., “Review of Online Food Delivery Platforms and Their Impacts on Sustainability,” *Sustainability* 12, no. 14 (2020): 5528, <http://dx.doi.org/10.3390/su12145528>.

A countertrend to this has been the growing appreciation for small, local businesses over large franchises and spending on high quality experiences over products.¹⁹⁹ These trends suggest a possible bifurcation in the food services industry towards the extremes of rich, sit down restaurant experiences and on-demand, convenient calories. The implications for cities and the KUP model are simply that convenience-oriented restaurants could be replaced with cloud kitchens that take up less space and are designed in conjunction with a better delivery network. Additionally, the more experience-oriented restaurants would be well suited to cluster or city centers, where they would be integrated into these pedestrian-oriented spaces with high concentrations of businesses or other resources within walking distance. Bars also fit into this category of experience-oriented food service establishments and they would similarly fit best in cluster and group centers, though flexible cafe-like coworking spaces in group centers could double as neighborhood pubs in the evening to get by with a smaller customer base.

While the sectors discussed above are relevant to future urban development, the elephant in the room that needs to be acknowledged is online shopping for clothes, electronics, most other manufactured goods, and groceries. The adoption of “e-commerce” has seen explosive growth in the past two decades and this is expected to continue, with a projected global compound annual growth rate of 11% for the next three years.²⁰⁰ While e-commerce was already growing rapidly, the Covid-19 pandemic accelerated this trend as many people who had never shopped online before began to.²⁰¹ This is true of groceries as well as other goods, with over half of the US population buying some groceries online in 2021.²⁰² As

¹⁹⁹ Blake Morgan, “NOwnership, No Problem: An Updated Look At Why Millennials Value Experiences Over Owning Things,” Forbes, accessed April 24, 2022, <https://www.forbes.com/sites/blakemorgan/2019/01/02/nownership-no-problem-an-updated-look-at-wh-y-millennials-value-experiences-over-owning-things/>.

²⁰⁰ Close-Up Media, “ResearchAndMarkets.Com Issues Report: Global E-Commerce (Online Shopping) Market: Insights & Forecast with Potential Impact of COVID-19,” accessed April 24, 2022, https://go-gale-com.offcampus.lib.washington.edu/ps/i.do?p=ITOF&u=wash_main&id=GALE%7CA627377428&v=2.1&it=r.

²⁰¹ Joan Verdon, “Global E-Commerce Sales To Hit \$4.2 Trillion As Online Surge Continues, Adobe Reports,” Forbes, accessed April 24, 2022, <https://www.forbes.com/sites/joanverdon/2021/04/27/global-ecommerce-sales-to-hit-42-trillion-as-onlin-e-surge-continues-adobe-reports/>.

²⁰² Meaghan Yuen, “Digital Grocery Will Be a \$243 Billion Market in the US by 2025: Here Are the Stats and Trends You Need to Know,” Insider Intelligence, accessed April 24, 2022, <https://www.insiderintelligence.com/insights/digital-grocery-industry/>.

the speed of delivery, affordability, and general customer experience of e-commerce continue to improve, it is likely that an ever larger proportion of goods will be bought this way. This paradigm shift has serious ramifications for brick and mortar retail, with more than ten thousand locations shutting their doors in 2020 and 2021 in the US alone.²⁰³

While the rise of online shopping will not replace stores entirely, it will certainly reduce their significance. There will likely be certain product categories that people feel more strongly about buying in person, such as produce or clothes. The same people may have no problem ordering their cereal and toothpaste online, however, especially if they arrive the same day and cost less than a store bought equivalent. There are also some common household goods that people need on short notice and won't want to wait for delivery. This sort of differentiated product availability profile could be facilitated easily by the KUP model since small "convenience" or corner stores would be very appropriate in a cluster center. Experience-oriented stores with highly curated selection of clothes and other specialized goods would make sense in the city center. These would complement or even be paired with online purchases and provide the shopping experience for those who desire it. In fact, this sort of small, high-end, experience-focused store with limited product stock is already the direction many organizations are moving for their brick and mortar locations.²⁰⁴

Eliminating big box stores like large super markets frees up a huge amount of space from the buildings as well as their associated parking lots. This also translates into massive cost savings from the initial construction as well as the stocking, cleaning, heating, and generally operating a consumer facing business. Even if the transition to online shopping doesn't go this far, a partial conversion would reduce the square footage of stores required and shift more inventory to distribution centers that don't need to be easily accessible. This obviously leads to the question of where in kernel-based cities warehouses should be located, but the answer is that they do not belong in cities of roughly 100,000 people. Instead, they belong in large

²⁰³ Mary Meisenzahl, "Nearly 3000 Stores Are Closing in 2021 as the Retail Apocalypse Drags on. Here's the Full List.," Business Insider, accessed April 24, 2022, <https://www.businessinsider.com/stores-closing-in-2021-list-2021-3>.

²⁰⁴ Jia Wertz, "Pop-Up Shops And Small-Format Stores Are Changing The Retail Landscape," Forbes, accessed April 24, 2022, <https://www.forbes.com/sites/jiawertz/2019/07/31/pop-up-shops-small-format-stores-changing-retail-landscape/>.

regional industrial centers (ICs) along with all of the other businesses that require significant space, operate best at scale, and are highly suited to automation or need few employees relative to their size.

The massive transition from store-based retail to e-commerce also requires advancements in package delivery systems, of which there have been many in recent times. From drones²⁰⁵ to robotic dogs,²⁰⁶ all of the proposed solutions for the logistics nightmare that online shopping has created have the same problem: they have to figure out how to operate with roads and laws that were not designed for them. The challenge of creating technical solutions for how to get goods from a regional distribution center to a city and then to a home in a kernel becomes almost trivial when these systems can be planned along with the road network. While I cannot claim to know what the ideal model would be, modern day package throughput could certainly benefit from a default autonomous road network and roundabouts in group centers or kernels where drop boxes could be located for package deliveries.

Localized Supply

Thus far, the adoption of online shopping has been the most notable aspect of the massive paradigm shift underway in our supply chain, but there is good reason to believe that it is just part of a broader transition. There are also major changes underway in how goods are produced, crops are grown, and what utility systems satisfy municipal needs. The importance of these sorts of advancements cannot be understated in regards to future urban forms as well as very real challenges that exist today. Most notably, the numerous supply chain disruptions that have occurred since the Covid-19 pandemic began have highlighted how brittle our international trade networks are.

The complex interdependencies of global flows of materials and products are exemplified by the situation currently faced by the silicon chip industry. Many other products

²⁰⁵ Insider Intelligence, "Why Amazon, UPS and Even Domino's Is Investing in Drone Delivery Services," Insider Intelligence, accessed April 24, 2022, <https://www.insiderintelligence.com/insights/drone-delivery-services/>.

²⁰⁶ Megan Rose Dickey, "Robot Delivery Dogs Deployed by Self-Driving Cars Are Coming," *TechCrunch* (blog), accessed April 24, 2022, <https://social.techcrunch.com/2019/01/07/robot-delivery-dogs-deployed-by-self-driving-cars-are-coming/>

are limited by a shortage in global chip output, but ASML - the single manufacturer of the most high tech chip manufacturing equipment - cannot increase output of its devices that produce chips because it needs more chips to produce them.²⁰⁷ Another catastrophic example of the global supply chain's limitations is currently playing out in the Russia-Ukraine war. Germany and other European countries have become so dependent on Russian oil and gas that they cannot afford to stop buying it, thereby financing the war they are actively denouncing.²⁰⁸ Another major supply chain disruption is manifesting in slow motion due to this conflict: a likely famine in many developing nations. There are various countries in Africa and elsewhere that are reliant on Russian and Ukrainian wheat, which is being devastated by the war. Additionally, Russia is the world's largest supplier of fertilizer and Ukraine is the primary supplier of neon gas, which is used in silicon chip manufacturing.²⁰⁹ The latter will likely exacerbate the global chip shortage while rising fertilizer costs have already caused many farmers across the world to plant fewer crops than they had previously planned, thereby worsening the expected food shortage.²¹⁰

Many governments have begun to take action to reshore certain critical supply chains, in order to increase resiliency and avoid the sort of economic impacts that we are currently facing. For instance, various nations have created programs to localize silicon chip production, with tens of billions of dollars in incentives now financing multiple chip fabs in the United States, Europe, and Japan.²¹¹ Similar efforts are being made with regards to rare earth metals

²⁰⁷ Paul van Gerven, "ASML Scrambles to Remedy a Chip Shortage That Nobody Saw Coming – Bits&Chips," accessed April 26, 2022, <https://bits-chips.nl/artikel/asml-scrambles-to-remedy-a-chip-shortage-that-nobody-saw-coming/>.

²⁰⁸ Samantha Gross, "Russia's War Is Driving a New Global Energy Crisis. Why This Time Is Different.," accessed April 26, 2022, <https://www.barrons.com/articles/energy-russia-europe-oil-gas-1ng-51649449573>.

²⁰⁹ London Business School, "Global Supply Chains Face Disruption Following Russia's Invasion Of Ukraine," *Forbes*, accessed April 26, 2022, <https://www.forbes.com/sites/lbsbusinessstrategyreview/2022/03/24/global-supply-chains-face-disruption-following-russias-invasion-of-ukraine/>.

²¹⁰ Tom Polansek and Ana Mano, "As Sanctions Bite Russia, Fertilizer Shortage Imperils World Food Supply," *Reuters*, March 23, 2022, sec. Business, <https://www.reuters.com/business/sanctions-bite-russia-fertilizer-shortage-imperils-world-food-supply-2022-03-23/>.

²¹¹ Economist Intelligence, "Chip Makers Increase Investment for 2022 amid Shortage," Economist Intelligence Unit, February 24, 2022, <https://www.eiu.com/n/chip-makers-increase-investment-for-2022-amid-shortage/>.

that are used in electric motors as well as lithium, nickel, and other elements that are needed for batteries.²¹² Additionally, financial pressures for reshoring have been pushing companies to act independent of government programs, as the cost of global logistics have exploded in recent times. For example, the cost to send a shipping container from China to the United States was roughly seven times higher in March 2022 than it was in March 2020, at the start of the pandemic.²¹³

Even prior to the pandemic-induced supply chain challenges, many people were making the argument that our globalized economic model has too many problems and shifting back towards more regional production is the direction to be moving. One common reason for this is the environmental impact since localizing production should eliminate a great deal of transport and much of the packaging involved in global trade. Locating production closer to consumption should also, theoretically, make it easier to establish the closed loop recycling processes needed for a circular economy.²¹⁴ Additionally, the creation of new local jobs is a major reason that certain governments are pushing to reshore manufacturing.²¹⁵ There is also an ethical case to be made since concentrating production in locations with cheap labor, which also bear the burden of industrial externalities, is arguably exploitative.²¹⁶ While there are many good reasons to consider a shift back towards more local and regional production, whether or not it makes sense really comes down to the underlying technology underpinning different

²¹² June Teufel Dreyer, "Rare Earths, Scarce Metals, and the Struggle for Supply Chain Security - Foreign Policy Research Institute," accessed April 26, 2022, <https://www.fpri.org/article/2022/03/rare-earths-scarce-metals-and-the-struggle-for-supply-chain-security/>.

²¹³ Ben Winck, "Sky-High Shipping Costs Could Keep Prices Surging until Mid-2023," Business Insider, accessed April 26, 2022, <https://www.businessinsider.com/shipping-costs-inflation-outlook-container-prices-high-supply-chain-crisis-2022-3>.

²¹⁴ Tanya Tsui et al., "The Role of Urban Manufacturing for a Circular Economy in Cities," *Sustainability* 13, no. 1 (2021): 23, <http://dx.doi.org/10.3390/su13010023>.

²¹⁵ Andrew Fish and Honora Spillane, "Reshoring Advanced Manufacturing Supply Chains to Generate Good Jobs," *Brookings* (blog), July 16, 2020, <https://www.brookings.edu/research/reshoring-advanced-manufacturing-supply-chains-to-generate-good-jobs/>.

²¹⁶ Bernd Sommer, "Externalisation, Globalised Value Chains, and the Invisible Consequences of Social Actions," *Historical Social Research / Historische Sozialforschung* 42, no. 4 (162) (2017): 114–32.

manufacturing processes. Luckily, There is a revolution underway in automation, digital fabrication methods, biomanufacturing, and materials science that could help to enable production to shift closer to consumption.

Numerous new tools have recently become available for creating 3D designs as well as turning these files directly into physical forms. Notably, this includes various types of additive manufacturing, or 3D printing. There have been many advancements in recent years, allowing for more consistent results, fewer limitations, greater selections of materials, and much higher speeds. The primary benefit of this technology is that they are generalized production platforms, which use bulk feedstock to produce nearly any shape out of a given material. This is in stark contrast to the dominant manufacturing paradigm today, in which highly custom and extremely expensive tools produce many thousands or millions of units that are then distributed across the world. Many experts argue that we are entering into a new phase, in which additive manufacturing is going to be implemented along with various other automation technologies - subtractive manufacturing systems and new robots that are affordable as well as easy to program - to enable high throughput production of end use parts, rather than its traditional role in prototyping. As a group from MIT puts it, recent progress in additive manufacturing "enables manufacturers to envision futures in which their products are fulfilled on-demand, customized to individual user or regional preferences, and fulfilled via an interconnected network of production facilities distributed around the world."²¹⁷

This is not, however, the extent of the manufacturing revolution that is likely to unfold in the coming decades. In addition to additive manufacturing plastic, metal, and ceramic goods, various groups are working on 3D printed and 3D knitting clothes.²¹⁸ Aside from other materials and processes suited to regional fabrication facilities, there are some groups, such as Arrival²¹⁹

²¹⁷ Haden Quinlan and John Hart, "Additive Manufacturing: Implications for Technological Change, Workforce Development, and the Product Lifecycle," MIT Work of the Future, November 24, 2020, <https://workofthefuture.mit.edu/research-post/additive-manufacturing-implications-for-technology-change-workforce-development-and-the-product-lifecycle/>.

