Visionary
Architecture Studies
VAS Scientific Journal

Vol.1, Issue 1, 49 Cities: Columbia University, 2025

The City in the City: A Fractal Pattern Language for Self-organizing Urbanism

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Abstract
The City in the City: A Fractal Pattern Language

In 1975, the mathematician Benoît Mandelbrot coined the term *fractal* to refer to complex structures that contain self-similar elements repeating at different scales, which can be described with mathematical precision. He and other researchers found that many behavioral patterns in nature abide by this fractal structure—as do the physical surroundings of human environments. The purpose of this research paper is to use the pattern language of fractals—which exhibit characteristics of self-growth and self-adaptation—as a model for resisting urbanistic and capitalistic dogmas that govern contemporary city design. This paper draws lessons from a fractal reading of cities and communities that exhibit complex fractal logic and give credence to the notion that cities, by nature, are inherently complex and unpredictable.
As a theoretical underpinning for the research paper, the text bridges theories in fractal geometry from Mandelbrot, design theory from Christopher Alexander, and critical temporality from Denis Ferreira da Silva's writings, in addition to other writings on fractal urbanism. Through these lessons, this paper concludes that the rituals, forms, and timelines in cities operate according to paradoxical but coherent logics—orthodox/fluid, predictive/generative, linear/recursive—and that fractal thinking can reconcile these paradoxes and guide more adaptive, autonomous urban futures. Ultimately, the text proposes a fractal city framework to imagine an ever-expanding series of rituals, forms, and timelines emerging autonomously from both within and without the metropolitan city of today—the *City in the City*.

Keywords
fractal; emergent; generative; descriptive; recursive; autonomy

1. Introduction: Fractal Thinking

Complexity is an inherent, necessary characteristic of cities. The current crisis in visionary city design stems from this fatal oversight. Today, the design of neighborhoods, streets, and parks stands in obvious disagreement with the complex and autonomous patterns of behavior exhibited by all forms of life—both human and non-human. The result is a sterile, fabricated fantasy based on predictive metrics and urban doctrines. This is especially relevant in the context of the mechanistic, predictive urban models of "smart cities" emerging in a world increasingly shaped by algorithmic planning and AI (Mehaffy, 2023). This model—inherited in part by modernist thinkers of the last century—assumes cities are more like machines: a series of zeroes and ones, binary relationships, and sequential logics. This paper posits that cities are more like organisms than they are like machines. In this sense, they are the product of countless individual and group decisions that do not conform to any grand plan.

Christopher Alexander's design theories from *A Pattern Language* and *A City is Not a Tree* offer an important conceptual counterpoint to these mechanistic models. In rejecting hierarchical, treelike urban systems, Alexander champions the semi-lattice: a model of the city as a complex, overlapping network of relationships that evolve organically from lived experience. His catalog of architectural and social 'patterns' sought to preserve the generative logic of traditional settlements, where space is shaped not by abstraction but by use, memory, and ritual—theories that held immense influence over architectural discourse for several years following the publishing of *A Pattern Language*. Yet while Alexander rightly observes that cities thrive when their patterns are recursive, relational, and situated, his approach ultimately leans toward an idealized coherence through a language of harmony that risks sanitizing the messy paradoxes and ruptures that animate urban life. His patterns, though numerous, strive for a kind of formal resolution, often privileging legibility and stability over disruption and difference. In doing so, his theory flirts with a prescriptive and linear rationale, subtly reintroducing the top-down logic it initially sought to critique.

Figure 1. Comparing structures of a city through the lens of human groups and subcultures, comparing the "homogenized" city, the "heterogenous" city, and the "mosaic of subcultures". Source: Alexander (1977), p. 43.

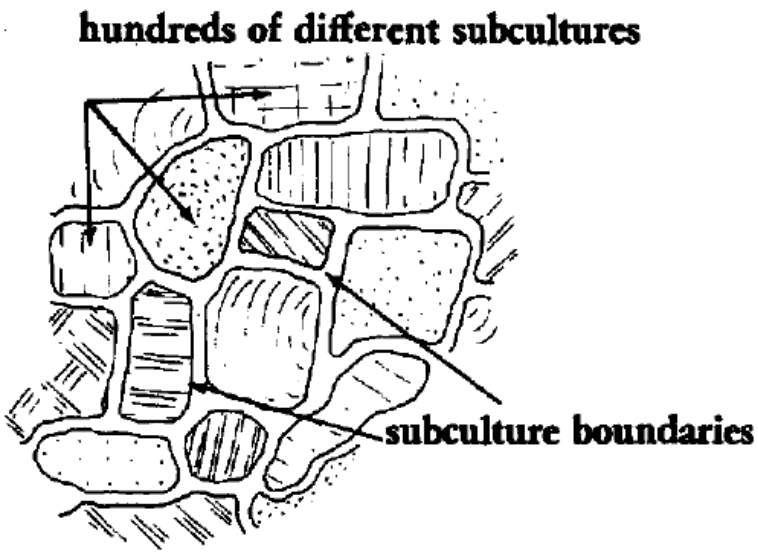


Figure 2. Christopher Alexander's imagining of distribution of subcultures and the a Pattern Language for their application in cities. Source: Alexander (1977) p. 50

Do everything possible to enrich the cultures and subcultures of the city, by breaking the city, as far as possible, into vast mosaic of small and different subcultures, each with its own spatial territory, and each with the power to create its own distinct life style. Make sure that the subcultures are small enough, so that each person has access to the full variety of life styles in the subcultures near his own. (Alexander, 1977, p. 50)

This tension came to the fore in the well-known debate between Christopher Alexander and Peter Eisenman on November 17th 1982 at Harvard Graduate School of Design, where Alexander vehemently defended the moral imperative of harmonious city design against Eisenman's provocative ideas of fragmentation, autonomy, and formal complexity (Rollino, 2024). Eisenman rightly criticized Alexander's nostalgia for wholeness as a reductive ideal, yet Eisenman's own stance fell short in a different way: his willful detachment from ritual, memory, and embodied use revealed an ignorance for the deeply relational and affective dimensions of space.

