



Morphogenesis of street networks in informal settlements: Building/plotting/extending/gridding

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Received: 27 January 2026 / Accepted: 3 July 2026
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Abstract

This paper articulates an urban design logic of informal settlement. While there are many different morphological outcomes of informal settlement processes, there are common patterns of expansion, intensification, and design of public space networks. Unlike formal urban design where the street network comes first, informal settlement involves a complex co-emergence of buildings and streets. Based on a global range of morphogenic studies, this paper articulates the spatial logic through which street/lane networks emerge incrementally in conjunction with building and plotting. Morphogenic mapping shows how settlements expand and intensify, how they stabilize or ‘overdevelop’. Understanding this logic requires new concepts such as ‘incremental gridding’, ‘back-to-back plotting’, and ‘interface creep’. This work expands our knowledge of how informal urban design works, and how the emergence of ‘slum’ conditions might be avoided. A better understanding of this morphogenic logic is the basis for any effective approach to in situ upgrading.

Keywords Informal settlement · Networks · Urban morphology · Assemblage · Morphogenesis

Introduction

Most urban design theory is based on formally planned cities of the global North, yet the most rapidly expanding cities of the 21st century are those of the global South—the majority world—where rural-to-urban migration and population growth have largely been absorbed through the development and expansion of informal settlements. Such settlements

are often seen as unplanned or chaotic, yet they embody complex and dynamic interrelations between informal and formal modes of production that remain poorly understood. Based on a global study (Dovey et al. 2023), this paper will articulate the morphogenic processes that shaped the street networks of a broad range of informal settlements at a 4-ha scale. We define informal settlement as the incremental, unauthorized, and self-organized production of new urban neighborhoods. Such definitions are contested: informality is often defined as illegal or extra-legal and outside formal planning controls; it is also widely identified by its incremental and irregular morphologies; and it is often conflated with the slum conditions that may emerge. The incrementality is geared to limited or fluctuating resource flows where buildings and streets are produced in small segments. Without the regularities of the formal city, informal settlement is often distinguished by its ‘illegibility’—our incapacity to understand it from the position of ‘seeing like a state’ (Scott 1998). The informal is often seen as a form of disorder in contrast with the order of the modern state, yet also embodies a deeper order (Jenkins and Smith 2023). The label ‘informal’ is contested in part because most such settlement is produced by various kinds of intersection and mixing of formal and informal. We use the word ‘informal’ loosely to cover the range from highly informal towards the formal.

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Informal settlement is a mode of production, a form of urban design and planning that embodies a complex set of socio-spatial logics that are poorly understood and are the focus of this paper.

The field of urban studies broadly known as ‘informal urbanism’ dates from the 1970s with the realization that much of the economic production in Global South cities was beyond state control or taxation (Bromley 1979). Research in this field is now vast and it is no longer seen as a separate sector; definitions of ‘informal urbanism’ and its usefulness as a conceptual framework are contested. On one hand, it is often linked to the politics of the ‘right to the city’, insurgency and a transition out of poverty (Lefebvre 1996; Turner 1972). Yet it is also widely understood as a product of neoliberal capitalism and state control, with deregulated planning enabling exploitation of cheap labor (Davis 2006; Roy 2005; Yiftachel 2009; Finn 2023). This paradox of informal urbanism—as produced by the state yet beyond state control—is important, but cannot be explored here (McFarlane 2019; Banks et al. 2020; Dovey 2025).

We stress ‘settlement’ as a verb rather than a noun, as a mode of production that typically helps lift people out of poverty. The best measures available suggest that the proportion of urban population living in slum conditions in developing cities has declined over the past three decades while informal housing production has increased (UN-Habitat 2016a; 2016b). Informal settlement may involve substandard conditions, but as a means of production it cannot be a euphemism for ‘slum’ (Dovey et al. 2021). In population terms, informal settlement has become the dominant mode of urbanization within most developing cities of the global South, absorbing population growth and rural-to-urban migration, and producing affordable housing and neighborhood infrastructure for those who cannot gain access to formal housing. While such settlements may seem unplanned, there is a spatial, social and economic logic that drives such development at the broader metropolitan scale. Informal settlements emerge in locations where there is a capacity to build and to gain access to jobs. While informal settlement is often hidden from the middle-class gaze, behind walls or seen from a distance, it is in no way marginal to the more formal city. When the state turns a blind eye to informal settlement it is often because it plays a crucial role in supplying cheap labor, products and transport, without which the more formal city could not function. Settlement is thus driven by the dual desires for the livelihoods of residents and the lifestyles of elites.

Informal settlement is not singular but differs with topography, geography, climate, culture, materials, economics and politics. It settles on both public and private land, with many degrees and kinds of land tenure. While broadly understood as ‘self-organized’, a multiplicity of agents can be involved beyond residents and community-based organizations,

including NGOs, land traffickers, land mafias, and state agencies. There are no purely ‘informal’ settlements, and no clear divisions between formal and informal. While informal settlement can occupy valued urban spaces such as parks, sidewalks, and natural assets, it more commonly brings underutilized land into use and expands across the urban fringe. It often produces new land as marshes are drained and waterfronts are filled; it brings inaccessible escarpments into productive use; and it fills the interstitial spaces of formal urban development. The incrementality and flexibility of informal settlement afford it the capacity to develop neighborhoods with affordable housing that formal urban development has been unable to produce. While poorer settlements develop incrementally, larger building types and more regular street grids are evident where more resources and organizational capacity are available. Informal settlement is shaped by the morphological conditions of the landscape and its existing infrastructure. It is also conditioned by the political context – construction may be camouflaged and may proceed swiftly or slowly depending on the threat of eviction or the prospect of de facto land tenure. The visibility of informal settlement from the formal city mediates the impact on the image of the city. Settlement residents mostly seek to avoid exposure, but may also engage in strategically leveraging visibility to attract resources, political advantage or slum tourism (Dovey and King 2011).

What is most at stake in this paper is the future of public space and street networks in existing and rapidly expanding informal settlements. While the demolition of such settlements continues at a global scale (van Oostrum 2025), the overwhelming majority are relatively permanent—the infrastructure of street/lane networks that becomes established in the early phases is the framework for future development. The structure of plots, streets and lanes affects the size and shape of future buildings and upgrading practices. The initial urban design has major impacts upon the capacity for densification and on the economics of upgrading the water and sanitation infrastructure. Once the urban morphology becomes ‘settled’, then it becomes difficult to change. Our focus is on better understanding the urban design practices that produce these public space networks.

This is a comparative study that prioritizes breadth rather than depth. While every settlement is shaped by distinct local conditions and grounded in local politics, there is also a pressing need for a comparative global understanding (Robinson 2021). We want to stress the materialities and morphologies of a shared spatial logic that is evident in these settlements and exposed through morphogenic mapping. This focus on morphology will raise many important questions about the interrelations between spatiality and sociality, which are inextricably intertwined. We will sketch such connections where possible, yet most will lie beyond the scope of this global study.



This work can help to counter the argument that informal settlements are chaotic, and it can expose capacities for effective in-situ upgrading. What are the different ways in which informal morphogenesis occurs, and how do they impact the emergent structure of buildings, plots and street networks? What are the impacts on the capacity of a settlement to function as a framework for future development? Morphogenic studies can also enable more effective slum upgrading practices that can harness the positive capacities of informal production, create pathways to regularization, and anticipate future settlement. Under what conditions and at what stages does the informal morphogenic process produce substandard conditions? While ‘upgrading’ is generally defined as a project applied within a settlement, informal settlement is already a form of upgrading of unbuilt land into affordable housing.