²¹⁸ L Mikahila, "3D Knitwear: How 3D Printing Is Revolutionizing the Fashion Industry," 3Dnatives, July 22, 2021, <https://www.3dnatives.com/en/3d-printing-knitwear-220720215/>.

²¹⁹ Condé Nast, "To Make a New Kind of Electric Vehicle, First Reinvent the Factory," *Wired UK*, accessed May 3, 2022, <https://www.wired.co.uk/article/arrival-electric-vehicles-microfactory>.

and LM Industries,²²⁰ that are building very small “microfactories”, which produce just a few vehicles per day. Regardless of whether manufacturing technology will be ready for that degree of localization in the near future, a city of 100,000 would not provide sufficient demand for a dedicated car factory. This suggests that, in the case of the KUP model, it probably makes more sense to have slightly larger factories in industrial centers. Additionally, many (if not most) things will still be difficult to produce without large dedicated facilities with specialized equipment for the foreseeable future. For instance, batteries, computer chips, and many other complex technology components will need to be produced at extreme scale to be made affordably and at high quality.

There are other product categories, however, where local production will be possible and drive further compression of supply chains. For instance, at-home on-demand production of any beverage is nearing feasibility thanks to advancements like Cana, a recently launched molecular beverage printer. The group behind this system recognized that it doesn’t make sense to package and transport drinks as we do currently when more than 90 percent of the mass is water, most of the rest is sugar or alcohol, and human perception of flavor is based on the ratios of just a few dozen flavor compounds. Leveraging recent advancements in microfluidics, this device is able to add precise amounts of alcohol, sugar, caffeine, and flavor compounds to water. In future versions it will also carbonate, heat or cool, and add micronutrients so that any drink can be recreated on demand using locally sourced water and standardized cartridges that are much easier to transport.²²¹

While a shift towards local and regional production is reasonable to expect on a short timescale relative to the life of a city, it won’t happen overnight. For at least a few decades, it is prudent to plan for products to be made far away and stored in IC distribution facilities, from which they could be quickly delivered to nearby kernels. Even after more production processes are localized to these industrial centers, the associated facilities for manufacturing and other

²²⁰ Michael Molitch-Hou, “Local Motors Forms LM Industries, ‘the First Digital OEM,’” Engineering.com, accessed May 3, 2022, <https://www.engineering.com/story/local-motors-forms-lm-industries-the-first-digital-oem>.

²²¹ David Friedberg, “Introducing Cana: A Molecular Beverage Printer in Every Home Helps Us Take a Giant Step towards Decentralized Manufacturing,” accessed May 2, 2022, <https://medium.com/@davefriedberg/cana-molecular-beverage-printers-e18cdf7c1871>.

industrial processes will still take up a significant amount of space. At an optimal scale, the output of such functions would be more than a city can fully utilize. Due to these factors as well as the noise, smells, and other byproducts that they produce, it is best to concentrate these functions outside of residential areas. Additionally, abstracting manufacturing and logistics processes out of cities would allow the transition from the current manufacturing paradigm to its likely successor to occur without any impact on the nearby cities.

Growing Land Availability

To reiterate, the elimination or abstraction of big box stores, distribution centers, manufacturing facilities, industrial processes, car dealerships, parking, and various other land-hungry urban functions from cities should shrink their footprint significantly, all else being equal. Regardless, I have described a regional network of cities and ICs that would take up a large amount of space so a reasonable question would be where these could possibly be built. What land could be used is a critical consideration if this urban model is to be useful in providing homes and infrastructure for the 5 billion people that will need them over the coming decades.

Before attempting to address this, it is worth stepping back and reviewing some statistics. Roughly 71% of Earth's surface is covered by ocean while 19% of the land is deserts, 10% is covered by glaciers, and 26% are (what remains of the planet's) forests. Humans are now using approximately 35% of the total land (10% of Earth's surface) for agriculture while only 1% of the land (0.3% of Earth's surface) is urban.²²² Using less stringent criteria for what land qualifies as urban, some estimates place urban land at closer to 3% of Earth's land, but that would still only account for about 10% of the area we humans are actively making use of.²²³

Many people are of the opinion that green field developments should be avoided at all costs to contain our sprawl and avoid any further depletion of forests. While this position is admirable in intent, it fails to acknowledge the reality of the situation in terms of the

²²² Hannah Ritchie and Max Roser, "Land Use," *Our World in Data*, November 13, 2013, <https://ourworldindata.org/land-use>.

²²³ Zhifeng Liu et al., "How Much of the World's Land Has Been Urbanized, Really? A Hierarchical Framework for Avoiding Confusion," *Landscape Ecology* 29, no. 5 (May 1, 2014): 763–71, <https://doi.org/10.1007/s10980-014-0034-y>.

environmental impact that cities already have. As the statistics above make clear, urban residents effectively occupy a great deal of land beyond their city's edge since they rely on all of the space required to produce their food, which is 10 times more than the cities themselves. If urban populations keep growing and cities continue to rely on external agricultural land in the same way, then that land used to grow crops will need to grow as well. In other words, squeezing everyone into cities does not save the forests. What we really need to be concerned with is the total land usage by humanity overall as well as the specific impacts of the way it is being used.

Our current agricultural paradigm, consisting primarily of massive industrial monocropped farms, has many negative environmental effects: soil depletion,²²⁴ fertilizer runoff,²²⁵ harm to pollinators,²²⁶ and excessive water use.²²⁷ On top of these harmful impacts, crops produced this way are less flavorful and nutritious than those produced using more traditional approaches to agriculture. The justification for these unsustainable modern techniques was that it is required to maximize output in order to feed the growing global population. The truth, however, is that the vast majority of all agricultural land is used to grow crops for livestock and many crops are used as feedstock for various chemical processes.^{228,229} Due to the extreme caloric and spatial inefficiency of animal agriculture, a greater than 70%

²²⁴ David Pimentel, "Soil Erosion: A Food and Environmental Threat," *Environment, Development and Sustainability* 8, no. 1 (February 2006): 119–37, <https://doi.org/10.1007/s10668-005-1262-8>.

²²⁵ Beatriz Altamira-Algarra et al., "A Review of Technologies for Closing the P Loop in Agriculture Runoff: Contributing to the Transition towards a Circular Economy," *Ecological Engineering* 177 (April 1, 2022): 106571, <https://doi.org/10.1016/j.ecoleng.2022.106571>.

²²⁶ Maggie Shanahan, "Honey Bees and Industrial Agriculture: What Researchers Are Missing, and Why It's a Problem," *Journal of Insect Science* 22, no. 1 (January 1, 2022): 14, <https://doi.org/10.1093/jisesa/ieab090>.

²²⁷ Food and Agriculture Organization of the United Nations, "Water for Sustainable Food and Agriculture: A Report Produced for the G20 Presidency of Germany," 2017, <https://www.fao.org/3/i7959e/i7959e.pdf>.

²²⁸ USDA Economic Research Service, "Feedgrains Sector at a Glance," accessed May 2, 2022, <https://www.ers.usda.gov/topics/crops/corn-and-other-feedgrains/feedgrains-sector-at-a-glance/>.

²²⁹ Hannah Ritchie and Max Roser, "Land Use".

reduction in land use per person could be achieved if everyone simply became vegan.^{230,231} Unfortunately, that is not a realistic solution due to the high value that many people put on meat in their diets, but it is indicative of how much animal products contribute to land usage.

Building new cities on agricultural land should be acceptable if, regardless of the mechanism, the average crop land required per person could be maintained or reduced. In other words, if the land used to grow crops for a certain number of people could be partially redeveloped into a city and still produce enough crops overall for those people, that would invalidate the primary concern with this type of green field development. Thanks to a suite of new technologies, this could be entirely feasible in the near future (without having to convince people to give up meat). For instance, cellular agriculture is the process of having cells - either yeast, bacteria, or cells from a specific mammalian tissue - grow into a desired product. Meat, dairy, and leather are just some of the products that are already being grown in bioreactors (essentially brewery equipment) without having to raise animals.²³² Recent breakthroughs have also shown that synthetic enzymes, which are only recently able to be produced at scale, can be used to sequester significant amounts of atmospheric carbon in the form of starch.²³³ These carbon negative carbohydrates could then be used as a feedstock for cellular agriculture and the related field of biomanufacturing, which uses microbes to produce chemicals like medicine, flavor compounds, plastics, and biofuel.²³⁴ These may sound like technologies that are still decades away from being practical, but recent advancements in synthetic biology have accelerated development timelines by at least an order of magnitude. As a result, there are

²³⁰ World Bank, "Share of Calories from Animal Protein vs. GDP per Capita," Our World in Data, accessed May 1, 2022, <https://ourworldindata.org/grapher/share-of-calories-from-animal-protein-vs-gdp-per-capita>.

²³¹ Hannah Ritchie and Max Roser, "Land Use".

²³² Heiko Rischer, Géza R Szilvay, and Kirsí-Marja Oksman-Caldentey, "Cellular Agriculture — Industrial Biotechnology for Food and Materials," *Current Opinion in Biotechnology*, Plant Biotechnology - Food Biotechnology, 61 (February 1, 2020): 128–34, <https://doi.org/10.1016/j.copbio.2019.12.003>.

²³³ Tao Cai et al., "Cell-Free Chemoenzymatic Starch Synthesis from Carbon Dioxide," *Science* 373, no. 6562 (September 24, 2021): 1523–27, <https://doi.org/10.1126/science.abh4049>.

²³⁴ James M. Clomburg, Anna M. Crumbley, and Ramon Gonzalez, "Industrial Biomanufacturing: The Future of Chemical Production," *Science* 355, no. 6320 (January 6, 2017): aag0804, <https://doi.org/10.1126/science.aag0804>.

many dozens of companies in these fields that are working to bring products to market in the near future.

While the costs still need to come down and challenges like growing structured tissue (i.e. steak rather than ground beef) are far from solved, significant progress is being made and there is every reason to believe that these methods will eventually be more affordable, sustainable, and require less land than traditional approaches. There is also, of course, the concern about consumer adoption. Many people decry new approaches to food production like those described above as “unnatural”, but agriculture is, by definition, unnatural. It is entirely arbitrary to consider our current model of industrialized crop production, factory farms, and food processing “less unnatural”. Regardless, most people have no idea about these systems that produce their foods so it is reasonable to expect that the vast majority will quickly get over any concerns if it tastes better and is more affordable - especially if these foods are genuinely healthier and more sustainable.

Another set of technologies that should enable a net reduction of agricultural land are those used for growing crops indoors. Using a combination of green houses, hydroponics, and robotics have enabled the Netherlands to become the second largest food exporter in the world, despite its small size.²³⁵ Many groups are working on the next iteration of indoor high yield farming, which is known as vertical farming or controlled environment agriculture since crops are grown in stacked layers within large airtight facilities. These “plant factories” often use hydroponics or aeroponics along with LEDs that provide only certain wavelengths and a significant amount of automation.²³⁶ In these airtight facilities, every factor - water, micronutrients, wind, light wavelengths, CO₂ concentration, and temperature - can be monitored and optimized for a given plant species.²³⁷ In addition to producing crops

²³⁵ Kate Whiting, “This Dutch Tomato Farm Can Teach the World about Sustainable Agriculture,” World Economic Forum, accessed May 2, 2022, <https://www.weforum.org/agenda/2019/11/netherlands-dutch-farming-agriculture-sustainable/>.

²³⁶ Till Weidner, Aidong Yang, and Michael W. Hamm, “Energy Optimisation of Plant Factories and Greenhouses for Different Climatic Conditions,” *Energy Conversion and Management* 243 (September 1, 2021): 114336, <https://doi.org/10.1016/j.enconman.2021.114336>.

²³⁷ Ramin Shamshiri et al., “Advances in Greenhouse Automation and Controlled Environment Agriculture: A Transition to Plant Factories and Urban Agriculture,” *International Journal of Agricultural and Biological Engineering* 11, no. 1 (January 31, 2018): 1–22, <https://doi.org/10.25165/ijabe.v11i1.3210>.

consistently year round, using 99% less land, and 95% less water, these crops are more nutritious, extra flavorful, and grown without pesticides or herbicides.²³⁸ The main limitations for now are cost and the range of crops that are suitable for vertical farming. Aerofarms, arguably the world leader in vertical farming, claims that they are approaching competitive pricing relative to traditionally grown greens and are now branching out to certain fruit, such as berries and tomatoes.²³⁹ As the cost of LEDs continues to decrease, their energy efficiency further improves, more of the processes involved are automated, and the ideal growing conditions are identified for different plants, this approach to growing crops should become cost competitive for many crops on top of the other benefits. Besides energy and equipment, the main driver of cost is the expense of urban land for these farms, but building them as part of green field industrial centers on affordable agricultural land would reduce this barrier as well.