In response, an alternative Fractal Pattern Language can embrace the city's paradoxes. Where Alexander's patterns pursue wholeness, the fractal city insists on multiplicity; where his language leans toward stability, fractal logic invites recursion, disruption, and nonlinearity. Drawing from both Alexander and fractal theory, this research reframes the city as an emergent entity whose rituals, forms, and timelines unfold across nested, self-similar scales. Rather than offer a definitive catalog of forms, the Fractal Pattern Language seeks to describe and understand how cities can remain generative, adaptive, and irreducibly complex.

To this end, fractal thinking can be further categorized into three elements that help describe the fractal city in a nested format: *Rituals*, *Form*, *and Time*. Each of these three elements represent key paradoxes of fractal thinking that emerge from readings of case study cities historically and globally. Ultimately, the paper aims to embrace the paradoxes as crucial for creating space for future city evolutions (as opposed to attempting to predict the 'future city' on a tabula rasa).

2. Rituals: Orthodox / Fluid

In domestic life, rituals like eating, cleaning, celebrating, and resting, can be either: *Orthodox*: repeated, stable, meaningful – anchoring daily life; or *Fluid*: constantly negotiated, subtly changing, personalized over time. At a fundamental level, these rituals of domesticity form the basis of behavioral patterns, emerging in a fractal pattern of dwelling.

Through fractal thinking, some cities exemplify how these rituals can remain rigid and fluid at the same time. Like domestic rituals, fractal patterns may repeat, but never exactly the same way. While the *shape* of the ritual repeats, the *content* adapts.

The fractal patterns of these rituals debunk the so-called 'boundary' of cities as they tend to be drawn. Rather than drawing a single outer perimeter delineating the extents of the city, the fractal draws multiple perimeters within perimeters, understanding each self-contained perimeter as a member of a larger network of perimeters, and vice versa, each perimeter as the host of multiple sub-perimeters.

In Tokyo, rituals of domestic and communal life subtly but powerfully shape the urban fabric. The city's alleyways, or '*roji*', are not merely circulation routes but intimate extensions of the home, where rituals of cleaning, gardening, drying laundry, and exchanging greetings unfold daily. These are orthodox rituals: repeated, shared, and culturally embedded, anchoring a sense of place and continuity. Yet within these narrow spaces, inhabitants adapt the same rituals fluidly—replacing a potted plant with a drying rack, setting up a seasonal shrine, or adjusting habits based on weather or generational shifts. These micro-adaptations demonstrate a fractal logic: the form of the ritual repeats across the city, but always with subtle variation, according to individualized needs and environmental shifts.

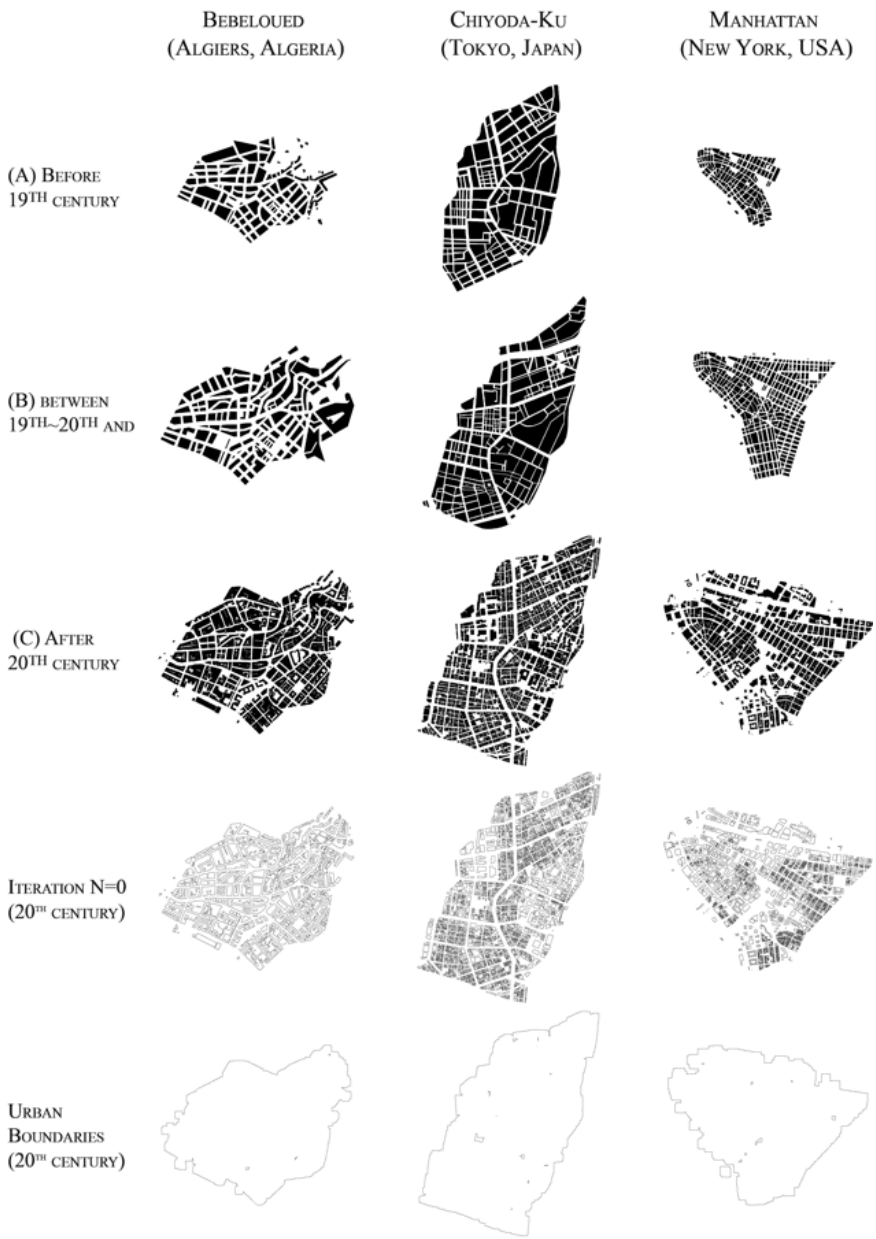


Figure 3. Urban fabrics and urban boundaries of three separate districts demonstrate the extraction of urban morphological identities related to fractal characteristics (Tokyo outlined above). Source: Kacha et al. (2022)

Fractal analysis of Tokyo's Chiyoda ward, as detailed in the 2022 study by Kacha, Abdessemed, and Matsumoto, confirms this insight formally: despite extensive modernization, the city retains a high degree of morphological complexity, with repeating yet heterogenous patterns of street grids, open spaces, and building typologies. These spatial fractals are not only formal but are also encoded with the everyday rituals of Tokyo's inhabitants. Alexander's *A Pattern Language* aspired toward a similar harmony of scale and life, though often privileging a more fixed and universalist notion of 'good form'. In contrast, Tokyo reveals a more fluid grammar, one that embodies a fractal urbanism grounded in evolving rituals.