Informal morphogenesis

Morphogenic studies of informal settlement have a very long but thin history, beginning with the pioneering work of Geddes (1999 [1915]) whose theories on the evolution of cities and Indian cities recognized an informal urban design logic. The idea of ‘conservative surgery’ proposed conserving informal street networks while public spaces are expanded and protected (Geddes 1947). Though his impact was little, his broader theories resonate today (Batty and Marshall 2009). Since then, typomorphologists such as Conzen (1968), Muratori (Cataldi et al. 2002) and Caniggia and Maffei (2001) have studied how building types shape urban form. In studies of European urban history, Humpert (1992) proposed a typology of six urban growth types, of which four informal (cluster of buildings or plots, along major routes, extension off routes, bridging between routes) and two formal (around a public nucleus and planned street network). More broadly, Kostof (1991) makes a clear distinction between planned and ‘organic’ cities, but this label says little and risks naturalizing socio-political processes. Marshall (2009: 79–82) distinguishes a ‘systematic’ urban order applied from above, from a ‘characteristic’ order which is emergent—both forms of ‘order’ that co-exist. Jacobs (1961) opened an enduring inquiry into the city as a system of ‘organized complexity’, and such approaches have been developed by Salingaros (2000) and Mehaffy (2008). There has been considerable application of theories of self-organization and complexity at the metropolitan scale (Portugali 2000; Batty 2013) but very little at the scale of buildings, streets and laneways.

There is a broad literature on the role of formal codes in urban planning and design governance (Ben-Joseph 2005; Talen 2012), however, understanding of the emergence of informal codes is rare. Ostrom (1990) has demonstrated how the ‘tragedy of the commons’ can be averted through

informal codes of self-organized governance, but this has only rarely been applied to informal settlements (Foster 2008). Arefi (2011) suggests that the logic of informal settlement is an implicit order, based on rules or patterns that are fluid, adaptable and not easily detectable. Some researchers have noted that informal settlements tend to pass through an expansion phase first, before ‘consolidating’ in an intensification phase during which buildings and access networks become more permanent (Fekade 2000; Alsayyad 1993; Zillman 2000). Turner’s (1972) work on the value of informal housing production was influential and challenged dominant planning paradigms by advocating for a user-centric design process. Hakim (2008) has shown how informal building codes have produced and maintained the qualities of public space in traditional Mediterranean urbanism. While there have been many studies of the morphology of informal settlements, detailed studies of informal morphogenesis are rare. Most of these are relatively recent and are limited to particular case studies (Iovene et al. 2017; Thinh and Gao 2021; Kamalipour and Iranmanesh 2021), regions (Verniz and Duarte 2020) or settlement expansion (Samper et al. 2020). What remains missing is a comparative, multi-scalar understanding of how informal morphogenesis emerges through everyday spatial practices across diverse geographies and socio-political contexts—particularly at the small, intermediate scales where street networks, plot divisions, and building forms co-evolve in incremental and often improvised ways.

Figure 1 shows 15 recent satellite images of informal or semi-formal settlements at a scale of four hectares (200×200 m). Each of these neighborhoods has been settled over the past two decades on unsettled or cleared land, and without state authorization or control. They are diverse but typical cases from rapidly expanding cities of the Global South, ranging from highly informalized at the top through different degrees and kinds of informal or semi-formal urban design. They include examples from different regions: five each from Latin America and Africa, four from Asia and one from the Middle East. These are the sites that will be mapped and analyzed in this paper (Figs. 3, 4, 5, 6, 7).

Research approach

Our approach involves a focus on the production of buildings, plots, streets/lanes and blocks—generally identified as morphological elements that are combined to produce the urban fabric (Scheer 2016). These conceptual types are defined relationally. In a formal neighborhood, ‘buildings’ are constructed on ‘plots’ which have access to ‘streets’ or ‘lanes’ which are defined as linear access routes lined with buildings and plots. ‘Blocks’ are defined as contiguous clusters of plots or buildings that are encircled by streets or lanes. The design of the street/lane network with blocks



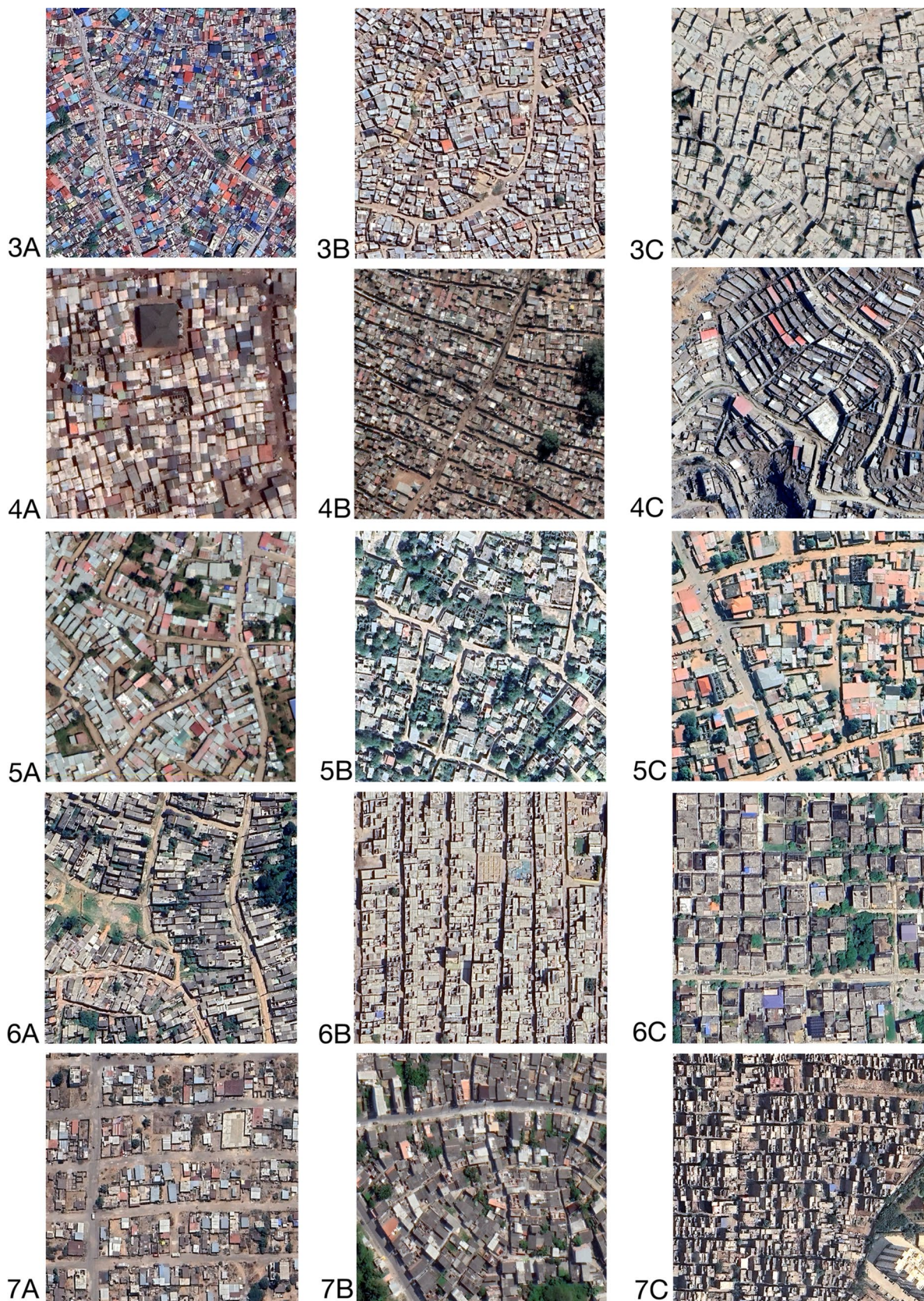


Fig. 1 Forms of informality (Source: Google Earth)



and plots is established first and the buildings follow within that framework. While we adopt this language, informal settlement requires that we rethink the morphogenic process. Informal settlement often begins with buildings that intensify incrementally; plots may not exist or remain unmarked in early phases. The access network often begins as tracks or leftover space that morphs into streets and blocks over time. This is a much more complex, emergent and less predictable process than formal urbanization.