A final category of agricultural technology that is relevant here are those that enable the automation of tasks involved in outdoor agriculture. From crop picking robots to weed spraying drones and satellite-based remote monitoring to small autonomous tractors, recent innovations are expected to reduce the need for human involvement.²⁴⁰ Additionally, many of these new systems are designed to operate in larger numbers, with each doing smaller portions of the overall task compared with traditional approaches.²⁴¹ It is conceivable that smaller scale farms could be managed roughly as efficiently by lesser numbers of these swarm-enabled, autonomous systems. Additionally, the shift toward more fine-grained, autonomous management systems should make polycultural farming more feasible. This is because despite being more productive (i.e. requiring less land) and sustainable, the varied maintenance and harvesting requirements for different crops has made polyculture impractical at scale until

²³⁸ Aerofarms, "Vertical Farming Technology - AeroFarms Vertical Farming for Elevated Flavor," AeroFarms, accessed May 2, 2022, <https://www.aerofarms.com/how-we-grow/>.

²³⁹ Jess Klein, "AeroFarms Is Trying to Cultivate the Future of Vertical Farming | Greenbiz," accessed May 2, 2022, <https://www.greenbiz.com/article/aerofarms-trying-cultivate-future-vertical-farming>.

²⁴⁰ Bateman, "3 Ways Autonomous Farming Is Driving a New Era of Agriculture," World Economic Forum, accessed May 3, 2022, <https://www.weforum.org/agenda/2022/01/autonomous-farming-tractors-agriculture/>.

²⁴¹ Tim Hammerich, "Rethinking the Tractor," Medium, December 17, 2018, <https://futureofag.com/rethinking-the-tractor-5a092dc4aeb1>.

now.²⁴² It is worth noting that, even before the adoption of these new systems, recent advancements in agricultural systems have created a greater need for workers with technical backgrounds who often don't want to live in the remote places where agriculture is currently done.²⁴³

Assuming that these technologies are indeed approaching commercial viability (and people will be willing to eat what they produce), there are major implications for the KUP model. Vertical farms and biofabrication facilities could be included in city centers, out on the urban periphery, or in industrial centers, depending on the scale that will make them most financially viable and how much human involvement they require. Small polycultural farms, enabled by autonomous tractors and drones, could be dispersed throughout cities, in the spaces between clusters (as in the case of Chinese Lilong) or out on the city's edge. These would serve as buffers between communities as well as between the city and the surrounding natural landscape (Figure 41). Including them would also increase the overall green space and pervious surfaces. Another advantage is that having all of these food production systems in cities or nearby ICs would solve the issue of technically capable workers that these systems require preferring to live in urban areas. Fully leveraging these advancements should reduce the average land usage per person to such a degree that (very affordable) agricultural land could be repurposed as callorcially self-sufficient kernel-based cities while also leaving a significant amount of land to be reforested. Natural landscapes that were destroyed to make way for agriculture could be nurtured back, thereby increasing ecosystem diversity and sequestering carbon - perhaps enough to make city construction carbon negative.

²⁴² Brenda B. Lin, "Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change," *BioScience* 61, no. 3 (March 1, 2011): 183–93, <https://doi.org/10.1525/bio.2011.61.3.4>.

²⁴³ Brian Ireland, "Farmers Face Nationwide Shortage of Trained Technicians," *Farm Progress*, April 28, 2022, <https://www.farmprogress.com/technology/farmers-face-nationwide-shortage-trained-technicians>.

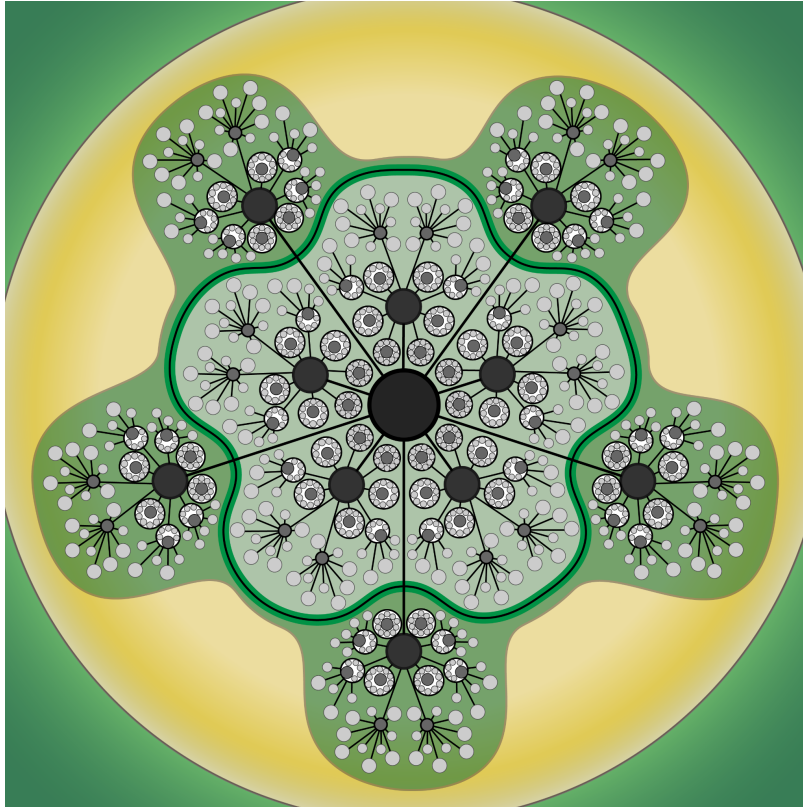


Figure 41. Kernel-based city with significant internal green space (includes some crops), a buffer zone of crop land (yellow), and natural landscape beyond that.

Independent Infrastructure

The final category of urban services and production systems that I want to briefly touch on are utilities. Cities provide energy, water, waste management, and now also connectivity. These functions are critical to the operation of any modern urban environment, but the systems that facilitate them are all facing disruption. More small scale, distributed options are emerging, in addition to new versions of larger centralized utility systems. As evidenced by how modern homes provide functions that were once enabled by wells and other community scale resources, greater localization of functions increases resiliency and convenience. These smaller distributed systems do, however, often come at higher costs or with other limitations. Another important consideration is that, if more functions are housed internally in a building or community, the broader utility ecosystem ought to reflect this since it no longer needs to provide those functions. Reimagining homes and other urban buildings in concert with municipal services enables new possibilities that are far more difficult to achieve in existing

urban environments due to the ubiquitous availability of legacy systems (and in many cases a legal requirement to connect to those systems).

Energy is the sector set to be most disrupted out of these and it should be uncontroversial at this point to claim that any new city must be planned to be carbon neutral. Beyond just electricity, energy includes the oil and gas that have been used for heating buildings as well as water. Luckily, there are energy efficient options like heat pumps that are actively being deployed to take on these roles, but electrifying them, vehicles, and most other functions will require a tripling of total electricity demand.²⁴⁴ Solar and wind have become exceedingly affordable and their cost declines are expected to continue, which should help to satisfy this electricity demand.²⁴⁵ In kernel-based cities, solar makes sense on roofs, over top of the car ports along radial lines, on steeper terrain between community units or around the urban periphery, and possibly on poles above shade tolerant crops (known as agrivoltaics, this actually increases yield and reduces water demands).²⁴⁶ Large wind turbines would make more sense on the edges of cities and around ICs, but microwind turbines might make sense in cities once their costs decline or efficiency increases.²⁴⁷

Regardless, certain locations don't work well for one or the other of these renewables, solar takes up a relatively large amount of space, and (most importantly) their outputs are limited by intermittency.²⁴⁸ This can be remedied to a large degree by pairing them with stationary storage, which will likely make sense as a standard appliance in any building going forward in addition to grid scale storage facilities that are paired with renewables (those around

²⁴⁴ International Energy Agency, "Net Zero by 2050 – Analysis," IEA, accessed May 4, 2022, <https://www.iea.org/reports/net-zero-by-2050>.

²⁴⁵ Mengzhu Xiao et al., "Plummeting Costs of Renewables - Are Energy Scenarios Lagging?," *Energy Strategy Reviews* 35 (May 1, 2021): 100636, <https://doi.org/10.1016/j.esr.2021.100636>.

²⁴⁶ Harshavardhan Dinesh and Joshua M. Pearce, "The Potential of Agrivoltaic Systems," *Renewable and Sustainable Energy Reviews* 54 (February 1, 2016): 299–308, <https://doi.org/10.1016/j.rser.2015.10.024>.

²⁴⁷ Nikolaos Chrysoschoidis-Antsos et al., "Wind Resource Characteristics and Energy Yield for Micro Wind Turbines Integrated on Noise Barriers – An Experimental Study," *Journal of Wind Engineering and Industrial Aerodynamics* 203 (August 1, 2020): 104206, <https://doi.org/10.1016/j.jweia.2020.104206>.

²⁴⁸ Jamshid Aghaei and Mohammad-Iman Alizadeh, "Demand Response in Smart Electricity Grids Equipped with Renewable Energy Sources: A Review," *Renewable and Sustainable Energy Reviews* 18 (February 1, 2013): 64–72, <https://doi.org/10.1016/j.rser.2012.09.019>.

the city rather than on buildings).²⁴⁹ Some baseload electricity production will certainly be necessary, however. In the locations where hydro and geothermal do not make sense (most places), the best option is next generation nuclear, many of which are well into development and have numerous benefits: they are much safer, produce less waste, and could potentially be cheaper.²⁵⁰ Despite being smaller, on average, and safer than traditional light water reactors, these would be best suited to ICs, where a great deal of energy would be required anyways. Overall, the distributed energy resources that future cities must rely on come in differentiated forms that are appropriate for various scales and, therefore, are well suited to a nested polycentric form.

Connectivity is an urban utility that has become ever more central to cities and their residents, but the old infrastructure - phone lines, cable lines, 3G antennae - is rapidly becoming outdated. Though there are high speed, high bandwidth satellite internet services coming online, fiber will always be cheaper and faster for local or regional connectivity.²⁵¹ Compared to gridded street networks, the nested radialconcentric roads of the KUP model are ideal for laying both fiber optic cable and power lines since they are structured similarly: with lower capacity lines feeding into high capacity lines, which feed into yet higher capacity lines, and so on. Antennae for 5G or later versions of wireless infrastructure located in each community scale center would naturally provide good distribution of coverage, though there could be multiple dispersed throughout less dense community units. As with all land and power hungry functions, data centers would make the most sense in ICs where they could provide low latency access to vast amounts of data and compute for nearby residents.

²⁴⁹ Peter Asmus, "Microgrids, Virtual Power Plants and Our Distributed Energy Future," *The Electricity Journal* 23, no. 10 (December 1, 2010): 72–82, <https://doi.org/10.1016/j.tej.2010.11.001>.

²⁵⁰ Leigh Phillips, "The New, Safer Nuclear Reactors That Might Help Stop Climate Change," MIT Technology Review, accessed May 4, 2022, <https://www.technologyreview.com/2019/02/27/136920/the-new-safer-nuclear-reactors-that-might-help-stop-climate-change/>.

²⁵¹ CP Ventures, "Elon Musk's Starlink vs. Its Competitors: A Race for Broader Internet," *The Startup* (blog), February 11, 2021, <https://medium.com/swlh/elon-musks-starlink-vs-its-competitors-a-race-for-broader-internet-818b034ef14c>.

Alternatively, decentralized data storage,²⁵² search,²⁵³ and computation²⁵⁴ networks are emerging thanks to incentivization and verification of node's actions via blockchain technology. If this movement continues to develop and replaces or co-exists at scale with large data centers, the centers of clusters or groups could be ideal locations for community owned network infrastructure modules.

Lastly, there are some potential changes on the horizon for municipal water and waste, though these are far less certain or dramatic than those described above. The drastic reductions in water consumption that cellular agriculture and vertical farming make possible would have the largest impact on overall water demand, as agriculture is responsible for 70% of total water usage. Regardless of municipal water being only 11% of the total, demand varies greatly by region, as does the availability of natural sources.²⁵⁵ As a result, there is no one-size-fits-all solution for sourcing water, but affordable and efficient atmospheric water generators (which condense water straight out of the air) are now available that can supplement other sources.²⁵⁶ Commercial applications of recent nanomaterials breakthroughs in water filtrations offer the possibility that community units or even individual homes in the future could recycle most of the water they use.²⁵⁷ This could be furthered by the adoption of new toilets that process waste internally and produce potable water rather than expelling

²⁵² Jeremiah Wagstaff, "Subspace: A Solution to the Farmer's Dilemma," n.d., 11.

²⁵³ Branimir Rakic et al., "First Purpose Built Protocol for Supply Chains Based on Blockchain," n.d., 27.

²⁵⁴ Hang Yin, Shunfan Zhou, and Jun Jiang, "Phala Network: A Secure Decentralized Cloud Computing Network Based on Polkadot," n.d., 15.

²⁵⁵ Food and Agriculture Organization of the United Nations, "AQUASTAT - FAO's Global Information System on Water and Agriculture," accessed May 4, 2022, <https://www.fao.org/aquastat/en/overview/methodology/water-use>.

