



RESILIENCE AND EVOLUTION

INTEGRATED GUIDELINES FOR SUSTAINABLE NEIGHBOURHOOD DESIGN

Urban Morphology & Complex Systems Institute

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RESILIENCE AND EVOLUTION

INTRODUCTION

The ecological neighbourhood is a living system, one that is never static. It displays the same evolutionary characters as living organisms and thus evolves over time. Its adaptability is what ensures sustainability. In a symbiotic relationship with nature and the climate, its energy comes for the most part from nearby natural sources rather than distant artificial systems, and this enhances its autonomy. Its conception uses the art of designing urban forms to create a living organism rather than a 'machine city'.¹

The design of eco-neighbourhoods entails

- an awareness of our participation in processes and in life cycles.
- a better comprehension of natural systems that interact with human activities.
- a better understanding of how non-linear complex systems work and develop.

Urban design is a process and management-driven activity. It rarely refers to a finished product. From the birth of an idea to the termination of the last construction phase, a lot of project parameters will need adjustment. Thus, time and evolution are intrinsic parts of the strategy. Many failures are the result of change denial.

Urban design can only assure the external shell. Life of the community then has to take root, filling the physical composition of the neighbourhood over generations, breathing soul into the abstract framework. It is only through community culture that unique places come into being. The prerequisite for this is the evolutionary capabilities of the neighbourhood as a system of systems². A neighbourhood is a set of social and physical components (people, jobs, streets, public

spaces, buildings, transport and utilities networks, etc.) interconnected in such a way that they produce their own pattern of behaviour over time. This web of connections happens all at once. Neighbourhoods are connected not just in one direction, but in many directions simultaneously. Like any system, a neighbourhood consists of elements, linkages, and a function or purpose. In traditional neighbourhoods, the organizing element was the all-encompassing public realm that permeated and interconnected everything and was extending from squares and streets into courtyards and the interior of large churches or temples. The continuous frontages of buildings were the façades of the public space. Streets were a complex, both physical and social, construct, where many functions were overlapping. The purpose of neighbourhoods was also multifaceted. Neighbourhoods were places of life, production, consumption, creation, culture, exchange, leisure.

Neighbourhoods as systems are more than the sum of their parts. They may exhibit adaptive, dynamic goal seeking, self-preserving and sometimes evolutionary behaviour. A neighbourhood as a system presents wholeness properties, and an active set of mechanisms to maintain that integrity. Neighbourhood as systems can be self-organizing and are often self-repairing over at least some range of disruptions. They are resilient and their evolution cannot be predicted. The Roman Empire legacy in hundreds of Mediterranean cities, or New York City transformation from 1811 Commissioners' Plan to the 21st century, have transformed in directions that would have been hardly imaginable when they were created.

The elements of a neighbourhood are often the easiest parts to act upon because many of them are visible,

overlay like in Japanese, Korean and European cities. The buildings should be easily adaptable and replaceable at need.

¹ Salat et al. 2011.

² The street network should be able to transform and grow through ramification, complexification and

tangible things, to which to apply a set of performance metrics. However, the relationships, the interconnections, that hold these parts together are often more important than the parts themselves. The interconnections in a neighbourhood are the people, energy, and material flow, the latter being referred as the neighbourhood metabolism. These interconnections are organized in networks of information, of movement, of energy, of material flows.³

The neighbourhood response to outside forces is characteristic of itself and that response is seldom simple. It is only when we see the relationship between system and behaviour that we understand how systems work, and how to shift them into better behaviour patterns. Historical cities, over the course of their long history, were slowly transformed by incremental phenomena of destruction and reconstruction. In a process of self-organization, they adapted their forms to fluctuations in their environment. They acquired the

RESILIENCE

Resilient neighbourhoods are adaptive and robust enough to maintain stability, evolve incrementally or foster transformational responses. Resilience is the ability of a system to bounce or spring back into shape, position, etc. after pressure or stretch. The opposite of resilience is brittleness or rigidity. Systemic resilience arises from a rich structure of many feedback loops. They can work in various ways to restore the system even after a large perturbation. Such loops operate through distinct mechanisms, at different time scales, and with redundancy – one kicking in if another one fails. Redundancy and connectivity with multiple loops are key properties of resilient infrastructure, urban fabric and services. They can offer alternative modes of operation: additional components are available in case of failure in crucial elements. If the system stops working, it must be able to rebound quickly to minimize disruption. In a transportation network, for instance,

³ Some interconnections in neighbourhoods are actual physical flows such as water, waste, and energy, or people moving to access jobs or amenities. Many interconnections are flows of information – signal that

capacity to absorb fluctuations by reinforcing their structure and order. They became more complex and richer because of change in time. The subsystems of historical cities are entangled and interwoven in a deeply structured and complex manner.

This document explores neighbourhoods as a complex system of systems through two sections.

RESILIENCE EVOLUTION

And case studies.