An informal settlement is a complex adaptive assemblage (Dovey 2012). The complexity derives from the multiplicity of social, economic, political, legal, topographic and climatic factors at play in any given settlement. The adaptation is embedded in the relational interplay between architecture and urban design—buildings and plots adapt to streets, and streets adapt to buildings and plots. It is an ‘assemblage’ (Deleuze and Guattari 1988) because it is clearly not a ‘system’; the whole is not an agglomeration of parts but a multiplicity of social, spatial and material interconnections. While we discuss buildings, plots, streets and blocks as morphological elements, they are not things-in-themselves. Our use of verbs—building, plotting, extending, gridding—embodies a focus on becoming rather than being, and distinguishes this approach from the analysis of spatial patterns (Kostof 1991; Marshall 2009). Mapping becomes a production of spatial knowledge rather than mimetic representation, a sifting and extraction of data to tell a story that is located between the maps as much as in them (Pafka and Dovey 2024). The diagram has a key role in assemblage thinking to show the productive relations of an assemblage in abstract form, an ‘abstract machine’ (Deleuze and Guattari 1988: 141–148). We acknowledge that it can be difficult to read the correlations between maps, satellite images, diagrams and text, but this is a key task of assemblage thinking.

The analysis that follows is drawn from the database of a much larger project based in a survey of several hundred contemporary settlements in cities across the Global South, and where reliable morphogenic data was available on Google Earth (Dovey et al. 2023). This data was supplemented by websearching, archival research, and fieldwork in many cases. This paper analyzes the morphology of 15 of these settlements at a 4 ha scale showing three phases of settlement development. Our focus on this scale is not to suggest that other scales matter less, only that it best captures the shaping of street/lane networks. Informal settlement follows a different set of spatial logics at the larger scale of connection to the formal city (Dovey and Recio 2024), and at the smaller scale of incremental architecture (Kamalipour and Dovey 2020). The sites have been selected to represent a global range of different urban conditions, degrees of informality and morphological outcomes. Detailed mapping of buildings and street networks, based on the evidence of the sequence of aerial photographs, is the key method,

augmented with Street View, websearching and archival research. All mapping is by hand to avoid distortions and misclassifications that can be produced by automated remote sensing. There are important limits to these data sources, particularly in relation to the micro-laneway network where the Google Earth data becomes less reliable. Our method is to use consistent criteria in this regard and not to speculate. In some cases, water bodies and access routes are blurred on the maps because the evidence shows this ambiguity. The original aerial photos can be found through the geolocations noted on each set of maps. These maps are not illustrations but rather the means through which these morphogenic processes have been studied—the findings are evident in the differences and interrelations between the maps.

Each informal settlement is a dynamic intersection of diverse forces, flows, desires and practices, all mediated by social, political, economic, legal, climatic and topographic conditions. Our focus is on the evolving morphology of public space over time as territories (buildings and plots) become settled, and as access networks (streets and grids) are incrementally defined, extended and changed over time. This process is best understood not as the realization of a fixed form but as the emergence of spatio-temporal arrangements—alignments of materials and desires. What emerges is not a universal logic, but a form of situated spatial knowledge or intelligence, a capacity for organizing and stabilizing life in uncertain terrain. Our maps and diagrams reveal socio-spatial solutions to generalized problems of shelter, access, economics, community and kinship. These assembled formations hold within them a certain provisional stability—like plateaus—yet remain open to transformation (Deleuze and Guattari 1988). Rather than attempting to fully pin down such arrangements, we are interested in how they emerge and produce urban space in ways that elude formal planning categories. Data from sequential aerial photographs were supplemented in each case with streetscape photography, literature review, websearching and fieldwork in some cases. Statements about the agency of different actors draws on triangulated evidence from multiple sources including Street View, aerial photos, websearching and archival sources, but remain somewhat speculative. The logic we have used is mostly abductive rather than inductive, providing the best explanation of a morphological outcome; a self-organized process will produce differences between increments of change, and these irregularities are evidence of self-organization.

The limits of this study are twofold. First, aerial photographs do not always show reliable data in relation to morphology and morphogenic change. Small lanes are often hidden and there are limits to the accuracy of reading differences between plot boundaries, buildings and lanes. We have chosen sites and images where data is more reliable, but the limits remain. Second, there are important limits



to our focus on morphology and spatiality. Other fields of research—ethnography, land tenure, health, governance, economics and politics—will provide different, if relatively aspatial, accounts of the same settlements. We don't seek to displace such approaches but to add to them and to expose some interconnections with urban design and built form. While we may use the term 'informal' in a generic sense to refer to self-organization, it is clear that most of these cases involve a complex assemblage of agents including state actors. While such questions will be raised and addressed in places, a detailed account of community organization and agency lies beyond the scope of this paper. This is a global comparative study with breadth rather than depth.

The paper proceeds loosely from the more informal to the more formalized morphologies, as shown in Fig. 1. We begin with the territorializing processes of building and plotting before proceeding to an analysis of street network formations. However, neither logically comes first since buildings and streets shape each other. Pre-existing access routes generally become the framework for the earliest buildings or plots, and the logic that all buildings and plots require access also drives the street network. Buildings and plots shape streets and lanes which shape buildings and plots. Architecture and urban design co-evolve in varying degrees and ways. This is more than a simple reciprocity or dialectic, but a set of interrelations that will play out over the next two sections.

Building and plotting

'Building' and 'plotting' are both practices of territorialization; alternate ways of asserting private claims to land. Building is a material act of claiming territory, where the building footprint becomes the public/private interface. Plotting involves staking out a territorial claim in advance of construction. In a formal design process, the plot comes first as part of a street plan, and buildings follow within legal boundaries—the public/private interface is clearly established in advance. In the case of informal settlement, territory is claimed through various combinations of building and plotting. A significant number of informal settlements have no plots, and territory is established by building. Building and plotting are different but intersecting modes of territorialization, different ways in which boundaries between public and private spaces become inscribed and established.

The diagrams in Fig. 2 outline the way different kinds of building and plotting intersect with different levels of organization to produce four common practices we call 'incremental building', 'semi-regular building', 'incremental plotting' and 'semi-regular plotting'. These are not settlement types since any particular settlement may have examples of more than one of these formations, or slip between them. What is

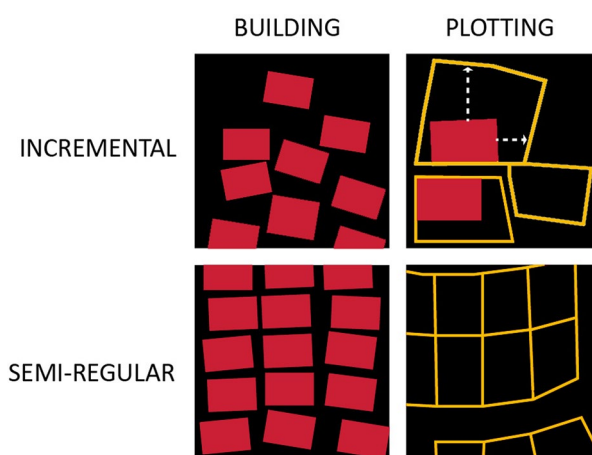


Fig. 2 Building and plotting (Source: Authors)

at stake here is how different configurations of building and plotting shape the emergence of public/private boundaries in the early stages of settlement, and how these configurations condition the long-term morphology of informal urbanism—particularly in terms of its capacity for densification, adaptability, and overdevelopment.