²⁵⁶ Frank Brigano and Eugene Kapustin, "Applications & Evolution of Atmospheric Water Generation Technologies," Water Quality Products, March 5, 2021, <https://www.wqpmag.com/one-water/applications-evolution-atmospheric-water-generation-technologies>

²⁵⁷ Nora Savage and Mamadou S. Diallo, "Nanomaterials and Water Purification: Opportunities and Challenges," *Journal of Nanoparticle Research* 7, no. 4 (October 1, 2005): 331–42, <https://doi.org/10.1007/s11051-005-7523-5>.

everything into a sewage system.²⁵⁸ In combination with atmospheric water generators, it is conceivable that groups or even kernels could be designed to be self-sufficient in terms of water, though it would probably make sense for them to still be connected to city water lines. It is also worth noting that water pipes (as well as sewage lines if they are included) tend to follow a similar hierarchical structure as roads, powerlines, and fiber. Since they would all be built at once along the same routes, this presents the opportunity to create prefabricated modules that could be assembled onsite, which would minimize construction costs. There are also advancements underway in solid waste management and recycling, such as FastOx gasification,²⁵⁹ which are mostly large format industrial processes that are suited to ICs.

This chapter, as well as the previous one, may have seemed like an overwhelming torrent of speculative applications of not-fully-proven technologies. We cannot know what the future will bring with any certainty, but planning for many decades to come requires that we make educated guesses about major trends and their likely impacts. Half or more of the advancements described above could turn out to be impractical for one reason or another, but the overall trend towards digitization, automation, decentralization, and localization would remain - as would the suitability of the KUP model for facilitating them. Similarly, the timeline on which they reach maturity may be a decade or it may take several, but they are still worth considering. When planning urban environments that will most likely remain for centuries, it is critical - especially as the rate of technological advancement continues to accelerate - to consider these factors as well as the projections of population size and other existing conditions that urban planners typically look at.

²⁵⁸ Doulaye Kone, "The Future of Sanitation: 10 Years of Reinventing the Toilet," Bill & Melinda Gates Foundation, accessed May 4, 2022, <https://www.gatesfoundation.org/ideas/articles/sanitation-reinvent-toilet>.

²⁵⁹ Power Technology, "Sierra Energy Raises Funding to Develop FastOx Gasification Technology," *Power Technology* (blog), July 29, 2019, <https://www.power-technology.com/news/sierra-energy-fastox-gasification/>.

CHAPTER 6: SOCIETAL OS

While it is important to consider the possible impacts of technology, humans should always remain at the center of the design equation. In the previous chapters, I spent a great deal of time discussing the types of resources that people may share within the context of a kernel and the larger community units they make up. The KUP model is, in fact, specifically designed to facilitate more common spaces and community-owned resources, but is this a reasonable thing to optimize for? In other words, do people want to share resources with their communities? Also, why might it make more sense to plan urban environments around sharing going forward when the trend has been in the opposite direction for a long time? These are some of the questions that I attempt to address in this chapter. First, I review some examples of such sharing practices in the world today before highlighting the recent growth and potential of sharing economy platforms. Next, I discuss the difference between shared resources, public resources, and rented resources, as well as why ownership and governance are inalienable parts of city planning. Finally, I discuss how the KUP model enables the customization of ownership and governance models for specific community preferences.

The Sharing Economy

The ability to collaborate and coordinate the sharing of resources as well as responsibilities is the primary factor that has enabled humans to do all that we have. The small, local communities that most people lived in throughout history tended to be highly engaged, mutually supportive groups that shared a great deal. In the recent past, however, various factors disrupted this norm. For instance, many systems that communities used to share have been incorporated into homes over time, which made access more convenient and eliminated the need to share. Additionally, wage labor and markets have become the primary means by which people's needs are met, in place of local production by essentially self-sufficient villages. As Yuval Noah Harari frames it, "most of the traditional functions of families and communities were handed over to states and markets" in the two centuries following the industrial revolution.²⁶⁰ The reduced need to share was reinforced by social influences that led to increased individualism as well as urbanization, which in turn yielded development patterns less

²⁶⁰ Yuval N. Harari, *Sapiens: A Brief History of Humankind*. 356

conducive to community engagement.²⁶¹ It is worth noting that this significant reduction in community sharing has occurred despite people owning far more possessions that also serve more specialized functions (i.e. there are more things suited to sharing now). "As our private world grows in breadth, our public world has become more remote and impersonal. As a result, our public space lacks identity and is largely anonymous, while our private space strains towards narcissistic autonomy."²⁶²

A large portion of humanity still lives in small communities that share a good amount, but these are becoming fewer and more dependent on external forces as time goes on. Additionally, there are various social movements that have been created as direct countertrends to the atomization of communities and the replacement of sharing with the cold hand of the market. For instance, cohousing is a movement that has gained momentum in recent years, which is simply defined by the inclusion of more common spaces and intentional, regular engagement among residents - typically in multifamily buildings. Each household still has its own private space with all of the standard amenities of a home, but they also share common spaces and regular activities with their co-residents. These small communities, which are usually made up of 20-40 households, vary in terms of building form, shared spaces, and community dynamics overall. While the level of engagement differs significantly between cohousing communities, examples of things they share include tools, gardens, responsibilities for common areas, and sometimes even vehicles.²⁶³ These communities are very similar to kernels except that they are slightly smaller on average and are independent enclaves that are constrained by existing urban environments, rather than cells of larger socio-spatial tissues.

German Baugrupen also fall under the umbrella of cohousing, but these apartment buildings with common spaces are collectively planned and funded by their future residents.²⁶⁴

²⁶¹ Ray Oldenburg, *The Great Good Place: Cafés, Coffee Shops, Bookstores, Bars, Hair Salons, and Other Hangouts at the Heart of a Community*.

²⁶² Peter Calthrope, "The Pedestrian Pocket," 1989.

²⁶³ Cohousing.org, "Cohousing," *Cohousing* (blog), accessed May 10, 2022, <https://www.cohousing.org/what-cohousing/cohousing/>.

²⁶⁴ Jessica Bridger, "Don't Call It A Commune: Inside Berlin's Radical Cohousing Project," *Metropolis* (blog), accessed May 10, 2022, <https://metropolismag.com/projects/dont-call-it-a-commune-inside-berlin-radical-cohousing-project/>.

Similarly, the groups mentioned in chapter 2 that are knocking down fences and combing backyards to form “pocket neighborhoods” are part of the countertrend towards community-scale urban sharing.²⁶⁵ A more extreme example is Kibbutzim, which are Israeli communities of 100 to 1,000 members that are highly engaged and organized around systems of production.²⁶⁶ Initially, these were highly utopian initiatives, in which no possessions were held individually, all decisions were made collectively, and family boundaries were deemphasized to place community as the central focus. Over time, most Kibbutzim became less collectivistic, with private ownership and nuclear family boundaries returning, but they remain highly engaged communities with strong internal bonds and a large amount of sharing.²⁶⁷ Outside of these movements, there is broad agreement among urban planners and designers that built environments should include more common spaces and shared resources.

While these initiatives exist, they have not gained significant momentum since sharing community resources presents many challenges as well as benefits. On the one hand, communities can share resources that individual households would otherwise have to purchase and store on their own, thereby improving efficiency in terms of cost as well as space. For instance, kernel-scale communities could share things like AVs, power tools, lawn mowers, and gardens, among many others. Additionally, aggregating demand can enable communities to afford and fully utilize resources or spaces that they would otherwise have to rely on larger entities to provide. Examples include outdoor common spaces and play equipment instead of parks provided by a city, a well-equipped small gym instead of a commercial gym (or home equipment), and group or cluster-scale utilities in place of municipal systems. Finally, sharing spaces and resources catalyzes chance encounters, encourages community engagement, and strengthens interpersonal bonds as well as trust overall.²⁶⁸

²⁶⁵ Paul Downton, “Pocket Neighbourhoods”.60–62.

²⁶⁶ Jewish Agency, “What Exactly Is a Kibbutz,” accessed May 10, 2022, <https://www.jewishagency.org/what-exactly-is-a-kibbutz/>.

²⁶⁷ New World Encyclopedia, “Kibbutz - New World Encyclopedia,” accessed May 10, 2022, <https://www.newworldencyclopedia.org/entry/kibbutz>.

²⁶⁸ Ray Oldenburg, *The Great Good Place: Cafés, Coffee Shops, Bookstores, Bars, Hair Salons, and Other Hangouts at the Heart of a Community*.

On the other hand, sharing resources requires both coordination and trust, both of which become more problematic with increasing group size. Coordinating is a challenge because the optimal utilization of resources (making sure things are available when they are needed) requires that all parties plan and communicate their intentions then coordinate in the case of scheduling conflicts. The complexity of coordination is even more pronounced due to decision making about collectively held resources, as there are often strong opposing opinions. Traditionally, this was solved by having a leader who made decisions on everyone's behalf or at least individuals with enough authority to coordinate a compromise, but this is clearly a suboptimal solution. Sharing also requires trust that all involved will do their part in terms of maintaining spaces, treating equipment well, and generally respecting agreed upon sharing practices. In small enough groups, concerns over reputation are usually sufficient to ensure people act according to agreed upon norms. This approach does not scale well, however, as the average bond strength between members is inversely proportional to a group's size.

New approaches for overcoming the coordination challenges involved in large-scale sharing have become feasible in the recent past thanks to the internet and mobile devices. AirBNB, the short-term home rental website, popularized the idea of sharing economy platforms, but these have proliferated and now facilitate many other types of "sharing". Besides AirBNB, "car sharing" platforms like Turo connect people who are willing to rent out their vehicles with those that want to rent them, "parking spot sharing" websites like JustPark connect home owners that have parking spaces they don't need at certain times with those who do, and Neighbor connects those who have things to store with those that have extra storage space they are willing to "share".²⁶⁹ A newer example that is somewhat different is Tesla's autobidder software, which coordinates the exchange of energy between distributed energy resources (like home batteries and solar systems), charging those who need energy and paying those who are producing or storing more than they need.²⁷⁰

²⁶⁹ Sarah Seright, "15 Companies Dominating the Sharing Economy | Neighbor," *The Neighbor Blog* (blog), October 1, 2018, <https://www.neighbor.com/storage-blog/sharing-economy-pioneers/>.

²⁷⁰ Fred Lambert, "Tesla Has a New Product: Autobidder, a Step toward Becoming an Electric Utility," *Electrek* (blog), May 3, 2020, <https://electrek.co/2020/05/03/tesla-autobidder-new-product-electric-utility/>.

Up until now, most of these digital sharing platforms have been run by large, for-profit corporations that charge a substantial premium for taking on the complexity of matching supply with demand and bearing the cost of users abusing equipment or homes that are “shared” with them. These are tremendous innovations that can lower the barrier to access resources while also providing a revenue stream to those who have them, but this mechanism cannot be honestly described as sharing. There are many other new forms of software-enabled peer-to-peer “sharing” that don’t rely on a central entity extracting value. For example, blockchain networks enable people to get paid for sharing their liquidity (money) for loans²⁷¹ or trading,²⁷² extra graphics processing capacity with those that need rendering jobs done,²⁷³ or their internet for nearby IoT and 5G devices.²⁷⁴ As in the case of intermediated platforms, the function these provide is more accurately described as lending or trading than sharing since they connect haves with havenots, which pay the former a fee proportional to their use. While these platforms currently support purely transactional relationships, they have incredible potential to replace trusted central administrators in coordinating the actions of many parties.

There have been attempts to create software platforms for coordinating sharing at the neighborhood scale, but these have not gained significant traction yet. The most successful example is the Nextdoor app, which is mostly a neighborhood social platform, but people use it to share resources as well as to coordinate local initiatives.²⁷⁵ It is still a centrally administered for-profit application, however, and there are privacy concerns regarding it. By contrast, there are organizations like Lend-Engine which provides database and account management

²⁷¹ Stani Kulechov, “Aave Protocol Whitepaper V1.0,” accessed May 12, 2022, <https://acrobat.adobe.com/link/track?uri=urn%3Aaaid%3Aasc%3AUS%3Ad442da8a-067e-490f-88cf-2c4511016ff7#pageNum=1>.

²⁷² Hayden Adams et al., “Uniswap v3 Core,” accessed May 12, 2022, <https://whitepaper.io/document/708/uniswap-whitepaper>.

²⁷³ OTOY, “Render Token (RNDR) Whitepaper,” accessed May 12, 2022, <https://acrobat.adobe.com/link/track?uri=urn%3Aaaid%3Aasc%3AUS%3Ad442da8a-067e-490f-88cf-2c4511016ff7#pageNum=1>.

²⁷⁴ Amir Haleem et al., “A Decentralized Wireless Network,” n.d., 20.

²⁷⁵ Meira Gebel, “What Is Nextdoor? How to Use the Social Network for Neighborhoods,” Business Insider, accessed May 12, 2022, <https://www.businessinsider.com/what-is-nextdoor>.

software that communities can use to manage tool libraries.²⁷⁶ There are various other applications that connect neighbors for specific functions like avoiding food waste,²⁷⁷ but no community sharing applications have seen anything like the success of AirBNB. This is, at least partly, because there has not been a market of defined, engaged communities which already share a great deal and would benefit from a better system for managing their sharing.

If software could be leveraged to empower communities to manage more commonly held resources with minimal effort, this would eliminate the need for a third party intermediary that must extract value to make a profit. There are a number of reasons that the KUP model is ideal for this sort of intermediate solution - between private ownership and the corporation-orchestrated lending/borrowing model. The core principle of doing everything on the smallest scale that is practical reduces the number of people involved, which makes it simpler to both coordinate and achieve trust. Compartmentalization of functions within clearly defined community units simplifies decision making processes since the delineation of internal versus external makes it clear who should have a voice in each decision that needs to be made. Most importantly, the nested community layers provide the opportunity for different degrees of (and approaches to) sharing in larger communities versus smaller ones. In addition to variation across community scales, having heterogenous kernels serve as the basic building blocks allows for variation between community units of the same scale. Rather than picking between highly engaged cohousing and total independence, there could be a spectrum of options for people to gravitate towards based on their preferences.