TRADITIONAL CHINESE CITIES MODULAR COMPOSITION

KYOTO: 1,200-YEAR EVOLUTION OF A CITY FABRIC

AMSTERDAM: EVOLUTION OF AN URBAN FABRIC

BETWEEN ORGANIC AND PLANNED

HILLSIDE TERRACE, TOKYO

mobility and accessibility are assured. Resilient communication systems guarantee reliable connections, for instance through continuous power supply via secondary lines in computer hubs.

Design that enables persistence, recovery, transitions and transformation of the physical, economic, and social fabric, enhances resilience. A rich web of redundant connectivity in the street patterns and a fine and diversified urban fabric provide the feedback loops. These stabilize the neighbourhood and help it to restore its functions after a perturbation. Quite the opposite, designs with large-scale monofunctional areas and oversized repetitive elements decrease resilience.

go to decision points or action points within the neighbourhood. With the digital transformation, these interconnections are likely to increase exponentially.

Key features and outcomes of resilience

<i>Sub-characteristic</i>	<i>Desired outcome</i>
Flexibility	Continuous interplay of evolution and adaptation
Bio- and social diversity	Multi-functionality and increased opportunities
Redundancy	Availability of extra resources. Capacity in case of other mechanisms failure
Modularity	Self-organization
Safe failure	Minimum damage: key service delivery is maintained even under failure
Uncertainty and learning	Comprehension and anticipation, drawing from lessons
Resourcefulness and responsiveness	Rapid and adapted actions

Sub-characteristics and goals of a resilient system. Source UNEP 2017.

RESOURCE EFFICIENCY AND RESILIENCE

Several actions are common to both resource efficiency and resilience. They provide a fertile ground for mutual reinforcement. Different inputs (materials, products, water, energy, food) are essential for urban functioning. They should be diverse and redundant with backup. Greater efficiency with more localized resources can enable a place to become more resilient, as it will depend less on single centralized systems supplying the resources. An example of synergy between resources and resilience is greening neighbourhoods. Certain types of green spaces – such as wetlands – can store water and release it gradually, allowing natural and continuous recharge of groundwater. Besides, vegetation can play a key role in absorbing carbon dioxide and mitigating climate change. It increases groundwater absorption, slows surface runoff and reduces flooding. It alleviates urban heat islands and keeps temperatures lower.

Diversity is a common goal for both resource efficiency and resilience. Resilience encourages diversity to make a system redundant and safer if one or more components fail, reducing reliance on unique mechanisms and providing alternatives. Cities with fine-grain physical, economic and social diversity adapt to change and disruption with more complex responses⁴. Variety in resources reduces dependency and achieves subsystem stability. Diversity of renewable sources and energy profiles is key to manage successfully distributed energy projects with smart grids. An integrated approach to resilience and resource efficiency can therefore help neighbourhoods leverage the range of available resources, their complementarity, and plan accordingly for different periods. The combination of resilience and resource efficiency would give priority to optimizing the resource chains and flows that ensure subsystem operation, thus preserving the metabolism of the entire urban system.

THREE KEY RESILIENCE PROPERTIES: FEEDBACK LOOPS, SELF-ORGANIZATION AND HIERARCHY

Resilience involves recognizing the intrinsic dynamic nature of urban systems. A resilience framework may comprise three main components: resistance in a period of small disturbance, adaptation in a time of greater disturbance, and transformation when conditions are becoming unviable or unsustainable⁵. A

system response depends on the severity and frequency of impacts. It is different when the system is subject to single shocks – more sudden, turbulent and difficult to predict – or ongoing stresses causing a progressive and continuous pressure. Societies tend to face shocks when they occur but long-term stresses are

⁴ For instance, fine grain-platting of the city fabric has allowed New York City to tailor to many cycles of

economic activity while maintaining its position as the dominant global city.

⁵ Béné et al. 2012.

by nature less obvious. They require transformation: the creation of a 'fundamentally new system when ecological, economic or social (including political) conditions make the existing system untenable'.⁶

Resilience does not assume a single equilibrium state. The urban system can evolve into diverse states through feedback loops, self-organization, and hierarchy.