Incremental building

Incremental building occurs when buildings are located, oriented and constructed based on individual decisions by a single agent. While there may be regularities based on terrain, building type and increment size, the evidence for incremental building lies in the irregularity of relations between buildings; the plan is best explained as the outcome of multiple household-level decisions. This pattern is common in the initial phase of many settlements. Figure 3 shows a set of morphogenic sequences for three settlements in different geographic regions. In each case three aerial photographs have been chosen and mapped to reveal key moments in this morphogenic process. We have developed a mapping language that is designed to enable the morphogenic process to be read as clearly as possible, but it requires some learning on the part of the reader. Informal building footprints are mapped in two tones of red with the brighter tone representing the most recent layer at each morphogenic stage; those demolished since the previous stage are olive. These building footprints are then related to access routes (white) with plot boundaries (orange), field boundaries (green) and water bodies (teal) added where necessary. Our analysis is focused on the interrelations between maps. In these maps incremental building is evident in the early phases of settlement as land is claimed before the street/lane access becomes clear. Building increment sizes differ according to local building types: single room increments in Fig. 3A (*Baseco*) and 3B

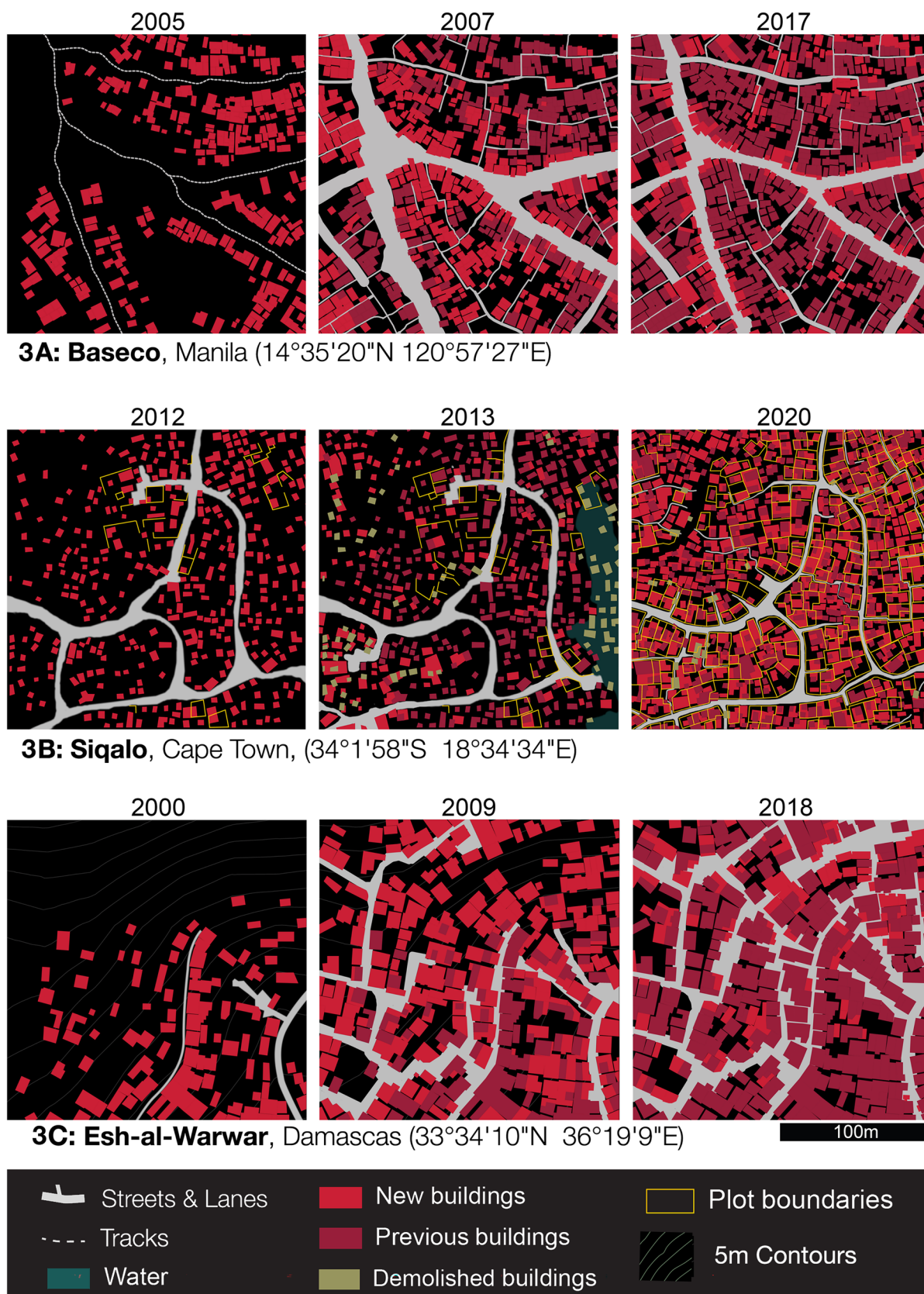


Fig. 3 Incremental building and plotting (Source: Authors)

(*Siqalo*), and multi-room buildings in Fig. 3C (*Esh-el-Warwar*), but in each case the building establishes the initial territory. This settlement expansion may be progressive as in the gentle escarpment of Fig. 3C (*Esh-el-Warwar*), or more distributed as in 2B (*Siqalo*) with flatter land. In Fig. 3A buildings are loosely aligned with pre-existing drainage patterns, which later become the main public lanes of the settlement. The empty spaces between buildings are filled as new buildings are added incrementally. The gradual reconfiguration of the public/private interface through a process where streets, lanes and open spaces are encroached through small-scale expansions is what we call ‘interface creep’—particularly evident in Fig. 3A (*Baseco*). This often produces a public space network with a few main laneways that allow car access, and a labyrinthine network of narrow laneways with pedestrian and motorcycle access. The resultant urban design is irregular, but is driven by informal logics that maximize the affordances of different terrain conditions.

Semi-regular building

Buildings in informal settlements are often roughly aligned or contiguous to produce a more efficient close-packing arrangement and reduce the wastage of interstitial space. The morphological outcome is semi-regular rows, often in blocks that are two buildings deep with access on both sides (Fig. 2). This mode of morphogenesis is characteristic of settlements with mostly single-room increments but where space is limited, producing semi-organized morphologies as in Fig. 4. This organization of back-to-back buildings forming narrow laneways means that public space tends to be more limited, with less capacity for interface creep in later phases. Semi-regular building often involves progressive layers, such as getting closer to the water (4A) or further up the escarpment (4C). Although driven by informal logics, this produces a semi-regular morphology. The olive-colored buildings show that the settlements in 4A (*Old Fadama*) and 4B (*Angelo*) were largely demolished but later re-emerged with a similar spatial logic. Figure 4C (*El Paraiso de Jicamarca*) shows a settlement on a steep escarpment where larger buildings of 2–3 rooms are aligned along contours; here the morphogenic process again can be described as semi-regular building, but begins to morph into what we call ‘Semi-regular plotting’ (Fig. 2).

Incremental plotting

While a formal plan is generally comprised of regular plots with pre-defined relationships between them, incremental plotting involves the claiming and enclosure of space in a self-organized manner; this may include the practice of extending the territory of a building to enclose adjacent land (Fig. 2). Incremental plotting is most common in the early

phase of settling land with existing tenure claims such as farmland and grazing land. In Fig. 5A (*Hana*) we can see the former field boundaries (green) become a framework for the emergence of plots (orange) that are often later subdivided. Figure 5B (*Jerusalem*) shows a case where plots were claimed first, followed by buildings and then subdivision. Figure 5C (*Wenji Maka*) is much more mixed and ambiguous; there are buildings without plots, plots without buildings, and buildings where adjacent land is later claimed as a plot. This mix of incremental building and plotting was also evident in the later phases of Fig. 3B (*Siqalo*). The process of incremental plotting generally incorporates subdivision as the settlement densifies, and the large earlier plots become subdivided. Where land is more scarce plotting becomes more controlled, efficient, and designed for local building types. The resultant public space network in processes of incremental plotting is irregular, with relatively little hierarchy between street widths. Where the initial plots are large, the subdivision process produces dead-end laneways. This morphogenic process produces significant amounts of private open space, although they often get built out.

Semi-regular plotting

As the urban design process becomes more organized, forms of semi-formal plotting emerge where plots become more standardized and arranged into contiguous blocks with street access. Such plotting is generally guided by the logic of ‘back-to-back’ plotting – just like the process of semi-regular building, plots are semi-organized into back-to-back rows forming blocks that are mostly two plots thick (Fig. 2). This is simply a close-packing rule that is the most efficient manner of providing street/lane access to a maximum number of plots without redundancy. This spatial logic results in a repetitive pattern of relatively consistent block width; it is independent of scale and operates more broadly in the design of street grids, shopping malls, car parks, dense office cubicles and library bookshelf layouts. Informal settlement often deploys the back-to-back logic as a mode of incremental expansion where each block and its adjacent streets are extended as the settlement expands. Some settlements, such as 4B (*Angelo*) begin with semi-regular building, and morph into semi-regular plotting in later phases.