Another important point is that, while sharing requires some degree of trust, it also stimulates community bonding and nurtures trust. This “chicken or egg” situation makes building trust harder to do retroactively. In the KUP model, differentiation of kernels creates a degree of selective pressure for people who want to live in a similar environment, which should instill a baseline level of trust from the start. Regardless of which side of the engagement spectrum a community falls, coexisting with others who have similar preferences should

²⁷⁶ Lend Engine, “Tool Library Software Powered by The Lend Engine,” accessed May 12, 2022, <https://www.lend-engine.com/software-for-tool-libraries>.

²⁷⁷ New Dream, “Top 10 Neighborhood Platforms for Connecting And...,” text/html, New Dream (New Dream, April 3, 2018), <https://newdream.org/>, <https://newdream.org/blog/top-10-neighborhood-platforms-for-connecting-and-collaborating>.

naturally lead to more engagement that further unites them. As will be discussed in the conclusion, there is the possibility that future kernel (and even group or cluster) members could self-select to some degree, which should bootstrap trust and further ensure alignment of expectations.

More False Binaries

At the kernel scale, sharing seems like an appropriate term for collectively owning and managing spaces or resources. However, as you move up the scale from groups (1,000) to clusters (10,000) to cities (100,000), the distinction between “shared” and “public” becomes increasingly muddled. This is because, in reality, there is no fundamental difference - there are only gradations of publicness or privateness. Urban designers often try to create a hierarchy of private, semi-private, semi-public, and public spaces, though the binary of private versus public property that legal systems assume have made this difficult.²⁷⁸ As one author puts it, “urban public spaces are perceived as nobody’s or local public authority’s places, rather than everybody’s places.”²⁷⁹ The KUP model makes possible a more defined spectrum from private to public areas, which extends from a bedroom to household common spaces (living rooms, kitchens, etc.) to common spaces in a kernel then those in group, cluster, and city centers. In addition to spaces, having defined community units within which resources can be shared creates a more defined spectrum from private resources to public ones.

Public resources are typically administered by governmental bodies, which coordinate what needs to be done, charge residents what is needed to fund these shared resources (through taxes), and serve as the trusted intermediary. Even neighborhood parks, libraries, or elementary schools are usually overseen by some city or county-wide administration, despite functionally being neighborhood resources. In democratic places, residents may get to vote every couple of years on officials that will oversee the department responsible for certain citywide resources, but there is still a significant disconnect between those making decisions

²⁷⁸ James Howard Kunstler, *The Geography of Nowhere: The Rise and Decline of America’s Man-Made Landscape*: 30.

²⁷⁹ Christian Iaione, “The CO-City: Sharing, Collaborating, Cooperating, and Commoning in the City,” *American Journal of Economics and Sociology* 75, no. 2 (2016): 415–55, <https://doi.org/10.1111/ajes.12145>.

and those impacted. This centralization of oversight and the discrepancy between neighborhood desires and city standards is a common friction point. Even in instances where neighborhoods have attempted to become more functionally autonomous for internal functions, cities have often combatted such challenges to their authority.²⁸⁰

Besides city or county governments managing public resources directly, there are also highly regulated private companies that administer certain city-wide resources (eg. utilities). More generally, it is worth considering the distinction between businesses and public or shared spaces. Is a cafe or a corner store not a community resource for those who live nearby? Certainly the relationship is different than the one those residents have with a library or park since access to the resources local businesses provide are paid for at the time of consumption, rather than once per year via taxes. However, these are really just different models for financing the things people want, coordinating supply to meet demand, and incentivising people to play the roles required for these resources to continue to operate as intended. Besides funding mechanisms, the primary distinction between these private entities and governmental ones comes down to ownership and oversight (i.e. governance).

It is important to recognize that ownership and governance are two sides of the same coin. Ownership is really just the legal formalization of decision-making domains as well as who has what degree of say in those domains. Systems of governance and economics are just a set of incentive and communication protocols that, respectively, serve to harmonize the actions of people within or across decision-making domains. From here forward, these two-part systems will be referred to as societal operating systems (or societal OSs). As with public versus private and urban versus rural, societal OS models fall along a spectrum. In this case, the spectrum extends from total private ownership and transactional relationships among all parties (capitalism and libertarianism) to centrally administered collective ownership (communism and authoritarianism). Neither extreme, however, actually works as a stable, practical option. For the former, this is due to a lack of coordination around mutually beneficial functions and a tendency for power centers to emerge that strengthen over time (thereby straying from the ideal of freely

²⁸⁰ Erica Pandey, "Seattle Mayor, Seeking More Diverse Input, Cuts Ties with District Councils," The Seattle Times, July 13, 2016, <https://www.seattletimes.com/seattle-news/politics/mayor-seeks-more-diverse-community-input-cuts-ties-with-seattles-district-councils/>.

transacting individual actors). The other extreme of totally centralized governance always leads to a disconnect between those making decisions and those impacted, which leads to inefficiency and discontent (that has historically led to revolution).

Due primarily to these issues, all real world societal OS models fall somewhere in the middle, usually coexisting as hybrid systems with some resources publicly owned and centrally managed while others are privately owned and managed via free market dynamics. In the United States, for example, there are many functions within a given city that are impacted or fully managed by federal, state, county, and city agencies. All of these are managed in a top down power hierarchy with someone at the apex that was voted in by different populations. These public functions coexist (or contend) with private property, condos, HOAs, privately owned businesses, publicly traded businesses, non-profits, and customer or employee-owned co-ops. There are good reasons to employ different approaches at different scales, but this collage of overlapping and competing societal OS models is difficult to tease apart and the illegibility of decision-making domains results in conflicts as well as gaps in responsibility.

The KUP model's ability to support varying societal OS models at different community scales is valuable since there is less trust and more complexity in coordinating collective action for *groups* than *kernel*, *cluster* than *groups*, and so on. As a result, more free market dynamics and privately owned businesses would likely make sense in larger centers, but the KUP model could facilitate whichever model the residents wanted. There is growing recognition that property rights need to be reconsidered and modified to ensure cohesion among urban residents and equitable outcomes. One idea that people have been exploring is community land trusts, which are membership-based non-profits that collectively own land in order to ensure affordability for future residents. The incorporation of such approaches to urban land ownership is being explored for new cities like Telosa,²⁸¹ but the potential of having discrete models of collective ownership at different scales is not being discussed as widely.

People criticize models of collective ownership based on the failure of communist experiments, but the truth is that they have never lived up to the ideal of communities collectively owning and overseeing resources. Instead, administration is always done from the

²⁸¹ Telosa, "Telosa | City of the Future," Telosa, accessed March 16, 2022, <https://cityoftelosa.com/>.

top down. Many people are also strongly opposed to the “privatization” of public resources, but this is due to (justifiable) concern that for-profit businesses will act selfishly in their administering of public services. In both cases, issues result from top down, centralized administration. By contrast, the community-scale sharing that I am describing is characterized by the scaling down of “public” jurisdictions so that various sizes of “private” communities can own and manage their own resources. In other words, what I am suggesting is the creation of nested smaller public domains within cities that functionally blur the lines between public government and private residents.

A Different Way to Decide

The compartmentalization of functions at specific community levels should make it more feasible for the members of a given community to make decisions relevant to their shared resources directly. The details of how this works in practice, however, will need to vary by community. Software can automate many of the routine coordination functions and dramatically reduce the overhead for sharing resources. There are still many decisions, however, that need to be made that are not routine coordination tasks. Digital communication and voting platforms could make it significantly easier for groups to decide what should be done. At larger scales, however, it becomes increasingly impractical for everyone to be involved in every decision, especially in the case of time sensitive matters.

The view that differentiated governance models are needed for more community-scale urban sharing is also present in urban planning literature. One article argues that the sharing economy will “require a significant reinterpretation of the role of local governments, businesses and citizens, which in turn might imply a complex re-organisation of governing.”²⁸² Even more specifically, the authors of the Shanghai community life circles study (discussed in Chapter 2) argued that more community-run businesses and bottom up governance would help to make that 15-minute city-style approach more feasible.²⁸³ This view is echoed in an article that

²⁸² Jenny Palm, Karolina Södergren, and Nancy Bocken, “The Role of Cities in the Sharing Economy: Exploring Modes of Governance in Urban Sharing Practices,” *Energies* 12, no. 24 (January 2019): 4737, <https://doi.org/10.3390/en12244737>.

²⁸³ Haoyuan Wu et al., “Analysis and Optimization of 15-Minute Community Life Circle Based on Supply and Demand Matching: A Case Study of Shanghai,” *PloS One* 16, no. 8 (2021): e0256904–e0256904, <https://doi.org/10.1371/journal.pone.0256904>.

studied the implementation of the 15-minute city model in Portland (Oregon), Paris (France), and Melbourne (Australia). The authors conclude that making this model really work will require a dramatic shift in social processes as well as the physical arrangement of resources relative to residences.²⁸⁴ The idea that bottom-up, community-led movements could result in more resiliency is also found in eco-city literature.²⁸⁵

In one particularly relevant article, the author explores how “urban assets and resources or the city as a whole can be transformed into sharing, collaborative, cooperative, commoning ecosystems that enable collective action”. He argues that “a new type of regulatory system... that aims at transforming people in distributed nodes of collective action” is the best way to “shift from closed centralized institutions to co-owned, co-managed, and co-produced institutions for the governance of urban resources.” Doing so should also allow the community as a whole to capture more of the value of such systems. This will require “organizational innovations inside city administrative structures, a communication plan with a democratic digital platform as the central tool,” and initiatives to get residents engaged.²⁸⁶

Localizing decision making processes to the physical domain which they are relevant to is in no way a new idea. The United States was planned around the nested jurisdictions of nation, state, county, and city or town, however modern American cities are far larger than cities at the time this model was conceived. As a result, the level of disconnect between mayors or city councils and urban residents has grown. During the Chinese Ming Empire, a nested governance model called the *baojia* system was used. *Jia* comprised 10 families each and each *bao* was made up of 10 *jia*. Each *bao* had one representative that interacted with the empire on behalf of all 100 families. This elder coordinated, among other things, the respective

²⁸⁴ Georgia Pozoukidou and Zoi Chatziyiannaki, “15-Minute City: Decomposing the New Urban Planning Eutopia,” *Sustainability* 13, no. 2 (January 2021): 928, <https://doi.org/10.3390/su13020928>.

²⁸⁵ Elizabeth Rapoport, “Utopian Visions and Real Estate Dreams: The Eco-City Past, Present and Future,” *Geography Compass* 8, no. 2 (2014): 137–49, <https://doi.org/10.1111/gec3.12113>.

²⁸⁶ Christian Iaione, “The CO-City: Sharing, Collaborating, Cooperating, and Commoning in the City,” *American Journal of Economics and Sociology* 75, no. 2 (2016): 415–55, <https://doi.org/10.1111/ajes.12145>.

tax burden of each *jia*, which in turn determined internally how much each family must contribute.²⁸⁷

There is also recent literature on polycentric governance, though the meaning of the term is somewhat different in this context than in planning literature and it is more suited to multi-tier polycentric forms. Some authors describe polycentric governance as governance by many semi-autonomous, often overlapping governing bodies - including overlapping or nested layers.²⁸⁸ In direct opposition to how the term polycentric is used in planning literature, the emphasis in polycentric governance literature seems to be on the relationship across nested layers, with less interest paid to relationships between co-equal centers.²⁸⁹ One paper on the topic does note, however, that further research into how polycentric governance relates to networked governance (between jurisdictions of the same scale) would be extremely valuable.²⁹⁰

Even more directly relevant to the KUP model is polycentric democracy, which Müller defines as "a political arrangement involving a multiplicity of decision centers acting independently but under the constraints of a democratically supervised and legitimized framework for institutional competition."²⁹¹ Essentially, this is just a polycentric governance model that is democratic at each level, in which the sphere of influence or decision-making jurisdiction of each layer is clearly defined. This is similar to the city-county-state-nation structure that exists in the United States. While voting to elect a representative for multiple nested jurisdictions is a step in the right direction relative to authoritarian governance, it still suffers from a significant degree of disconnect between those making decisions and those impacted. The bandwidth of communication in such models is constrained to voting - usually

²⁸⁷ Yuval N. Harari, *Sapiens: A Brief History of Humankind*: 357.

²⁸⁸ Keith Carlisle and Rebecca L. Gruby, "Polycentric Systems of Governance: A Theoretical Model for the Commons," *Policy Studies Journal* 47, no. 4 (2019): 927–52, <https://doi.org/10.1111/psj.12212>.

²⁸⁹ Harini Nagendra and Elinor Ostrom, "Polycentric Governance of Multifunctional Forested Landscapes," *International Journal of the Commons* 6, no. 2 (2012): 104–33.

²⁹⁰ Keith Carlisle and Rebecca L. Gruby, "Polycentric Systems of Governance: A Theoretical Model for the Commons".

²⁹¹ Julian F. Müller, "Order Ethics: The Turn towards Polycentric Democracy," *Zeitschrift Für Wirtschafts- Und Unternehmensethik* 18, no. 3 (2017): 401–15, <https://doi.org/10.5771/1439-880X-2017-3-401>: 2

between two candidates, every couple of years - and public hearings that are simply not very effective.