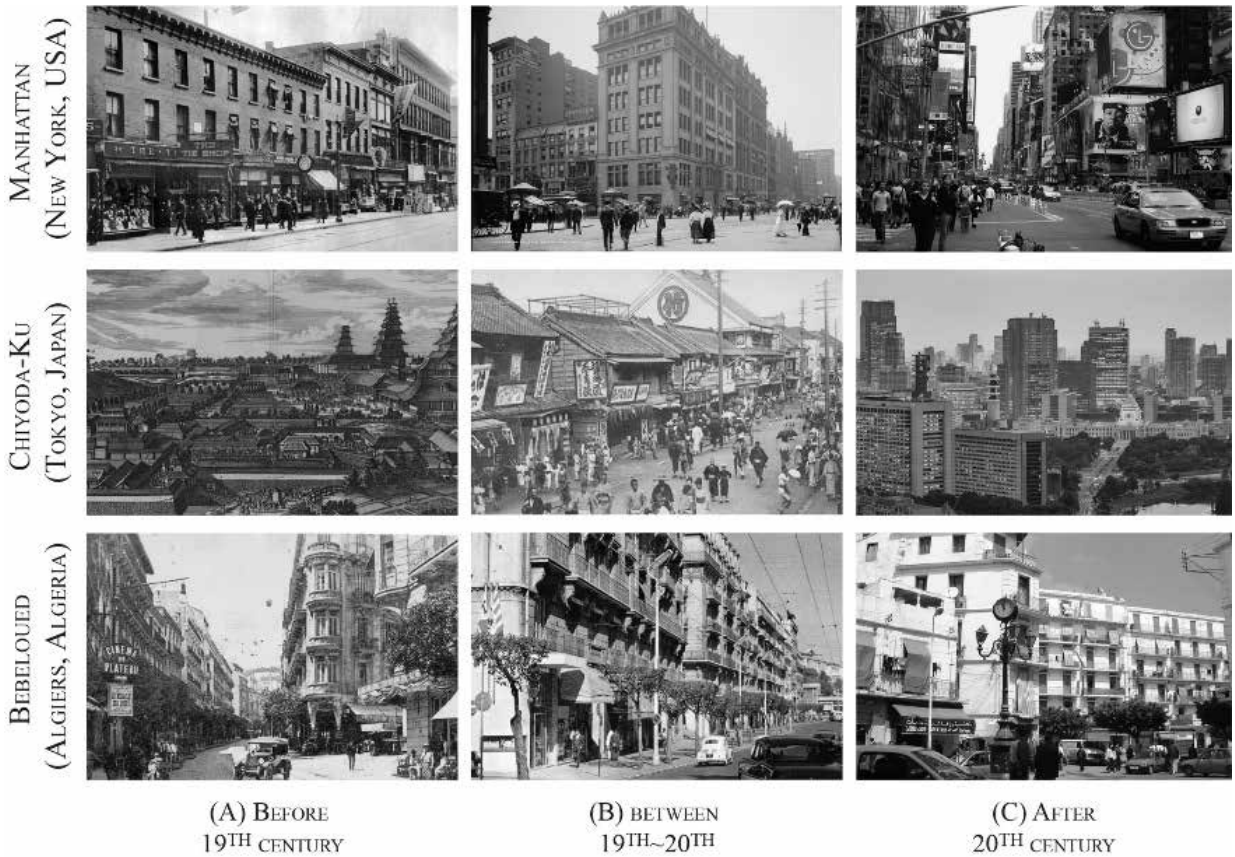


Figure 4. Evolution of urban landscapes by identification of urban edges, which result in an urban pattern consisting of many individual buildings or groups of buildings with the distances between them varying considerably over time. These distances and edges shift as rituals, both urban and domestic, evolve and transform over time (Tokyo outlined above). Source: Kacha et al. (2022)

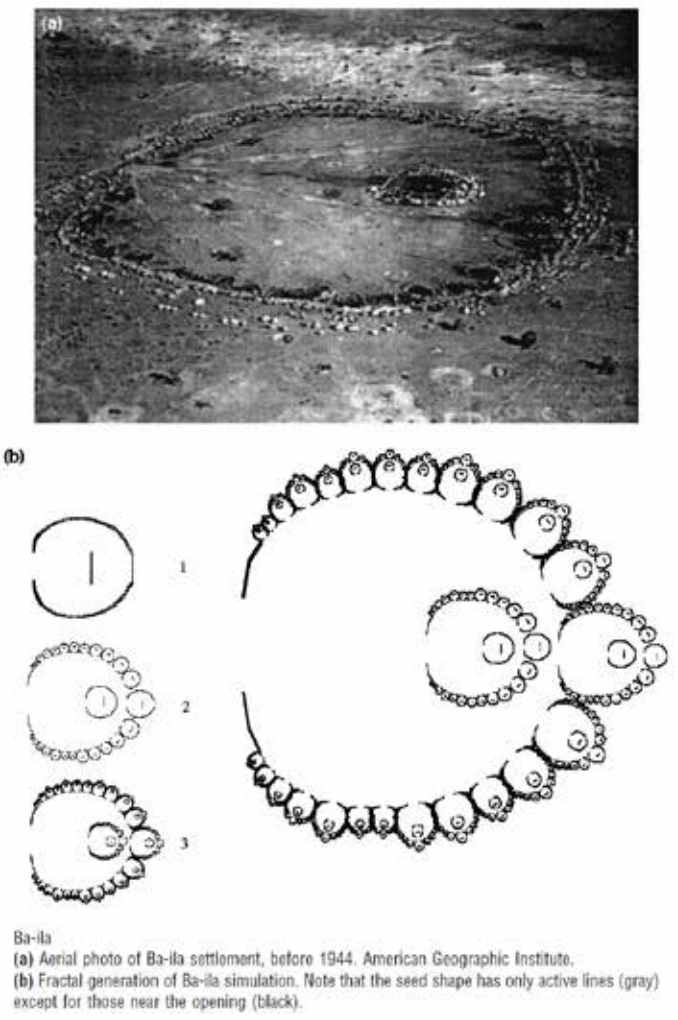
3. Form: Predictive / Generative

One can set up a distinction between two kinds of forms based on the rituals that precede them. First, there is form that lives, that is *generated* by a living ritual that emerges in response to a full range of contextual forces. Second, there is form that cannot be alive, but is *predicted* by a data set that informs a process of organizing, such that each step in the process does not adaptively build on the results of the prior step, because each step is mechanically pre-selected from an existing data set.