Figure 6A (*Rio Abaixo*) shows a production of relatively regular plot size and shape. These plots are geared to local row-house types and the narrow shape makes subdivision difficult. Figure 6B (*Gulshan-e-Sikarandabad*) shows back-to-back plotting that is extended incrementally as a waterbody is filled to produce new land; the street becomes the means of producing the territory to which it will then provide access. In a parallel manner, Fig. 6C (*Maxicun*) shows a village development in China where the plotting process is geared to the production of small apartment buildings, and



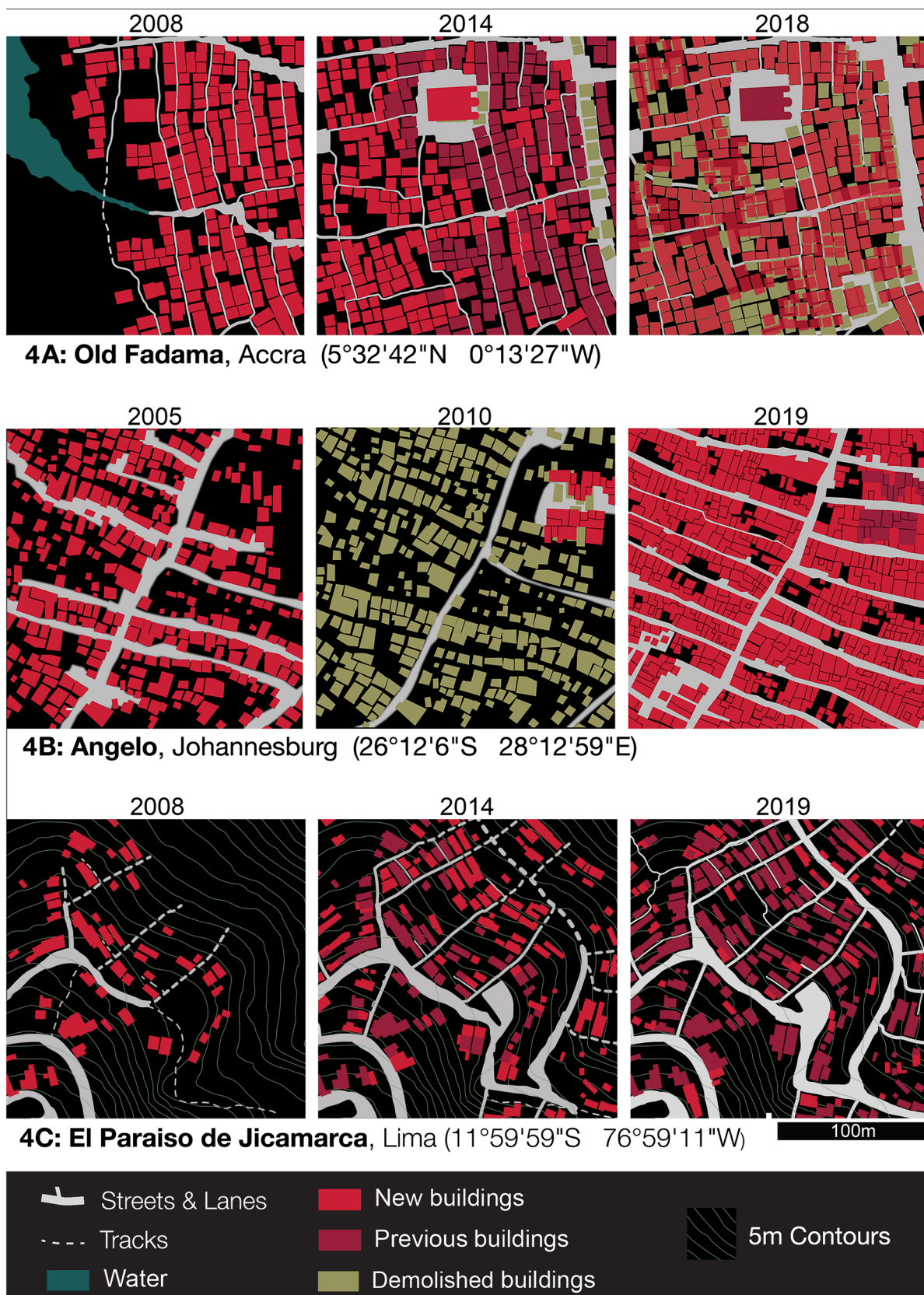


Fig. 4 Semi-regular building (Source: Authors)



5A: Hana, Addis Ababa ($8^{\circ}55'2''\text{N}$ $38^{\circ}44'0''\text{E}$)



5B: Jerusalem, Port-au-Prince ($18^{\circ}39'31''\text{N}$ $72^{\circ}15'12''\text{W}$)



5C: Wenji Maka, Luanda ($8^{\circ}54'54''\text{S}$ $13^{\circ}17'5''\text{E}$)

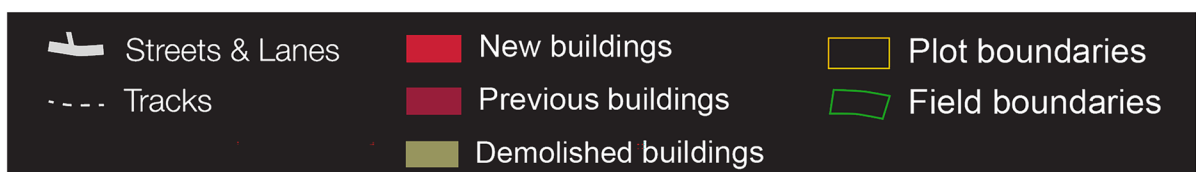


Fig. 5 Incremental plotting (Source: Authors)





6A: Rio Abaixo, Sao Pãolo (23°31'2"S 46°17'13"W)



6B: Gulshan-e-Sikarandabad, Karachi (24°49'28"N 67° 0'27"E)



6C: Maxicun, Haikou (20° 3'47"N 110°22'39"E)

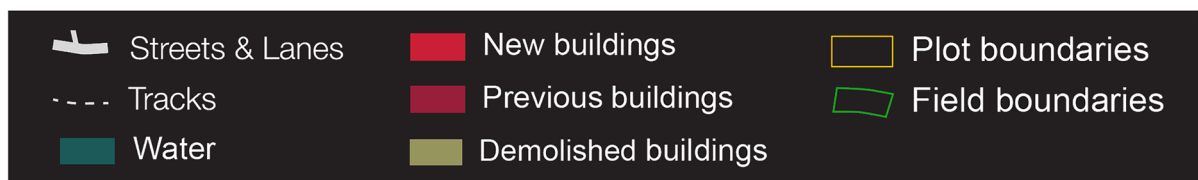


Fig. 6 Semi-regular plotting/incremental gridding (Source: Authors)

organized to align with a pre-existing grid of farm fields. Semi-regular plotting can produce long and roughly straight streets with blocks that may seem formally planned. They also typically have larger building typologies that include private or semi-private open space. What they generally indicate is a higher level of organization that may include village councils (6C) and land traffickers (6B).