Direct democracy, in which individuals vote on specific issues rather than representatives, has not been logistically feasible anywhere besides small villages until now. With secure, real-time digital voting platforms and constant connectivity allowed by mobile devices, however, the logistical barrier to collective decision making is greatly reduced. As noted above, a digital voting mechanism is central to laone's proposal for reforming city governance for sharing economies, along with a dramatic restructuring of administrative structures and a shift in academia's role from the bestower of expert knowledge to facilitator of self-directed learning.²⁹²

While these advancements would make direct democracy more feasible than before, it is still extremely inefficient at scale. As the size of the voting population increases, it becomes increasingly impractical for everyone to be involved in every decision, especially in the case of time sensitive matters. Some delegation of responsibilities is required for not only making decisions, but performing the various (often specialized) roles required for managing and maintaining shared ("public") resources. Luckily, there are new tools emerging that make this more feasible as well.

The rapid adoption of blockchain technology is driving experimentation and iteration on novel approaches for bottom-up governance of defined, often nested, communities. Simply put, blockchains are distributed protocols that no central entity has control over, which keep track of scarce digital assets and allow countless strangers to interact in a rules-based environment. Finite sets of tokens that represent fractional ownership over some system can be sold or given away to community members. These can then be used to vote on certain decisions (typically token-weighted, though quadratic weighting and other options are being explored), which are enacted automatically based on the outcome.²⁹³ There are also

²⁹² Christian laone, "The CO-City: Sharing, Collaborating, Cooperating, and Commoning in the City," *American Journal of Economics and Sociology* 75, no. 2 (2016): 415–55, <https://doi.org/10.1111/ajes.12145>.

²⁹³ Del Jr. Wright, "Quadratic Voting and Blockchain Governance Symposium Issue: Blockchain Technology and the Law," *UMKC Law Review* 88, no. 2 (2020 2019): 475–96.

non-transferable tokens that can be provided to individuals who have had their real world identity verified on chain, which allows for one-person-one-vote governance.²⁹⁴ Despite initial skepticism from the academic community and world at large, the potential for blockchain technology to revolutionize voting, finance, and various other areas is increasingly being accepted. A paper by Lumineau and colleagues argues that the implication of such systems for collaboration amongst individuals across many different scales cannot be ignored. They stress that organizations of all varieties need to begin considering how this new tool for coordination and achieving consensus could impact them.²⁹⁵

A common function in blockchain protocols is the “delegation” of tokens to other users in return for some reward, but this mechanism can also be used to delegate voting power.²⁹⁶ By issuing tokens representing fractional ownership of any community resource, it can be defined as a decision making domain. Partial owners could then delegate their voting rights for this resource to a community member they trust who is willing to take on that responsibility. This would usually be someone who is more engaged with or knowledgeable about that specific community resource. Since delegated tokens can always be reclaimed (though protocol can be built with undelegating periods), this allows for highly liquid flows of voting power between delegates if some of them make decisions that their delegators are unhappy with. This organic, bottom-up consolidation of voting power should make direct democracy more practical while minimizing the disconnect between those making decisions and those impacted. Especially at larger scales, more people would be involved and the complexity of decisions would increase so the need for delegation would increase proportionally.

While I have mostly focused on shared resources, not every business or resource needs to be community owned and governed, nor does everyone in a given community layer need to be a token holder (partial owner). Also, not all token holders would need to be directly

²⁹⁴ Jacob Oliver, “Vitalik Buterin Discusses Benefits of Non-Transferable NFTs,” *Crypto Briefing* (blog), January 26, 2022, <https://cryptobriefing.com/vitalik-buterin-discusses-benefits-of-non-transferable-nfts/>.

²⁹⁵ Fabrice Lumineau, Wenqian Wang, and Oliver Schilke, “Blockchain Governance—A New Way of Organizing Collaborations?,” *Organization Science* (Providence, R.I.) 32, no. 2 (2021): 500–521, <https://doi.org/10.1287/orsc.2020.1379>.

²⁹⁶ Polkadot Wiki, “Participate in Democracy,” accessed May 15, 2022, <https://wiki.polkadot.network/docs/maintain-guides-democracy>.

involved in the operation or maintenance of the corresponding system or space. Some of them could take these functional roles on and essentially be employees in addition to being co-owners that are involved in the decision making process. These community owned and operated resources could also function as businesses in the sense that they could still charge community members to use them, similar to a community-owned co-op. Many different models can co-exist, but having various shared systems concentrated in a given community layer would allow for the same group to own and oversee the same set of related community assets while managing each as a distinct decision-making domain.

Finally, it is worth noting that any form of governance can be built on top of this architecture, despite the emphasis placed here on its potential for facilitating bottom-up decision making. For instance, everyone could agree to delegate their voting power on all matters to whoever gets the most votes during regular elections, as in a representative democracy, or every resident could agree to delegate all voting power to a supreme ruler indefinitely, as in autocratic regimes (though hopefully few would choose to do so). These software defined governance protocols could also morph over time since they are much easier to update than urban form, though there is great potential in spaces in parallel with the societal OS model that will be deployed there.

To reiterate, scaling systems down as much as possible and leveraging digital communication as well as voting platforms should make it easier for groups to collectively oversee shared resources. The greatest benefit of deploying this societal OS in the KUP model, however, is that many different variations can coexist within adjacent or nested community units, each optimized for the preferences of those who live there.

~~CONCLUSION~~ MANY PATHS FORWARD, TOGETHER

In this final chapter, I will be discussing some of the practical considerations of building cities according to this model and how future residents could play a role in the design process. Additionally, I explore some of the implications it would have for the field of planning if this

were to become the dominant approach to urban development. I covered a large number of topic in this thesis, however, so it is worthwhile to start with a review of the main points.

Review

The primary goal of this thesis was to identify a better approach for organizing and constructing urban environments during the coming decades of rapid development. This is a critical topic because humanity will need to add capacity (home, infrastructure, jobs, ect.) for at least 5 billion people by the end of the century. Additionally, existing cities are facing enough challenges before factoring in decades of sustained growth. Using a human-centric design process to reimagine cities from first principles could conceivably yield alternate development patterns that better support accessibility, sustainability, community, and a diverse range of lifestyles.

Current urban development patterns are not categorically different from the way that cities traditionally grew: via continuous, radial expansion out from a center and densification that is largely defined by previously laid down streets. The unprecedented scale and pace of recent urbanization, however, has resulted in a state of chronic disequilibrium between residents and the resources they rely on. As the symptoms of this process became increasingly apparent, various 20th century urban theorists proposed alternate layouts for cities and approaches to scaling. While these also had flaws, such as being overly standardized and prescriptive, they also had certain insightful design attributes that have reverberated through decades of urban planning literature. A common characteristic of these proposals was a modular structure, in which each city or neighborhood unit contained resources appropriate for the surrounding population.

This general principle of clustering communities around resources they need regular access to is still found in urban planning concepts like the 15 minute city, urban villages, and superblocks. Additionally, it seems to emerge naturally over time, as in the case of Linpan and pocket neighborhoods. While this intuitive design principle can be found at many sub-city scales, urban planning literature tends to reserve the term polycentric for district or city-scale centers. It would be very reasonable, however, to employ polycentric layouts at many scales simultaneously since different types of resources and spaces are suited to different sized

populations. This is exactly what England's Urban Task Force advocated for in their landmark study *Towards an Urban Renaissance*, though many in the field of planning seem to have bought into Christopher Alexander's confused arguments against this sort of nested, "tree-like" urban form. Outside of planning literature and historic development patterns, bottom-up emergence of holarchies (nested whole-part entities) can be found everywhere throughout nature.

Designing urban areas according to this nested polycentric layout is best done from the bottom-up, using heterogeneous community units that serve as building blocks. In order for these basic community units to benefit from being combined around a common center, they must be of a similar population. Dunbar's number and other factors suggest that the ideal size for these "kernels" is approximately 100 people, though this will need to be confirmed via research and experimentation. With 8-12 subunits arranged around a center to form each community layer, the fourth nested layer would be a reasonably-sized small city. Kernels could vary in size, density, building type, amount of common space, and the presence of sub-kernel community units. There are certain geometrically sensible ways of combining these varied kernels in a roughly radial fashion around a common center. Doing so can produce differentiated groups, which in turn can be assembled into clusters that fit well around a city center - regardless of topographical constraints. This combinatorial process naturally yields differentiated environments that are suited to a broad range of lifestyles and community dynamics.

This urban form also results in a unique street network, compared to traditional gridiron and radial concentric layouts. The combination of (mostly) on-way ring roads and linear connections between centers results in a drastic reduction in intersections as well as total paved surface area. This layout is well suited to autonomous vehicles, which are nearly technologically mature and are the sensible option to plan any new city's transport ecosystem around. The combination of drop-off roundabouts on ring roads and carports along group-cluster connections should eliminate the need for parking in any center while providing convenient point-to-point travel and ensuring that AVs have a place to wait (and charge) between drives. These nested radial concentric street networks also better facilitate commuting by foot, bike, and micro mobility devices due to the much smaller number of intersections as well as the clustering of people around the places they will need to go most often. It is

important to note that, while travel between any two points is possible, this model only works well when the majority of trips are from a person's kernel to their local group, cluster, or city center and then back.

Cities are complex, multifaceted entities with many overlapping and interdependent systems. The utility of any novel urban form can only truly be assessed by considering how all of these urban functions could be adapted to it. Furthermore, designing cities that will be around for centuries during this period of rapid technological advancement requires that major disruptive trends be considered and planned around. This is no easy task to do fully or concisely, but I attempted to provide a brief overview of the major factors that are likely to transform where and how: work is done, people access goods and services, manufacturing takes place, food is grown, and utilities operate. There are a few key takeaways from this overview. Many functions are being scaled down and relocalized, while others are being fully digitized or eliminated entirely. These consolidations and more efficient agricultural techniques should reduce the average land use per person sufficiently for crop land to be developed. Additionally, it seems probable that most categories of urban functions will be facilitated by a combination of differentiated resources and spaces that range from smaller, generalized ones to larger, specialized ones. These will likely coexist and the different scale centers of the KUP model are ideally suited to supporting all of them.

The defined community units of the KUP model and the presence of community-specific resources should make sharing a lot more feasible, especially if new software tools are employed for coordinating this sharing. Different communities - either nested or adjacent - could adopt their preferred sharing practices, but there should be a relatively strong correlation between certain kernel or group typologies and the amount sharing among residents. These factors should create a degree of selective pressure for those with similar lifestyle preferences, which should, in turn, harmonize residents and strengthen community bonds. With different nested communities that each have a unique set of shared spaces and systems, there must also be community-specific ownership models and governance practices (societal OS models) for these commonly held resources. Ideally everyone who is a co-owner of some "public" resource should have a say in decisions regarding it. Scaling down and localizing resources helps to make this direct democracy more feasible, but at larger community scales more delegation of decision making. The community layers of the KUP model define discrete decision-making

domains, within which voting power can easily be delegated using new blockchain protocols. This could make bottom-up governance more feasible, but it can also serve as the foundation for more traditional societal OS models.

Building on this review, it is worth summarizing the types of shared or privately held resources that are reasonable to expect in different scale community units. Figure 42 provides an overview, but it is important to stress that these are examples of what resources could make sense in given centers rather than a prescriptive list. Most of these would be best located in centers, but there are some examples like parks, crop land, vertical farms, solar power plants, and carports make more sense as non-central resources. In reality, the specific makeup of resources in each community unit would be determined by community preferences, geographic constraints, and year of construction (as a proxy for technological capability).

Kernel	Group	Cluster	City	Industrial Center
◦ Very small gym	◦ Small generic gym	● Large gym	● Specialized gyms	● Distribution hubs
◦ Workshop/shared tools	◦ Larger workshop/tool library	● Track & field/sport courts	● Specialized sport facilities	● Specialized fabrication
◦ Common building:	◦ Coworking space	● Secondary school	● College	● Silicon chips
◦ Theater	◦ Primary school/daycare	● Specialized workplaces:	● Specialized workplaces:	● Batteries
◦ Large kitchen	◦ Small flexible event space:	● Satellite offices	● Dedicated central offices	● General production facilities
◦ Storage	◦ Religious worship	● Some research	● More research	● Data centers
◦ Garden	◦ Celebrations	● Common medical/dental	● Hospital	● Storage warehouses
◦ Large yard	◦ Large garden/grass field	● Small shops/bodega	● Branded stores	● Biomanufacturing facilities
◦ Pool/hot tub	◦ Small local utilities:	● Few restaurants/bars	● Many restaurants/bars	● Vertical farms
◦ Swing set	◦ Virtual power plant	● Mid-sized event space	● Large event space/stadium	● Bulk crop land
◦ Trampoline	◦ Internet antennae	● Park/crop land/vertical farm	● Central park/green belt	● Energy production/storage
◦ Shared AEVs	◦ Water collection/filtration	● Mid-sized utilities	● Larger utilities	● Raw materials processing
◦ Some micro utility systems	◦ Solar covered carport	● Solar covered carports	● Hyperloop/logistics hub	● Hyperloop hub/airport

Figure 42. Lists of resources that could reasonably be included in different scale community units.