The paradox here lies in the fact that many domestic and urban routines of city life are inherently repetitive (e.g. "ritualistic") and are therefore also predictively derived from a set of historical routines that have created patterns of behavior, or patterns of living. Conversely, it is also generative because these behaviors do not conform to any grand plan but are instead produced by countless individual and collective decisions. The fractal form is therefore both generative and predictive. Rather than existing as binaries, fractal cities depend on both generative and predictive characteristics.

The 1999 essay written by Computer Scientist Dr. Eglash titled *Fractals in African Settlement Architecture* provides an effective starting point for the analysis of fractal form by looking into the self-organizing patterns of various African settlements and their spatial relation to their domestic rituals. In addition to observing the generative forms emerging from their rituals, the fractal logic allowed for a predictive modelling as well by using geometric algorithms that abstract these patterns on the computer.

A striking example of generative form shaped by domestic rituals can be found in the Ba-ila village compounds of Zambia, as analyzed in Dr. Ron Eglash's publication (Eglash, 1999). These settlements are organized around a recursive, self-generating structure, where the layout of the compound reflects a fractal logic. A central courtyard is surrounded by a ring of huts, each representing an individual household. This pattern is recursively repeated: within each hut, the arrangement of objects, hearths, and storage spaces echoes the concentric spatial logic of the compound itself. The design is not imposed from a top-down planning approach, but rather emerges through repeated domestic actions such as cooking, cleaning, gathering, which in turn recursively shape space in response to family needs, social relations, and spiritual beliefs. These actions are not random but grounded in cultural memory, forming patterns that are recognizably similar across generations and scales.



Ba-ila
(a) Aerial photo of Ba-ila settlement, before 1944. American Geographic Institute.
(b) Fractal generation of Ba-ila simulation. Note that the seed shape has only active lines (gray) except for those near the opening (black).

Figure 5. Bai-la settlement, where ring-shaped livestock pens, one for each extended family, can be seen in the aerial photo. The formal concept of the settlement is rings within rings. Computer simulations extract a predictive fractal pattern model despite the settlement's inherent generative quality. Source: Eglash (1999), p.24.

This recursive process, while highly structured, is not strictly predictable. The specific arrangement of a given Ba-ila homestead evolves over time with births, deaths, marriages, and seasonal cycles—morphing according to internal and external shifts (Eglash, 1999). The ritual of space-making is therefore both generative, in that it responds to evolving life conditions, and predictive, in that it conforms to culturally encoded spatial logics that maintain coherence. Eglash's computational models of these village layouts demonstrate their fractal nature mathematically, but more importantly, they reveal how deeply social and spatial forms are entangled. These forms do not emerge from algorithmic determinism as illustrated in Eglash's computational renderings, but from the repetition of lived, embodied practices. Thus, they exemplify how fractal thinking reconciles the paradox of design as both emergent and orderly. The fractal city can evolve adaptively and autonomously without abandoning cultural continuity or spatial legibility.

4. Time: Linear / Nonlinear

In addition to being manifested in a spatial dimension, fractal thinking must extend into the temporal dimension to grasp the city's inherent ephemerality. Here, fractal thinking disrupts the binary between linear and nonlinear time. In *A Pattern Language*, Alexander's design ethos is deeply temporal, even though he rarely uses that word explicitly. The patterns of living he describes encode rhythms and cycles that are recurrent but adaptive; *linear* at the scale of the day, but *non-linear* across generations, as patterns are revived, layered, and reinterpreted.

Through a reading of Denis Ferreira da Silva's critique on linear time, fractal time proposes that the city and its inhabitants are not bound by a before/after, but exist in entanglement – relationally, across scales, in simultaneity (da Silva, 2022). Here, histories, cosmologies, and futures coexist. Linear time follows a colonial imposition of history as progress, mastery, and development, while non-linearity is non-causal and multi-voiced.

Figure 6. Aerial and perspective views of one of several stilt-housing settlements in La Ciénaga Grande de Santa Marta, Colombia, taken in 2018. Source: Perez et al. (2022), p.50.

La Ciénaga Grande de Santa Marta, a vast coastal wetland in northern Colombia, is home to stilt-house communities that resist the logic of linear time. These '*palafito*' (stilt-house) settlements emerged as fugitive geographies where Afro-Colombian refuges and Indigenous groups escaping colonial violence and land-based surveillance could reside. These amphibious dwellings express what Denise Ferreira da Silva calls "fractal time" in *Unpayable Debt: a time of entangled scales*, where history, ecology, and futurity coexist without hierarchy. The tides structure life rhythmically but not predictably; rituals of fishing, cooking, and repairing dwellings repeat each day, but respond dynamically to saline flows, fish migrations, and seasonal flooding, which become increasingly unpredictable through climate change. This is not a city 'progressing' through time, but a city in recursive adaptation.