Demolishing

Building and plotting involve the establishment of territories, but this story is not complete without a brief discussion of demolition. Demolished buildings are evident in the olive-colored buildings in the maps above, which show that incremental demolition is common in the later phases of all but the most formalized of these settlements. The initial layer of construction may be makeshift, built swiftly as a temporary land claim due to limited resources or access, or purposely planned to be demolished and replaced once the land claim is more secure or more resources are available. This is particularly evident in Fig. 5B (*Jerusalem*) and 6A (*Rio Abaixo*). A different process that we call adaptive demolition occurs when there is a collective benefit such as to make way for new street connections, as evident in the second phase of Fig. 4A (*Old Fadama*). Figure 7A (*Santa Catarina*) is a settlement where a non-orthogonal and semi-regular street grid was demolished and replaced with a more orthogonal one. The spatial logic here extends beyond the efficiencies of closely packed plots to include the desire to match the street morphology of the more formal city as a strategy to achieve formalized tenure. Informal urban design is an experimental and adaptive process shaped by feedback loops, where designers adjust and respond to evolving socio-spatial developments. Figure 4A (*Old Fadama*, phase 3) and 4B (*Angelo*, phase 2) show cases of wholesale forced demolition by the state. In both cases, informal resettlement soon followed, based on a similar spatial logic, although more organized in the latter case. Figure 3B (*Siqalo*) shows a patch of demolished housing during the middle phase that was caused by flooding, and the same morphology re-emerged.

Extending and gridding

The most basic spatial principle of any settlement involves public access to every private territory. While buildings and plots establish territories, flows of traffic access those territories. While connections to the broader city are crucial to livelihoods, our focus in this paper is on the emergence of access networks within settlements. How is access to buildings and plots established and what logic drives the street and lane formation? What street/block morphologies are

typical and how are they formed? The top row of diagrams in Fig. 8 shows a range of morphological practices that we identify as fundamental to the incremental emergence of informal street/lane networks—‘extending’, ‘branching’, ‘bridging’ and ‘deleting’. Again, these are not settlement or network types but topological transformations that are broadly evident within informal settlements.

Extending, branching, bridging and deleting

Existing access routes are an obvious location for initial settlement, and ‘extending’ an existing road or track to produce newly accessible land is a logical urban design decision as settlement proceeds. ‘Branching’ is simply the production of laterals from an existing road to access further land on one or both sides, generally producing ‘comb’ or ‘fishbone’ formations, as evident in most of the morphogenic maps in Figs. 2, 3, 4, 5, 6. Branching is undertaken to both open up new territory and to provide access to subdivided properties. The practice of ‘bridging’ between existing roads increases network connectivity by reducing the size of large impermeable blocks. What begins as a branch may be extended to become a bridge. ‘Deleting’ involves converting redundant access routes into private territories as evident in Fig. 5C (*Wenji Maka*) and 5B (*Jerusalem*). This is most common where multiple pathways emerge in early phases of settlement, and some disappear as plots and buildings fill the gaps. It reduces the permeability of the network, and for this reason it is rarely found in blocks of more than ~100 m in length.

These four forms of spatial logic – extending, branching, bridging and deleting – are primary generators of irregular street/lane networks and are evident to some degree in every informal settlement except the most organized. A key factor is the impact of these morphogenic principles on the urban intensity of the settlement. Under conditions where the settlement extends and branches progressively from its earliest street connections, then these early streets tend to become and remain the main streets with more traffic, functional mix and density. This is often the case in escarpment settlements such as Fig. 3C (*Esh-el-Warwar*) and 4C (*El Paraiso de Jicamarca*). However, every bridge or deletion redistributes traffic flows across other connections and thereby re-shapes the movement economy; density and functional mix become more distributed, less predictable, and will often change over time.

Gridding

An urban grid is generally defined in terms of a formal process that generates a network of parallel streets that cross each other to form regular rectangular blocks. Irregular grids have often been seen as ‘distortions’ or ‘hybrids’





7A: Santa Catarina, Mexico City (19°18'6"N 98°57'53"W)



7B: Iriguacu, Salvador (12°49'47"S 38°28'59"W)



7C: Mandoli, Delhi (28°42'32"N 77°19'30"E)

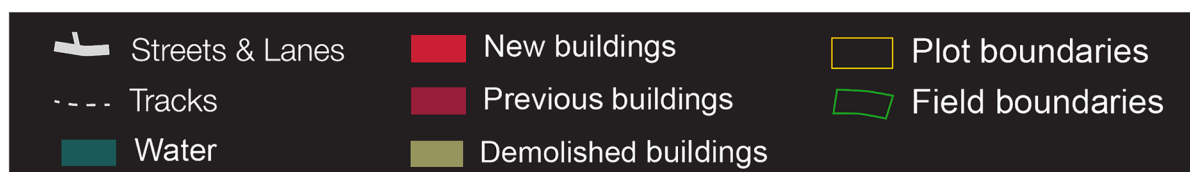


Fig. 7 Gridding (Source: Authors)

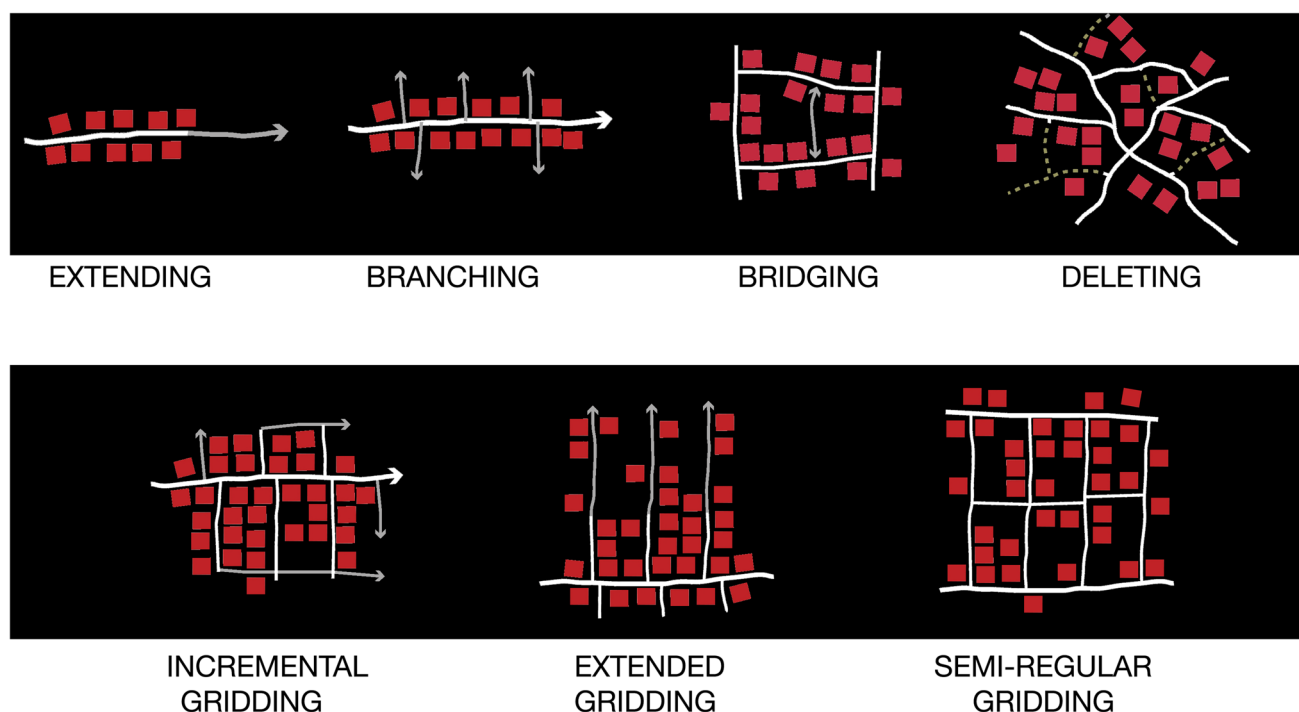


Fig. 8 Extending and gridding

(Marshall 2005), as if the grid would be the desired ideal, compromised for topographic or other constraints. Informal settlements often show the characteristics of a distorted or semi-formal grid, but the morphogenesis is fundamentally different. ‘Incremental gridding’ is where a grid formation emerges from a process of incremental extending, branching and bridging until blocks are formed as in Fig. 8 (lower left). This process is most evident in Fig. 7B (*Iriguaçu*) where successive branching and bridging generates an irregular grid. An important variation here is ‘extended gridding’ where a similar logic produces rows of back-to-back plots or buildings that are progressively extended without lateral connections. This process is diagrammed in Fig. 8 (lower center); as plots or buildings are added, the block gets longer and longer without completion, producing a highly impermeable settlement with blocks exceeding 100 m in length. The logic here is that every extension generates an extra building or plot, and since the same logic applies to the next increment, the common interest in lateral connectivity is repeatedly deferred in favor of more private plots. Any later bridging connection becomes difficult because it requires the demolition of two private properties. This process occurs when the logic of back-to-back plotting or building is applied, but the logic of walkable access is not. It can be common on waterfront conditions where land is slowly produced by dumping soil and extending onto the new land, as evident in Fig. 6B (*Gulshan-e-Sikarandabad*). It often indicates

the involvement of land traffickers where the imperatives of profit displace common interests.