The following renders should hopefully make this more tangible. Each group center would likely have a coworking space (Figure 43), which could possibly also be used by the community for events in the evening, while cluster centers would be appropriate locations for more dedicated offices (Figure 44). These dedicated spaces could be simple satellite offices or they could have more specialized equipment and layouts, which should allow them to serve as

research labs, standard medical offices, dental offices, or many other functions. A major benefit of planning such large developments with the expectation that many people will congregate in a center is that this allows for taller buildings and thus higher density to be achieved than would normally emerge in a community of the same scale under normal urban development patterns. It is worth noting that the cluster center shown in these renders is likely significantly oversized and less dense would ideally be the case. City center and industrial center renders were not created simply due to time constraints.



Figure 43. Group center coworking/event space, shown in an abstract cylindrical style.



Figure 44. Cluster center towers with coworking space and floors for dedicated businesses, shown in an abstract cylindrical style.

In group centers, a community workshop and tool library would probably make a great deal of sense (Figure 45), even though many kernels would probably choose to share a significant number of tools and a garage-like workspace regardless. Larger maker spaces would be suitable for clusters or cities, even though most manufacturing would make sense in ICs since some smaller scale artisanal production would need to be facilitated. Additionally, these larger warehouse-like buildings (Figure 46) could also host microfactories, vertical farms, biomanufacturing plants, large event spaces, or other semi-industrial functions that would be acceptable near residential areas. These buildings could be in cluster centers (as shown in Figure 46) or city centers, but would generally make more sense in the gaps between these larger subunits or on the urban periphery.



Figure 45. Group center workshop/tool library, shown in an abstract cylindrical style.

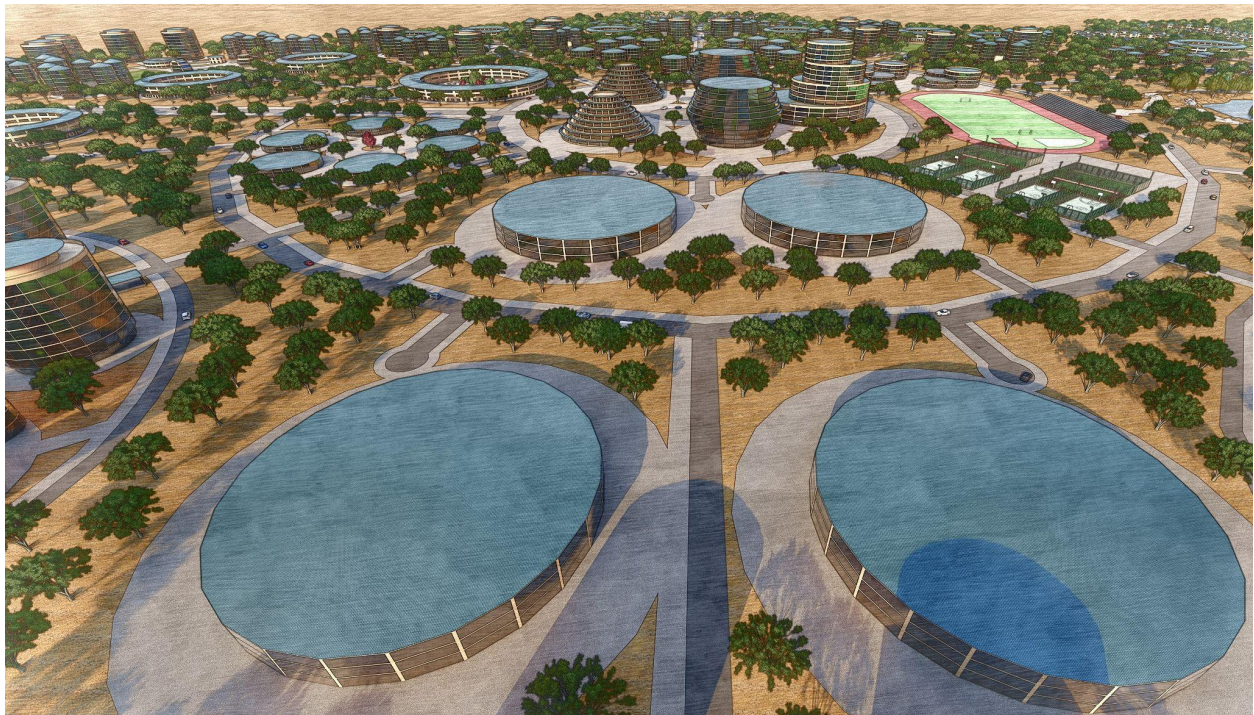


Figure 46. Cluster center warehouse, shown in an abstract cylindrical style, that could serve as an event space, vertical farm, small fabrication facility, or another space hungry function that is needed locally.

Elementary (primary) schools, which could also include daycare, would likely make the most sense in group centers (Figure 47). Junior high and high (secondary) schools would make more sense in cluster centers (Figure 48), where they could aggregate demand for specialized teaching knowledge as well as equipment. These would also be a reasonable place to include a track and field, as well as other specialized sport facilities. City centers would be more appropriate locations for colleges, a stadium, and other specialized sport facilities (not shown).



Figure 47. Group center primary school/daycare, shown in an abstract cylindrical style.



Figure 48. Secondary school with a track and sports facilities, shown in an abstract cylindrical style.

Reduced land usage per person should allow more green space to be included throughout kernel-based cities, but dedicated natural areas should be included as well. A generic field, garden, or landscaped park area would likely make sense in a group center (Figure 49). Clusters could contain dispersed park or agricultural space in the gaps between groups as well as a larger park, perhaps in between the radial lines leading from its most distant groups (Figure 50). These would be in addition to the green belt park/pedestrian path that weaves between inner and outer clusters, a central city park, and bulk crop land on the urban periphery (not shown).



Figure 49. Group center with a large grass field, rather than a garden or more park-like landscaping.

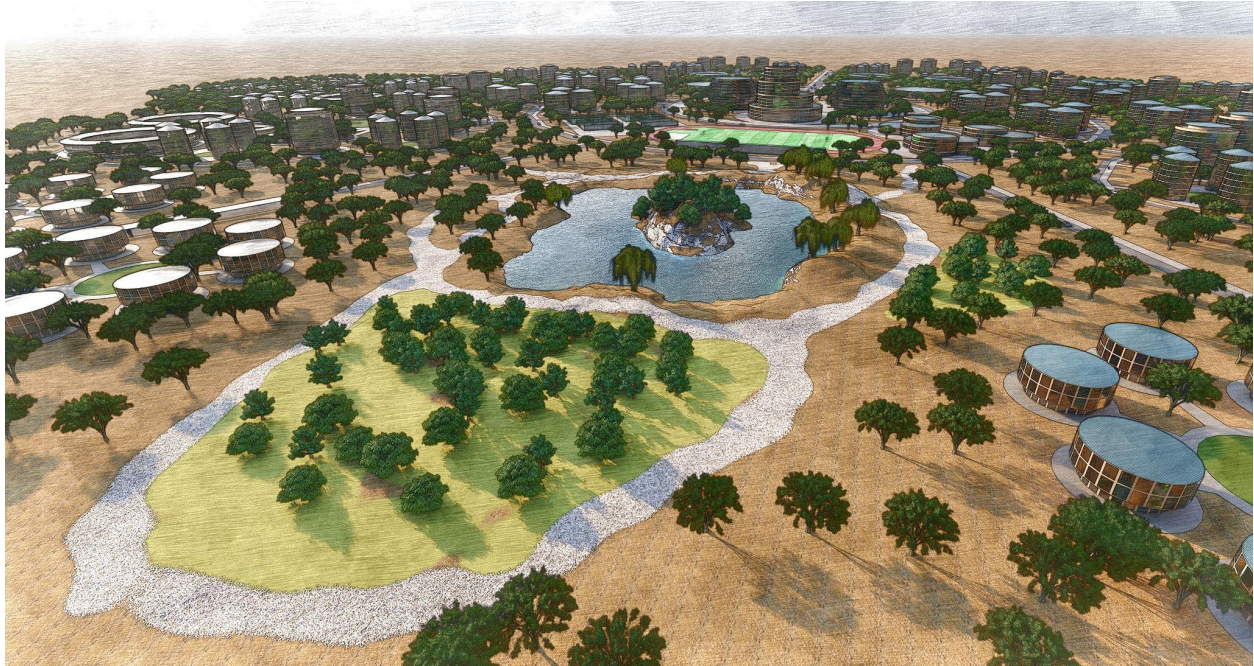


Figure 50. Park near a cluster center, located between the roads from the most distant groups.

Cluster and city centers would also have pedestrian oriented collections of smaller buildings for little shops and other businesses (Figure 51). Restaurants, bars, and cafes in the center could similarly be in pedestrian-oriented small buildings or they could be in a larger food court-like complex with common seating (Figure 52). Designing a center all at once allows for this type of synergy among businesses and spaces much more than fragmented parcel-by-parcel development patterns. There are many more resources that could be included in the different scale centers, but hopefully these renders have provided a better understanding of the general distribution.



Figure 51. Restaurants/food courtyard in a cluster center, shown in an abstract cylindrical style.



Figure 52. Stores and assorted businesses in a cluster center, shown in an abstract cylindrical style.

Organic Growth

While I have explored many facets of this proposed urban model, I have not discussed the development process with any degree of depth. There are many practical considerations for deploying the KUP model in the real world, especially if it is to be part of the solution for adding capacity for 5 billion urban residents. Unfortunately, however, this is a master's thesis that is already quite long. As a result, I will only be able to briefly touch on some of the key advantages that kernel-based urban development presents.

The largest barriers to building full cities from scratch include government approval, financing, planning them, actually building them, and convincing people to go live there.²⁹⁷ Affordability should be less of a problem for kernel-based cities since a large number of businesses and a great deal of infrastructure would be eliminated while many redundant, privately owned resources could be replaced with commonly held equivalents. Additionally, building all at once allows for many synergies in the design process as well as economies of scale during construction. Most importantly, however, the agricultural land they would be built on is multiple orders of magnitude cheaper than land in existing cities.

While building a kernel-based city on a green field site may be cheaper than adding equivalent capacity in an existing city, it would still not be cheap. Convincing investors to provide the tens of billions of dollars required would be difficult if you are simply relying on the assumption that "if you build it, they will come". Many of the green field, full city developments that have actually been realized have shown that convincing people to move to a new city can be extremely difficult.^{298,299} Furthermore, governing bodies will be reluctant to take any proposals seriously and engage in necessary discussions without secured financing. This catch-22 makes gaining any momentum on city development efforts extremely difficult.

²⁹⁷ Praxis, "Introducing Praxis," accessed May 24, 2022, <https://www.praxissociety.com/content/introducing-praxis>.

²⁹⁸ Manish Chalana, "Urban Design and Informal Urbanism: Case Studies from Delhi and Mumbai".

²⁹⁹ Max D. Woodworth and Jeremy L. Wallace, "Seeing Ghosts: Parsing China's 'Ghost City' Controversy," *Urban Geography* 38, no. 8 (September 14, 2017): 1270–81, <https://doi.org/10.1080/02723638.2017.1288009>.

The approach being adopted by Praxis, a recently founded city building organization, is to unite a group of future residents around a common vision and engage them in the design process.³⁰⁰ Besides nurturing strong community bonds and ensuring future residents are happy with what is built, bootstrapping demand this way should make it easier to convince investors and government agencies to take the project seriously. This approach is an extremely capital efficient and low risk way to begin developing cities compared with the top-down, nation state orchestrated build-it-and-they-will-come approach.

The KUP model is ideally suited to this approach of engaging future residents by involving them in the design process. This is primarily due to its modular form and the suitability of certain kernel, group, or cluster layouts for specific lifestyles and community dynamics. The alignment of certain physical and non-physical parameters (such as more private ownership and less desire for proximity to the city center in dispersed kernels) makes it easier to create a library of discrete options that residents can pick between. This is important due to the combinatorial explosion of possibilities which results from the large number of variables that can be adjusted: kernel layouts, how they are assembled, what resources each community unit includes, and the societal OS model they implement. Similar to selecting from a number of colors for a certain product, providing prospective residents with a library of predesigned archetypes for the most important attributes would simplify the process. This would make involvement in the design process accessible to people, most of whom have neither the technical background nor the desire to design their ideal built environment from scratch.

Kernels and larger community units are shared environments that must be suited to many different individual's preferences so customization must be a collaborative process among community members. Beginning by selecting among kernel archetypes and standardized options for the most important community parameters should make it easy to match people with similar preferences. A social platform could be built that allows people to network with potential community members and determine if they are actually a good fit. Since virtual reality is approaching mass adoption, it should also be possible for prospective neighbors to spend time together in their selected kernel environment while they decide if they want to move forward. The platform could conceivably enable these communities to further

³⁰⁰ Praxis, "Praxis Raises \$4.2mm Seed Round Led by Bedrock," accessed May 26, 2022, <https://www.praxisociety.com/content/seed-round>.

customize their virtual space while spending time in it, using pre-built modular components or custom ones that they import. In addition to facilitating customization and strengthening bonds, engaging this way should help prospective community members test out collaborative decision making via their chosen societal OS.

This idea of social platforms paired with a collaborative world building environment is not a novel idea, nor is the use of such platforms in democratizing urban design. There are many examples in urban planning literature where Minecraft^{301,302} or Half Life³⁰³ were used to engage the public. These have been shown to be useful, but require significant time commitments to get comfortable building in them. Furthermore, games like Half Life are constrained by the limited libraries of modular components while Minecraft is simultaneously too open ended and limited by the coarse grained substrate that its worlds are built from.³⁰⁴ At the same time, however, there are also millions of highly engaged players and well organized communities of builders in Minecraft, which is the best selling game in history and has had the largest player base for years.³⁰⁵ It seems that many people simply enjoy socializing and building together, even without the possibility of living in their creations or living with the community they built them with.