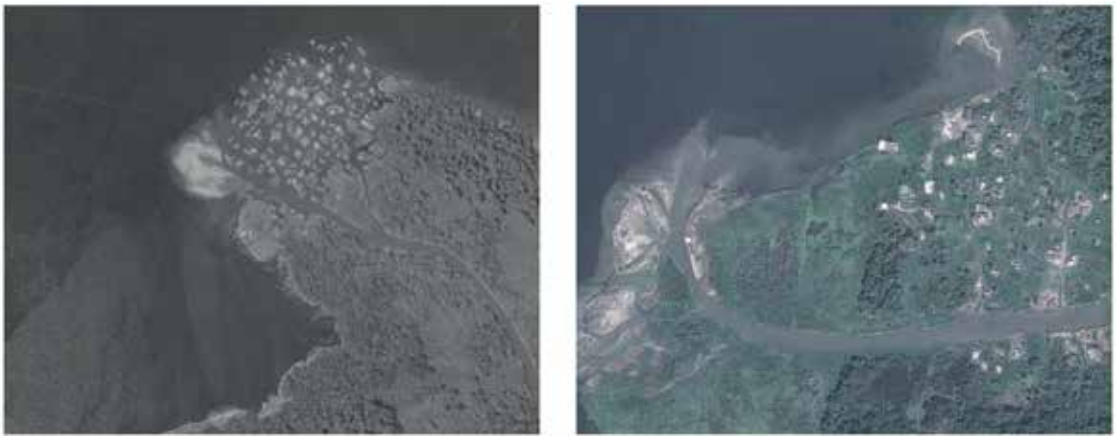


Figure 7. Aerial views of stilt-housing settlements in La Ciénaga Grande de Santa Marta, Colombia, from 1974 (left) to 2016 (right), revealing the coastal and climatic changes that led to the emigration and eventual erasure of one of these settlements (marked in red), to be relocated in a different area. Source: Perez et al. (2022), p.50.

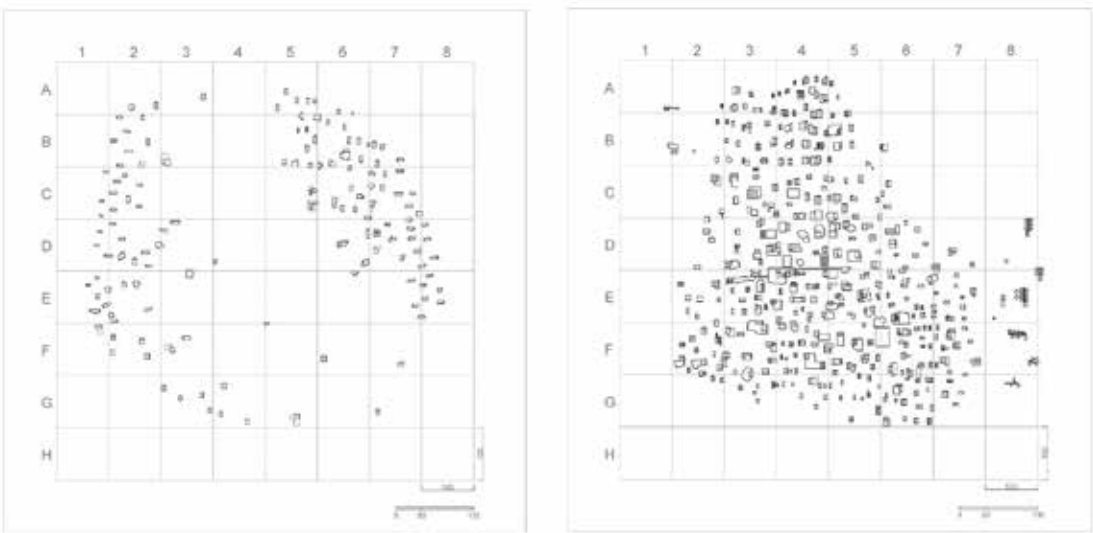


Figure 8. Examining the plan view of stilt-housing settlements in La Ciénaga Grande de Santa Marta, Colombia, through time. In the left, settlements present in 1961 that disappeared by 2018. In the right, settlements that make up the urban footprint of the community in 2018. Rather than exhibiting a linear progression of expansion, this fractal urban timeline depicts the recursive nature of transient settlements, displacement, and migration that occur due to a variety of external factors, including climate change, political persecution, and sea-level rise. Source: Perez et al. (2022), p.74.

This temporal criticality is similarly alluded to in earlier visionary city proposals, such as those of the Japanese Metabolists in the 1960s. In envisioning his proposal for *Clusters in the Air* (1962), Arata Isozaki introduced notions of fractal time and recursive time in a profound quote about the lifecycle of cities:

Future cities are themselves ruins. Our contemporary cities…are destined to live only a fleeting moment. Give up their energy and return to inert material. All of our proposals will be buried. And once again the incubation mechanism is reconstituted. That will be our Future. (González, 2019).

Fractal thinking disrupts the binary between linear and nonlinear time by embedding cycles of life into built form. While Christopher Alexander's A Pattern Language hints at temporal continuity through recurring spatial rituals, it falls short of recognizing time as simultaneously historical, ecological, and cosmological. In La Ciénaga, domestic rituals such as cooking with brackish water, weaving nets, and hanging clothes to dry recur with variation, drawing on ancestral knowledge with micro-variations in the present. These practices form a fractal pattern of time: daily routines that encode centuries of displacement and resilience, unfolding with both memory and evolution. La Ciénaga offers a living, liquid urbanism where time is porous, recursive, and co-shaped by human and non-human actors.

5. Envisioning the Fractal City

A final paradox of the fractal city lies in how one describes or envisions the city itself. If, by its own unpredictable nature, the fractal city is recursive, generative, and fluid, then it eludes the fundamental tenets of modern city design as we know them: linear, predictive, and orthodox. Even within contemporary theories of fractal urbanism, architects and city planners eventually succumb to computational and mathematical methodologies to derive at predictive and linear models of the fractal city (Jahanmiri et al., 2015). The entrapment of the mathematical and predictive approach that theorists such as Dr. Eglash propose in his paper *Fractals in African Settlement Architecture*, albeit empirical and rigorous, ultimately yield reductive models that suppress the inherent complexity and unpredictability of the fractal city. In other words, fractal design analysis is always a posteriori – an after-the-fact reading of emergent fractal behavior. As has been discussed in the previous case studies, however, the fractal city is never designed; it is always emergent.

As such, the fractal city must question the nature of space and how one experiences fractal space itself. Following the previous points on rituals, form, and time, fractal space is bound by both generative and predictive logic. This creates space that can be defined as either *prescriptive* or *descriptive*. A *descriptive* reading of space is about observing and experiencing how space is structured *as it is* from a bottom-up perspective, often revealing emergent patterns that weren't explicitly designed. A *prescriptive* reading of space is about analyzing how fractal patterns form a coherent template for shaping space from a top-down perspective – similar to Christopher Alexander's *A Pattern Language*, where a set of variables emerge for designing cities, or how Dr. Eglash deduces algorithms to prescribe the form and shape of African settlements.