Incremental and extended gridding are outcomes of the extending, branching and bridging practices outlined earlier. ‘Semi-regular gridding’ is when a street network is pre-conceived or planned during development, as can be seen in Fig. 7C (*Mandoli*). In other words, the increment of development changes scale from a single building, plot, street or lane to a block or several blocks framed by streets or lanes. The common outcome is a semi-regular grid with blocks that are two plots or buildings thick in the shortest dimension with laterals at semi-regular intervals, as diagrammed in Fig. 8 (lower right). Semi-regular gridding requires some level of organization in advance of construction, whether initiated by community-based organizations or pirate developers.

The diagrams we have sketched in Fig. 8 are not discrete. Most informal settlements show evidence of a mix of morphogenic processes. Figure 6C (*Maxicun*) shows a mix of incremental and semi-regular gridding with local community playing a key role as land holders and developers. Figure 6B (*Gulshan-e-Sikarandabad*) and 7C (*Mandoli*) both mix extended and semi-regular gridding, and both involve pirate developers or land traffickers.

Permeability

The permeability of pedestrian networks is widely understood to have a profound impact on the economy and

sociality of any neighborhood; here it becomes an emergent property of informal morphogenesis. While these 4-ha maps cannot show the broader connectivity, they do show high levels of variability in block size and shape. We have pointed out the extreme impermeability produced by extended gridding, but there are also patches of hyper-permeability where each building is surrounded by publicly accessible space. Most settlements begin as open sites and become less permeable as building and plotting intensifies and territories are claimed. Many settlements are highly permeable in one part, or one direction, while impermeable in another, as evident in Figs. 4B, 6B, C and 7C. We note that impermeability is more often produced by more organized forms of development. The production of both hyper-permeable networks and hyper-extended blocks is a key difference between an incremental morphogenesis compared to formal urban design. A further key difference is that the incrementalism of an informal process means that settlement permeability changes over time through the processes of bridging, deleting and demolishing.

Rights of way

The width of streets and lanes is one of the most significant factors in the morphogenesis of informal settlement since it shapes the sociality, connectivity and productivity of public space. Street and lane widths range from a half meter to 12 m, but 2–5 m is most common. Within this range, differences of width are crucial because every extra meter enables a different range of uses and modes of access. An incrementally produced street will often vary in width along its length, and can be widened or narrowed over time through demolition or interface creep. Mode separation between pedestrians and vehicles tends to be enforced by lane-width rather than sidewalks. Where residents or developers are relatively organized, then road widths are wider and may follow prevailing formal standards in anticipation of formal legitimation.

Pedestrian rights-of-way are at least a half-meter wide; however, 1–2 m is much more common. Access routes wider than this may be encroached by building extensions, stairways and so on, but only up to this limit. Many access routes emerge between 1 and 2 m width, which also enables access for motorcycles, depending on the extent and sharpness of turns and steps. There is no clear matching of street width to transport modes because such access is in turn mediated by other factors including terrain, interface conditions, turning radii and the appropriation of lanes for social and productive functions. Car access requires at least 3 m width, but 4–7 m is more common due to the need for turning and negotiated passing. Building entrances, steps, parking, greenery, seating and vendor stalls frequently project into public space and may restrict car traffic. Interface creep, as outlined earlier,

can produce a more permanent variation of street width. Rights-of-way are always mediated socially as well as physically; plot boundaries are often ambiguous and lanes may be restricted or gated.

Understanding informal morphogenesis

We have presented detailed mapping of the morphogenesis of 15 case studies, used to exemplify a range of morphological logics as outlined under the broad headings of ‘building’ ‘plotting’, ‘extending’ and ‘gridding’. We have shown how settlements expand through the extending, branching and bridging of streets and lanes, in conjunction with the territorialization of buildings and plotting. While we have presented building and plotting first, followed by the emergence of street/lane networks, there is no logic to this sequence. Practices of building and plotting are based on having rights-of-way that enable access to them, and the streets and lanes adapt to these buildings and plots as they attract more of them. These studies show how settlements expand and intensify, how they improvise and improve, how they work to create diverse morphologies and standards. They also reveal the dangers of over-development when informal urban design controls fail to control escalations of density. The diagrammatic map in Fig. 9 depicts some of the key interrelations between these 15 settlements and the seven logics we have articulated; it also shows that these logics are often global.

Assemblage thinking has been a primary methodological framework here—an approach that is embodied in this work rather than in conclusions drawn from it. We seek to counter any idea that the key ‘elements’ of urban design—streets, lanes, buildings, plots, blocks, settlements—can ever be things-in-themselves or more important than each other. Rather than looking for singular origins or root causes, we ask how settlement works and how it is changing (Deleuze and Guattari 1988); DeLanda 2006). We have introduced a more dynamic and relational way of thinking about urban design, stressing the ‘settling’ more than any ‘settled’ outcome. We seek to augment the nouns of urban morphology—streets, lanes, buildings, plots and blocks—with a language of informal settlement as a verb. This is a language of building, extending, plotting, demolishing, subdividing, gridding, bridging, branching and plotting. This is an approach where the materialities of the urban fabric are ‘matters of concern’ (Latour 2005), a grounded understanding of the importance and agency of the material world, without descending into determinism. Most importantly for urban design practice, this is an approach that seeks to understand the city as a space of possibilities and capacities. Every waterfront, swamp, field, escarpment or urban space that becomes informally settled is identified first by its capacities for settlement with access to jobs and livelihoods.