In recent years, the tools for collaboratively building virtual worlds have advanced significantly. For example, realtime rendering software like Lumion and TwinMotion make it easy to design realistic environments using simple tools to pick and place plants, furniture, buildings, and many other elements from libraries of pre-built models. They also allow users to import custom ones from other 3D modeling applications like SketchUp or from the quickly

³⁰¹ Ahmed Hanie Elmerghany and Gernot Paulus, "Using Minecraft as a Geodesign Tool for Encouraging Public Participation in Urban Planning," *GI Forum ...* 1 (2017): 300–314, https://doi.org/10.1553/giscience2017_01_s300.

³⁰² Anthony Pellicone and June Ahn, "Building Worlds: A Connective Ethnography of Play in Minecraft," *Games and Culture* 13, no. 5 (2018): 440–58, <https://doi.org/10.1177/1555412015622345>.

³⁰³ David L. Tulloch, "Many, Many Maps: Empowerment and Online Participatory Mapping," *First Monday*, February 5, 2007, <https://doi.org/10.5210/fm.v12i2.1620>.

³⁰⁴ Hamza Bashandy, "Playing, Mapping, and Power," *American Journal of Play*, n.d., 363–89.

³⁰⁵ Charlotte Silcock, "How Many People Play Minecraft In 2021?," *Cultured Vultures*, September 5, 2021, <https://culturedvultures.com/how-many-people-play-minecraft-popularity/>.

growing online libraries of models that can be used as is or edited. Increasingly, these platforms are also VR enabled. As intuitive gesture-based controls and voice commands are incorporated into these platforms, the barrier to entry for component-based virtual world building should be significantly lowered.³⁰⁶ In short, technologies that could help democratize urban design and make it a collaborative endeavor are nearly mature.

After a self-selected kernel community uses this platform to design their ideal shared environment and other defining features, they could network with others to form a group. These group members could then collaboratively decide on shared resources and a societal OS before repeating this staged process to form a cluster and then a city. At each successive scale, shared resources would include more infrastructure and businesses or business-like operations. Designs for these more complex components could be licensed out as franchise-like plug and play packages that include the designs, specialized hardware components, community resource management software, and protocols for operation. A marketplace of these “Community Resource Modules” (CRMs) would create a whole new industry that is analogous to the smartphone app industry, spurring innovation and creating jobs.

It is worth reiterating that this urban development process is optimized for entire cities to be constructed all at once, rather than through continuous scaling. It is possible to leave some extra natural or agricultural space between community units that could be developed into additional kernels or even groups later on. Only a small number could be added, however, before creating a discrepancy between the supporting resources in the nearest center and the demand from the surrounding residents. Some of Dunbar’s later research highlighted how communities historically grew in population then subdivided to return to more optimal sizes.³⁰⁷ Of course, this process cannot be imitated precisely in urban development since moving buildings is very difficult, but planning and building full cities nearby existing ones is a good modern approximation. As Howard recommended, regional growth and population capacity

³⁰⁶ David Heaney, “Oculus Quest Gets Voice Commands, Link Now Supports AMD,” December 10, 2019, <https://uploadvr.com/oculus-quest-v12-update/>.

³⁰⁷ Robin I. M. Dunbar and Richard Sosis, “Optimising Human Community Sizes,” *Evolution and Human Behavior* 39, no. 1 (January 1, 2018): 106–11, <https://doi.org/10.1016/j.evolhumbehav.2017.11.001>.

expansion should be handled through adjacent replication of cities rather than densification or center-out scaling.³⁰⁸

As discussed in Chapter 2, biology also provides evidence that healthy growth is replication rather than continuous scaling. Aside from resiliency, however, being made of many cells that are largely self-sufficient makes organisms more adaptable. Evolution can modify the relationship between these basic units and produce a drastically different form or function overall without having to significantly modify the cells themselves. At the genetic level, this is facilitated by the iterative refinement of gene variants through a continuous process of proliferation and natural selection. If kernel-based urban development patterns were to gain significant traction, this could stimulate the creation of many differentiated CRMs and novel ways to organize communities. Similar to genes, this should catalyze competition and natural selection among the modular options in the marketplace. As a result, each kernel (analogous to the cellular units of society) or larger community unit would include improved or hybridized aspects of previously built communities. The resulting process of iterative advancement that could aptly be called “societal evolution”.

Besides generating new forms and functions, iterative design processes like this facilitate a process of continual renewal. All systems benefit from periodic resets to clear out legacy constraints. Just as each new human can benefit from all accumulated knowledge without being burdened by the habits and worldviews of their ancestors, each new city built would be free from the limitations of its predecessors while benefiting from their experiments. While each kernel-based city would be new, having this sort of overarching framework helps to ensure that all urban development efforts learn from one another and are part of a global initiative to build towards a better future. Facilitating this sort of coordinated worldwide effort is exactly the proposition of BIG’s masterplanet initiative, though it is particularly focused on building sustainably.³⁰⁹ Given the scale and scope of what must be built in the coming decades, it seems apparent that some uniting framework is required to ensure the many paths we take move forward - in different directions, yet - together.

³⁰⁸ Ebenezer Howard, *To-Morrow: A Peaceful Path to Real Reform*.

³⁰⁹ Ciara Nugent, “Architect Bjarke Ingels’ Plan for Addressing Climate Change,” TIME, accessed May 28, 2022, <https://time.com/collection/great-reset/5900743/bjarke-ingels-climate-change-architecture/>.

Implications for Cities, Urban Planners, and Allied Fields

In this final section, I want to close by briefly discussing the implications that widespread adoption of kernel-based development would have for: existing cities and towns, urban planners and designers, architects and landscape architects, and real estate developers.

The most important implication for existing cities is that they would stop growing if kernel-based development became the dominant approach to meeting growing demand. Today's urban environments are not going anywhere, however. They will remain a critical part of human civilization for centuries to come, but they face a rough road ahead. Stunting cities' growth would cause some new challenges, such as necessitating that they begin to operate in a more fiscally sustainable manner (i.e. not relying on the expectation of ever increasing tax revenue to finance a growing debt burden). Overall, however, this transition should allow cities to focus on adapting to a new normal and achieving a stable equilibrium, rather than fighting to survive endless growing pains.

It is possible for the KUP model to be adopted in existing cities to some degree, however, it would require substantial buy-in from citizens and governing bodies since a great deal would have to change. Beyond political will, the current road network-defined urban form and building mix in existing cities would constrain and complicate transition efforts. As a result, the KUP model and alternate societal OS described here would most easily be deployed in green field developments. Once their theoretical benefits have been proven out elsewhere, convincing existing cities to change will become more feasible.

Another possibility worth noting is that these developments could be built adjacent to smaller cities or towns if local residents were open to that possibility. As a result, these existing communities could essentially grow into kernel-based cities, with the original town or city becoming just one group or cluster in the new development. This would also take a lot of political will, but achieving the supermajority approval that would be needed is more realistic with smaller groups. Local landowners would also have to be willing to sell the land required and county, or national authorities would have to be okay with it. While this is more feasible

than a complete overhaul of a large city, the necessary parties would likely be much more open to this idea after the model has been shown to work in some green field developments.

As this document is an urban design thesis for a master's of urban planning (in college that also includes architecture, landscape architecture, and real estate), it seems appropriate to conclude by discussing the implications of kernel-based development for urban planners and those in allied fields. To be blunt, urban planning needs to change - significantly. After two years of studying this field, it is not apparent to me why it is deserving of the title "planning". As one of my professors noted, "planners tend to follow growth rather than direct it".³¹⁰ Unfortunately, planners have limited power to implement changes their research suggests are necessary while also having inadequate means of determining what the populations they are planning for actually desire. Both of these limitations stem from the limitations of modern government and private property rights - specifically, the disconnect between the representatives making decisions and the citizens they are meant to be supporting. Public participation in the planning process is extremely limited and the engagement processes that do exist select for a non-representative subset of opinions.³¹¹

An end to incessant growth would not solve these problems, but it would allow (and force) the field to change. As it currently operates, urban planning would be more accurately titled urban growth management - so what will it do if urban growth stops? Instead of creating ineffective bureaucratic constraints to guide growth based on unreliable forecasts, planners could focus on mediating discussions among residents to create a vision for their neighborhood, district, or city overall. Rather than studying problems in greater depth when there is already broad consensus that they are problems, planners could use their energy to engage residents to come up with solutions. Since residents are going to have many different and often opposing opinions, there would still be a need for someone to facilitate this interaction between parties with different interests. This is never going to be easy, but it should be more feasible for planners to serve this critical role if they are not overwhelmed by trying to minimize the worst outcomes from incessant growth.

³¹⁰ Himanshu Grover, Comprehensive Planning & Implementation Lecture, February 2021.

³¹¹ Brenda Case Scheer, "The Debate on Design Review," in *Urban Design Reader* (Routledge, 2007), 335-42, <https://doi.org/10.4324/9780080468129-48>.

It is important to stress this idea that the proper role for urban planners and designers is as expert mediators, rather than unelected representatives who make decisions for the public. As the Urban Task Force wrote in their follow up report, “too often, design is imposed on communities rather than involving them... It is a fragmented process that creates fragmented environments... Design quality is threatened by an excessive reliance on design codes rather than design professionals.”³¹² Facilitating community-driven urban design is often discussed in planning literature in the context of Lefebvre’s idea of “right to the city”³¹³ or the growing discussion around learning from bottom-up design of informal settlements.³¹⁴

Just as urban planning is currently a misnomer, urban design today is really closer to architecture of the public realm. This would remain a critical role in kernel-based developments as well as existing cities, but the term urban designer should be broadened to also encompass the design of kernel, group, cluster, and city layouts as the demand for these larger format designs grows. Similarly, urban planning should evolve to be a field that is dedicated to empowering communities to holistically plan the construction and operation of these built environments. This inherently includes many other non-physical components so urban planners must work at the intersection of many fields.

These proposed roles are a relatively minor transition relative to what many planners and designers do today, but the widespread adoption of kernel-based development would essentially eliminate the demand for many other common planning functions. This is because there is no need for any forecasts, zoning, incentives, or complex development plan approval processes when planning full cities at once. If growth stopped in existing cities, these functions would largely become irrelevant there as well. While unfortunate for the career prospects of those who are only experts in a city’s municipal code and legacy processes, the shift away from today’s excessive focus on bureaucracy should be viewed as a positive development.

³¹² Urban Task Force, “Towards a Strong Urban Renaissance: An Independent Report by Members of the Urban Task Force Chaired by Lord Rogers of Riverside,” November 2005, http://image.guardian.co.uk/sys-files/Society/documents/2005/11/22/UTF_final_report.pdf: 7

³¹³ Henri Lefebvre, “The Right to the City,” *Praktyka Teoretyczna* 5 (2012): 183–97, <https://doi.org/10.14746/prt.2012.5.14>.

³¹⁴ Manish Chalana, “Urban Design and Informal Urbanism: Case Studies from Delhi and Mumbai”.

Aside from urban designers and planners, this paradigm shift would have major implications for related design fields. This is primarily because the marketplace of modular community components would provide many new work opportunities for architects and landscape architects. Interoperable building variants for a given community layout would be needed so that communities could customize their aesthetics and internal layouts. Landscape architects would largely work with urban designers in the creation of community layouts, but they could also create alternate planting (for different aesthetics and climates) and furnishing options for those layouts that function as another modular community component. Whereas most designs today are one off creations for a specific site (or highly standardized suburban options), these designs could be used many times and improved through successive iterations based on feedback.

Finally, there are significant implications that kernel-based development patterns would have for real estate developers. Currently, the vast majority of effort in this field is spent analyzing sub-markets (housing, retail, industrial, etc.) within existing cities, projecting demand, assessing available building sites for financial feasibility, and then slogging through government bureaucracy. All of these roles that real estate developers play in current urban development patterns would be irrelevant in fully pre-planned green field city development. It is worth stressing that an enormous amount of effort is dedicated to figuring out what the customer wants, but future residents explicitly decide what they want in a community-driven design process. There are many approaches that could be taken in financing kernel-based cities, however, which real estate developers' skill sets and knowledge would be valuable. As a result, the field would not be entirely eliminated, but it would change significantly. Critically, this would allow the field to transition to a role that is more in line with the well being of residents, unlike the misaligned incentive structures that drive real estate development today.

- *Final Remarks* -

I covered a lot in this thesis, but many questions remain. My intention was to prioritize breadth over depth in order to provide a comprehensive argument for a drastically different approach to urban development. This is just the first step though - it is meant to be the beginning of a conversation. My hope is that many urban designers and planners, as well as those in allied fields, engage with this idea in whatever way they believe would be most impactful. Numerous master's theses could be written to critique and further develop the ideas presented here: whether 100 people is actually the ideal size for kernels or if 8-12 subunits per layer is the right range; how to optimize nested radial concentric road networks in practice; how to mitigate the potential downsides of community self-selection and the challenges of democratizing urban design. I welcome any engagement and feedback, however critical. Anyone who agrees that my proposed urban development framework could be a powerful force for positive change should feel free to reach out and help me figure out how to deploy it. Even if you are not immediately inspired to take action, I hope that you reflect on these ideas as you move about your urban environment and find your own way to build towards a better future.

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