A more helpful model for envisioning the fractal city may emerge from Constant Nieuwenhuys (1920 – 2005) and his vision of New Babylon. Here, architecture would become a global network of nodes and sectors supported by pillars and common open spaces in which life would be subject to perpetual change and transformation (Wigley, 1998). Architectural elements like walls, stairs, floors, and ladders would be non-static, instead allowing New Babylonians to continually build, un-build, and create new links and pathways, resulting in non-descriptive growth through time.

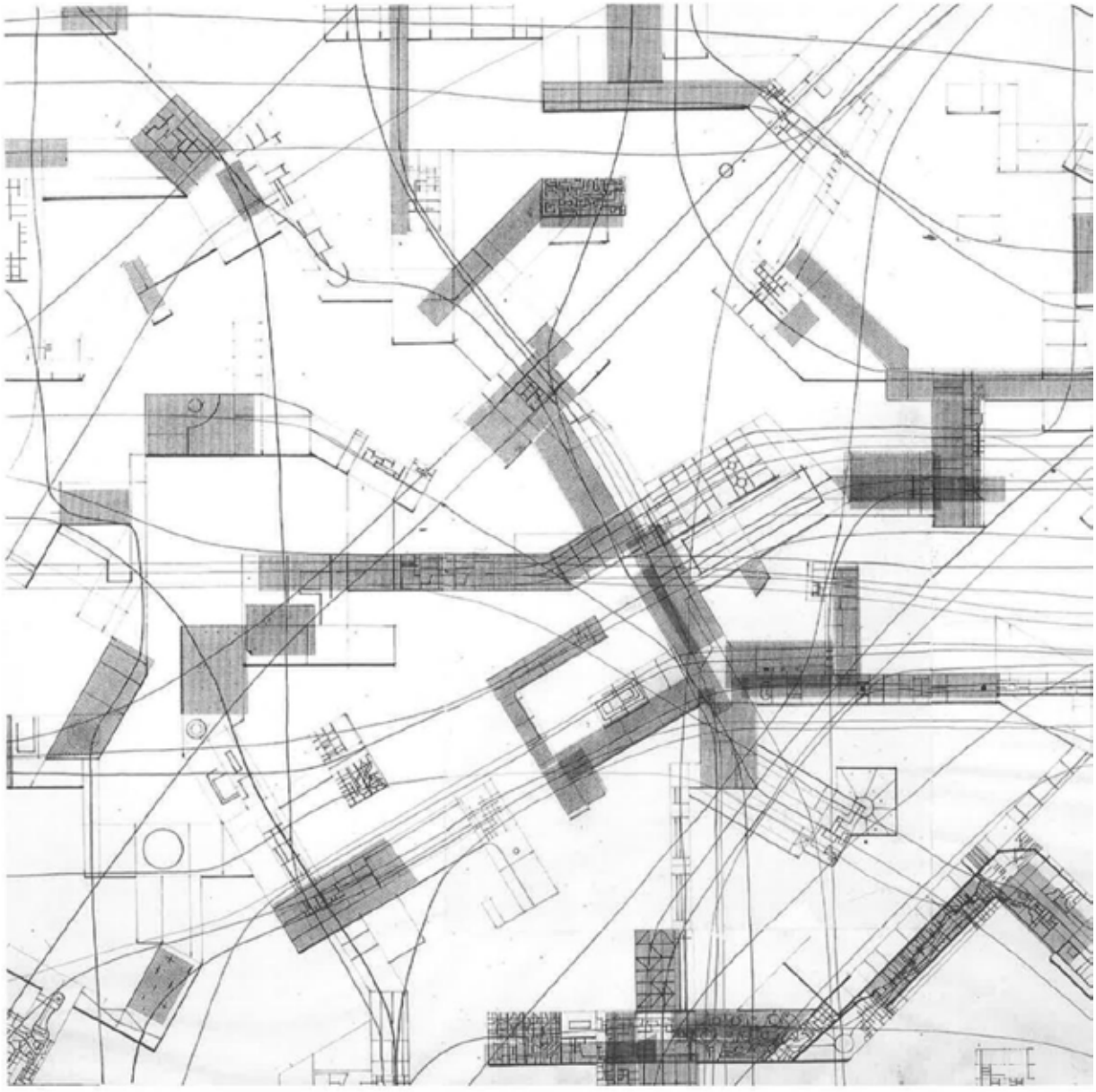


Figure 9. Plan of Constant's New Babylon, illustrating the looseness of self-establish links and pathways that unapologetically pierce through the urban fabric. Source: Wigley et al. (1999), p.9.

Whilst the descriptive view envisions the fractal city as it is, the prescriptive view imagines it as it ought to be. Here, one can borrow from Bernard Tschumi's arguments on the *Architectural Paradox* (or *The Pyramid and the Labyrinth*) to further elaborate on the paradox of experiencing the fractal city. As he states,

The paradox is not about the impossibility of perceiving both architectural concept […] and real space at the same time but about the impossibility of questioning the nature of space and at the same time making or experiencing a real space. (Tschumi, 1966 p. 30)

Fractals bridge the divide between *prescriptive* (e.g. 'designed') and *descriptive* (e.g. 'emergent') space by looking at the ways cities both evolve naturally based on socio-spatial dynamics and simultaneously offer a template for designing spaces attuned to complex patterns of behavior. Although similar to Alexander's point, this observation also reveals the necessary tension between cognitive coherence (reliance on familiarity) and organic complexity (chaos) (Batty, 2012). The fractal city is therefore both prescriptive and descriptive; ordered and chaotic.

6. Conclusion I

In the context of a transactional, capitalistic society where there is an ever-increasing privatization of urban space and maximization of environmental extraction, fractal thinking offers a model of resistance through the unfolding of patterns across nested, self-similar scales. Ultimately, this logic yields a concept of cities within cities. In this fractal model, the city is a living entity composed of multiple inner cities with their own spatial autonomy and temporal trajectory. These 'inner cities' exist alongside and within their hegemonic counterpart—the modern city. The fractal city thus becomes a node within a larger network of city nodes, whilst simultaneously hosting multiple sub-networks of inner cities. In other words, the fractal city exhibits both a bottom-up descriptive model and a top-down prescriptive model.