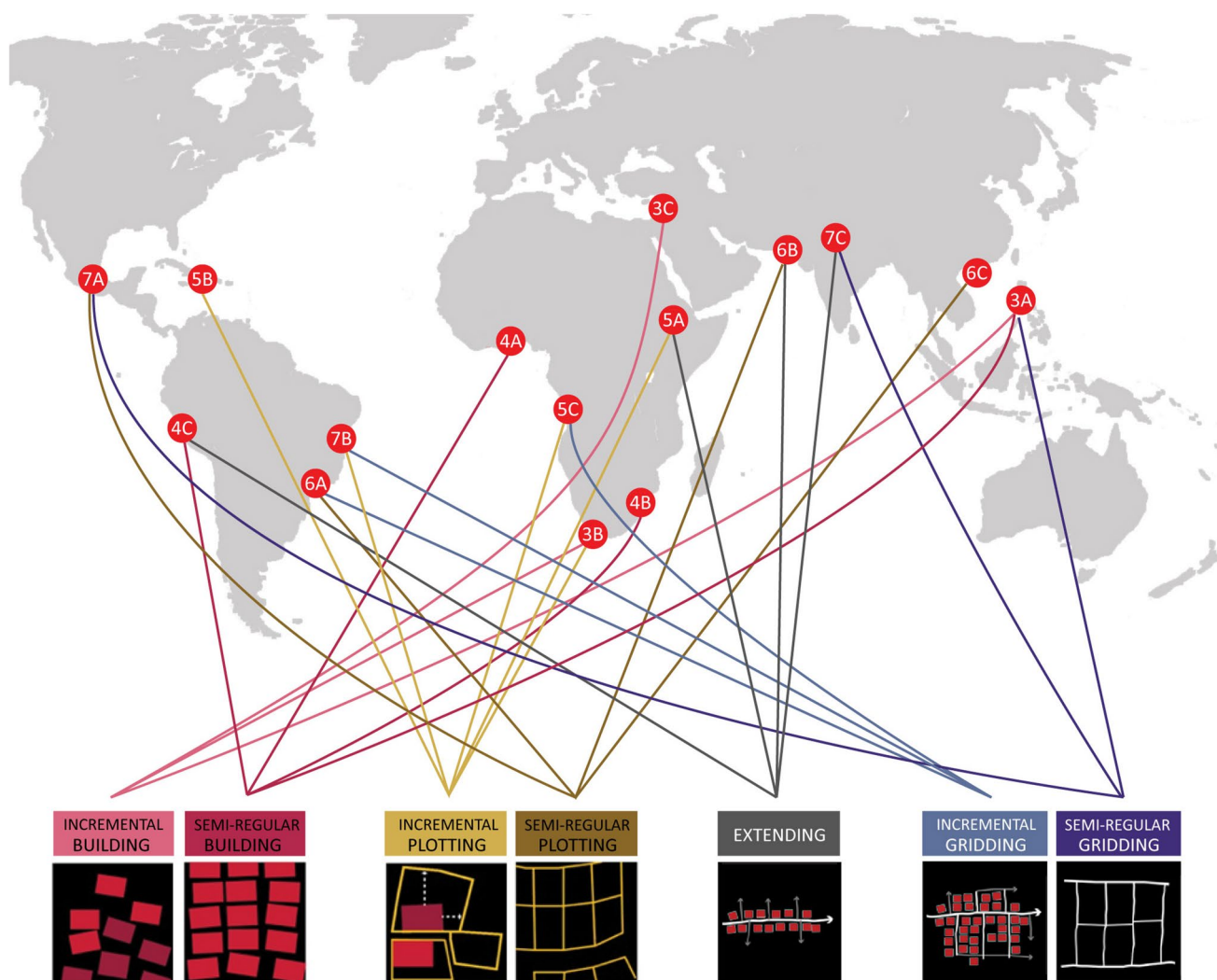


Fig. 9 Informal morphogenesis in the majority world (Source: Authors)

There are many more dimensions we could explore, but our scope here is limited. Our focus on urban morphology is not to replace social issues of livelihoods, poverty, health, land tenure and social justice, but to augment such studies and to draw out the interrelations between them. The morphologies of informal settlement matter precisely because of these socio-spatial interconnections, and because they are so rarely studied. We know relatively little of what there is to learn about how informal settlement works, but one thing we do know is that most of this knowledge is local knowledge—residents already have the know-how for self-organized urban design. The cases we have discussed above loosely proceed from the most irregular and incremental morphologies of Figs. 3, 4, towards the more formal and semi-regular gridding of Figs. 6, 7. We have noted the increased levels of state engagement, community organization and land-trafficking in these later cases. The roles of the more organized agents in these complex processes lie

beyond the scope of this paper. Every settlement is different and our comparative engagement with them here is relatively superficial. While based on the morphological evidence, the spatial logics we articulate here remain speculative rather than conclusive and many dimensions remain unexplored. Informal settlement is not a singular process or logic; it is far more complex than formal settlement precisely because it is irregular and irreducible. A key function of formal urban design is to produce a regular and orderly city that is both legible and predictable.

We have juxtaposed settlement morphologies from vastly different regions and contexts in order to draw global comparisons between these morphological patterns. In doing this, we do not seek to discount context; there are significant regional patterns based in climate, topography, culture and politics. Our examples include the more typical escarpment settlements of Latin America (4C, 7B), shack settlements of South Africa (3B, 4B), semi-formal suburbs of Sub-Saharan



Africa (5A, 5C), a water-based settlement of Southeast Asia (3A) and a Chinese urban village (6C). These are the stereotypes, but they account for only half of our examples; they reveal similarities and differences both between and within regions. We acknowledge that we raise more questions than we can answer; this is a research agenda as much as a theory of informal settlement morphogenesis.

What is most at stake in understanding the morphogenesis of street/lane networks is the future of informal settlements and the livelihoods of those who call them home. Wholesale demolition and replacement is rarely a solution because it destroys existing assets and livelihoods, and because it defies the logic of how such cities are generated. Settlements are located where they need to be, and they perform a key role in the production of affordable housing, urban infrastructure and cheap labor for these cities. The key challenge is to leverage such informal processes in a way that fosters the skills, resources and aspirations of their residents. A broad and deep knowledge base about how self-organized neighborhoods are designed and planned is crucial to understanding how informal settlements produce substandard conditions, but also in understanding that informal settlement is always already a form of upgrading of unclaimed land into habitable neighborhoods. A key risk is that formal upgrading practices can paralyze informal production. Any effective in-situ upgrading process relies on a better understanding of informal morphogenesis as a mode of production. The challenge for urban design practice lies in working with informal settlement residents to bring a broader and deeper knowledge base to this task—learning from those with local knowledge, and working with rather than against the logic of informal settlement. This means learning how to better harness the capacities of informal production; to co-develop informal codes and limit overdevelopment; to expand public open space; and to design the infrastructure for anticipated expansion. We suggest that understanding how informal settlement is produced is a pre-condition for any kind of professional designing, planning upgrading, formalizing or regulating. These settlements are not ideal, but they cannot be improved by imposing idealized designs or plans. Each settlement has both a history and a space of possibility that structures what can happen in a particular location. Yet these design possibilities need to be considered in light of the spatial logic we have sought to articulate, and in collaboration with residents who hold the local knowledge.

Understanding of the broader relations of informal settlement to the state and political economy is very complex and beyond the scope of this paper. Our account of building, plotting, extending and gridding is ultimately a theory of how citizen-based power is practiced through urban design. Such micro-spatialities and materialities of urban form are often subsumed within broader geopolitical critiques which explain a lot, but the micro-scale

cannot be reduced to the macro-scale. This is a multi-scalar relational assemblage where informal settlement plays a key role in the entrenched inequalities of the neo-liberal city, where livelihoods of marginalized residents and lifestyles of middle-classes are bound into symbiosis (Dovey and Recio 2024). Morphology matters, in part, because visible images of informality are used as proxies for socio-economic conditions—visibility mediates the ways the state can choose to demolish, upgrade, or turn a blind-eye. We portray informal settlement as largely a process of improvement because that is how it is seen by the designers and builders. The outcomes may be substandard in some ways, however, the morphology of the street/lane network generally follows a spatial logic that is sustainable, and within which standards can be upgraded without wholesale demolition. While political and economic reforms are crucial, there is no case to demolish informally produced infrastructure unless the state can offer a better livelihood as understood by the residents.

While informal settlement has expanded rapidly over the past century and appears to many as a blight on the modern city, the logic of informal urbanism is as old as urban history; formal and informal urban design and planning have coexisted for millennia (Dovey 2025; Dovey and Smith 2025). Informal settlement often embodies the logic of walkability, permeable access networks, intensive street life, active edges, mixed-use and density—the ingredients that have always produced great urban neighborhoods (Jacobs 1961). There is much that might be learned from informal settlement and applied in the more formal city, which is often overdetermined and constrained by car-dependent, inequitable, unwalkable and unproductive ideologies. Many of the fashionable slogans that are used to legitimate new formal projects could describe much informal settlement: ‘creative’, ‘productive’, ‘walkable’ and ‘low-carbon’. Informal settlements are smart and resilient in ways that much of the ‘smart’ and ‘resilient’ cities rhetoric would not recognize. While there is a pride of place in many informal settlements, these are not equitable cities. They all remain in a process of becoming settled—a better understanding of this morphogenic process is a crucial knowledge base for those engaged with urban change on the ground, and for urban theory more generally.

Acknowledgements The views expressed in this paper are those of the authors only and do not reflect those of the United Nations Human Settlements Programme.

Author contributions All authors contributed to all aspects of this manuscript.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. No formal funding was received.



Data availability The primary database is the Google Earth archive as accessed by geo-coordinates listed in Figs 3–7.

Declarations

Competing interests The authors declare no competing interests.

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