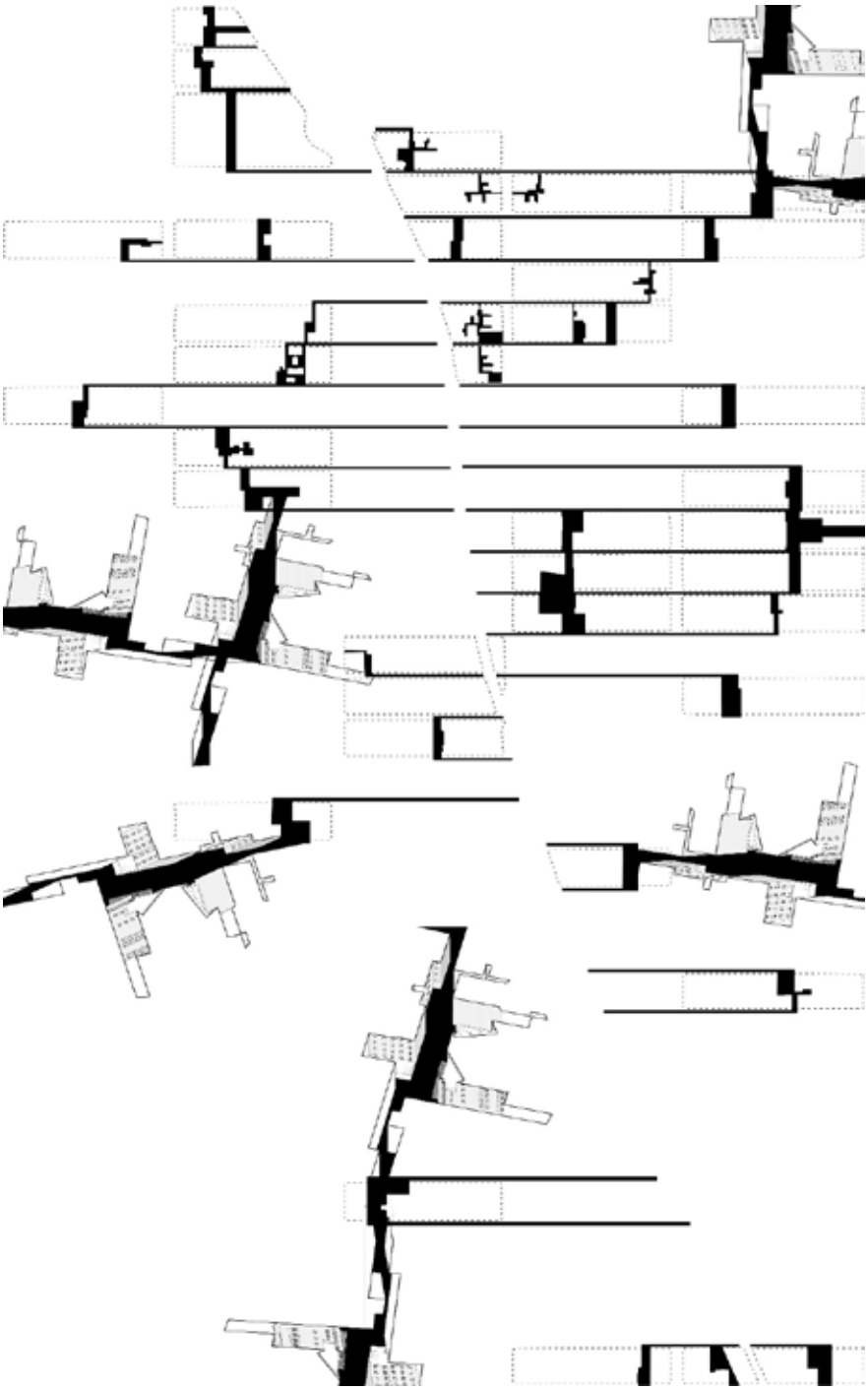
Through cracks, crevices, and the negative space that binds cities, fractal logic is ever-present, emerging as a kind of urbanism without urbanists, resisting against commercial forces that aim for maximum real estate returns. The fractal city expands slowly from within even as broader forces continue to delimb its growth trajectory. As such, to envision the fractal city is to describe it, rather than prescribe it. This is *The City in the City*.

The City in the City follows the narrative of a fractal city emerging out of an imaginary metropolis, slowly, connecting its crevices and in-between spaces, binding scales together, expanding and shrinking the city's perimeters all at once…

7. Conclusion II: *The City in the City*

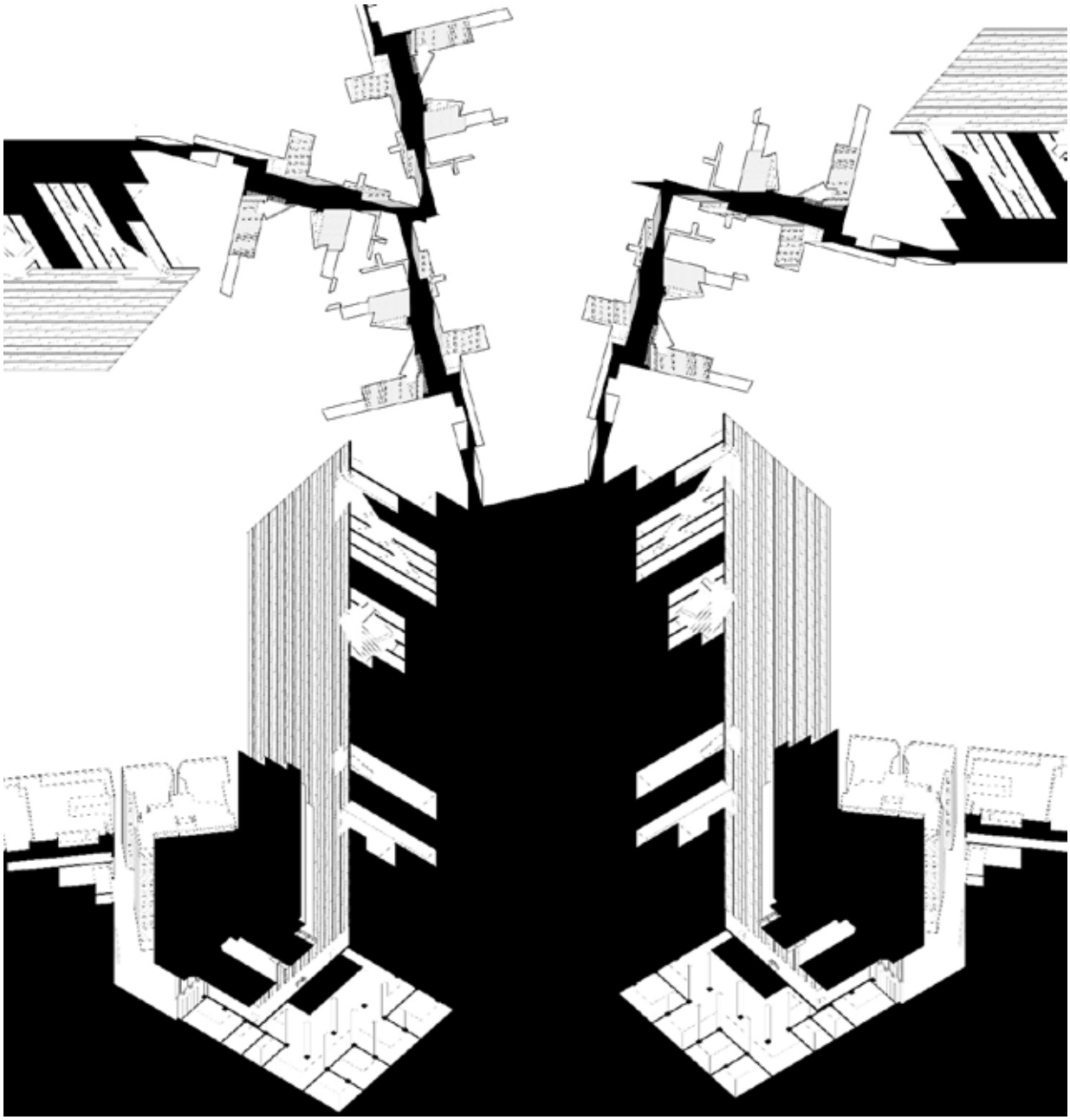
The metropolis holds an inconspicuous secret.

Snaking through its gridded form is a slow and gentle rupture; a growth that's both parasite and host. It latches onto the liminal as it extends new limbs, each a spatial binder linking territory with ritual. The result is an unconscious choreographing of space and time—a continuous assembly and disassembly of an armature for city life.



The armature is labyrinthine in form. It includes extensions of domesticity that swell beyond the private dwelling and coexist alongside nonhuman patterns of living, spilling into the gaps and crevices of the city. Cavities and left-over spaces become refuge for human and non-human life, like the nesting and roosting spaces of the migratory birds that frequent this metropolis. These actors discretely erode the city's boundaries; the planetary scale of their own rituals supersedes any human-defined perimeters, linking broad patterns of migration and evolution across territories and geographies.

A new armature is born out of these cavities. Operating as an incubator with its own set of histories and cosmologies, it belongs to a broader network of incubators, each expanding and contracting beyond the perimeters of the city. Sometimes these operate as a shroud, setting the stage for a clandestine act of urbanistic disobedience, or serving as a space of social insurgency. From the solid blocks of concrete, these tentative structures frame the opportunistic endeavors of its city dwellers—both human and nonhuman alike. Here, all lifeforms cross paths, linking fugitive timelines through cross-continental geographies, unfolding profusely against the modern forces that seek to suppress it.



Bibliography

Alexander, C. (1965). *A city is not a tree*. *Architectural Forum*, *122*(1), 58–62.

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A pattern language: Towns, buildings, construction*. Oxford University Press.

Batty, M. (2012). *Cities as complex systems: Scaling, interaction, networks, dynamics and urban morphologies*. In B. D. Malgorzata & K. R. Meckenzie (Eds.), Encyclopedia of complexity and systems science (pp. 1041–1071). Springer. https://doi.org/10.1007/978-3-642-27737-5_122

Eglash, R. (1999). Fractals in African settlement architecture. In *African fractals: Modern computing and indigenous design* (pp. 111–137). Rutgers University Press.

González, M. F. (2019, March 8). *The city in the air by arata Isozaki*. ArchDaily. https://www.archdaily.com/912738/the-city-in-the-air-by-arata-isozaki

Jahanmiri, F., & Parker, D. C. (2015). An overview of fractal geometry applied to urban planning. In *Proceedings of the 14th International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences* (pp. 280–287).

Batty, M., & Longley, P. (1994). *Fractal cities: A geometry of form and function*. Academic Press.

da Silva, D. F. (2022). *Unpayable debt*. Sternberg Press.

Griffith, D. A., & Arlinghaus, S. L. (2025). Urban Geography Compression Patterns: Non-Euclidean and Fractal Viewpoints. *AppliedMath*, *5*(1), 9. https://doi.org/10.3390/appliedmath5010009\

Kacha, L., Abdessemed, M. A. E., & Matsumoto, N. (2018). *Fractal features of urban fabrics and urban landscapes in Algiers, Tokyo and New York*. Cybergeo: European Journal of Geography, (867). https://doi.org/10.4000/cybergeo.38984

Lagarias, A. (2012). *Fractal analysis of the urbanization at the outskirts of the city: Models, measurement and explanation*. University of Thessaly, Department of Planning and Regional Development. https://doi.org/10.13140/RG.2.1.1515.2486

López Pérez, C., Arteaga Botero, G., Medina Garzón, H., & Anzellini, M. (2022). *Hábitat palafítico: Vida acuática en el Caribe colombiano*. Fundación Terpel; Universidad de los Andes.

Mandelbrot BB., 1982, *The fractal geometry of nature*, New York, W. H. Freeman.

Mehaffy, M. W. (2023). Patterns of Growth: Operationalizing Alexander's "Web Way of Thinking." *Urban Planning*, *8*(3). https://doi.org/10.17645/up.v8i3.6688

Rollino, A. C. (2024). *The Alexander-Eisenman debate on the background of different spatial theories*. Rethinking Space and Place. https://rethinkingspaceandplace.com/2023/11/22/the-alexander-eisenman-debate-on-the-background-of-different-spatial-theories/

Tschumi, B. (1996). *Architecture and disjunction*. MIT Press.

Wigley, M., & Constant, C. V. H. K. (1998). *Constant's new Babylon : The hyper-architecture of desire*. http://ci.nii.ac.jp/ncid/BA42176889