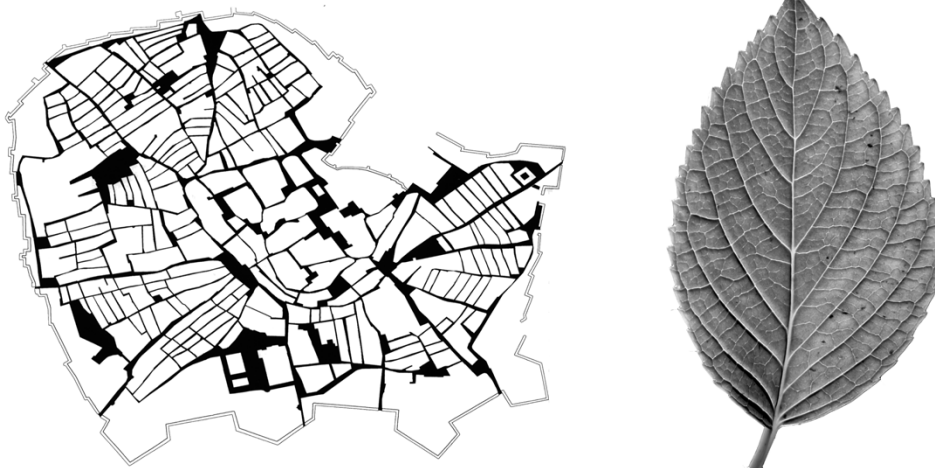
- **Feedback Loops.** A set of feedback loops that can *restore or rebuild feedback loops* is resilience at another level – meta resilience. Even higher meta-meta resilience comes from feedback loops that can *learn, create, design, and evolve* even more complex remedial structures. Systems that can do that are self-organizing⁷.
- **Self-Organization.** Complex systems have the property of self-organization – the ability to structure themselves, to establish new structures, to learn, diversify, and complexify. Complex forms

of organization may arise from simple rules. Out of simple rules can grow enormous, diversifying crystals of technology, physical structures, organizations, and cultures⁸.

- **Hierarchies.** Hierarchies are brilliant system inventions, not only because they give a system stability and resilience, but also because they reduce the information that any part of the system has to track. In hierarchical systems, relationships *within* each subsystem are denser and stronger than relationships *between* subsystems. Everything is connected to everything else, but not equally strongly. If these differential information links within and between each level of the hierarchy are designed right, feedback delays are minimized. No level is overwhelmed with information. The system works with efficiency and resilience. Hierarchical systems evolve from the bottom up. The upper hierarchy layers serve the purposes of the lower layers.

NEIGHBOURHOODS SHOULD BE DESIGNED LIKE LEAVES

*'Plants are a spectacular system to work on as a physicist, because they are beautifully mathematical.'*⁹



Evora, Portugal. The pattern exhibits a leaf structure, with radial connectivity at the intermediate scales.
Source: salat et al. 2011.

⁶ Walker et al. 2004.

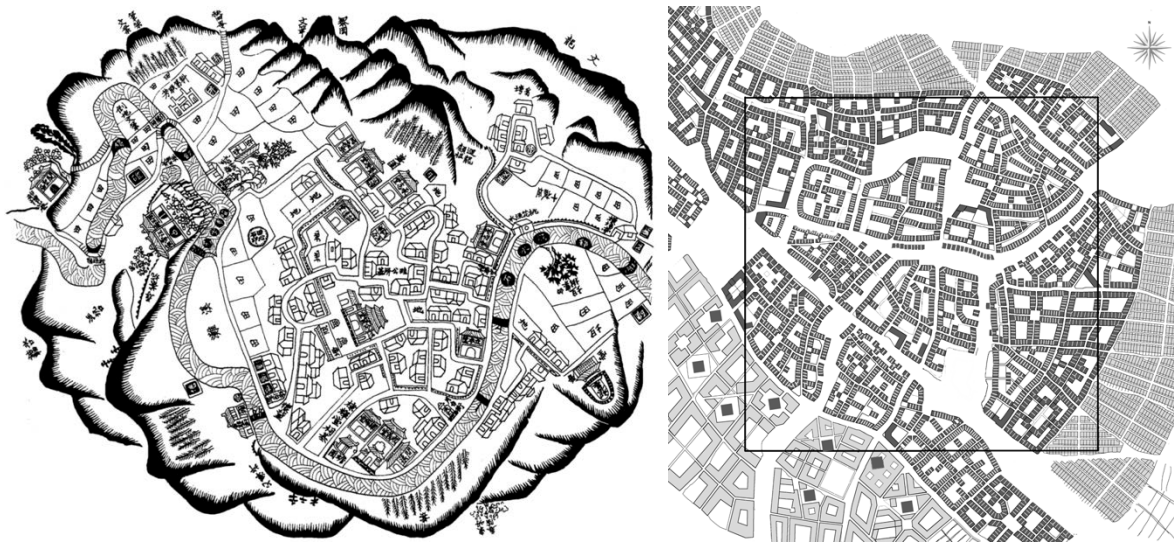
⁷ When they will have achieved their full potential with billions of IoT elements interconnected by feedback loops and AI algorithms, smart cities systems will acquire the ability to “learn” and evolve like natural ecosystems.

⁸ All of life, from viruses to redwood trees, from amoebas to elephants, is based on the basic organizing rules encapsulated in the chemistry of DNA, RNA, and protein molecules.

⁹ Eleni Katifori quoted in Singer 2013.

For an urban fabric to be efficient and resilient, it must be structured in a complex way and strongly connected in the manner of a leaf. One can readily see that street networks are not structured like trees: small streets are more often linked to one another or to several higher-level streets. This is not the case in a tree structure. Leaf structures can secure optimal efficiency of flow networks, while limiting the propagation of local perturbations. The fine-grained connectivity of their subjacent structures is fundamental for the resilience of cities. A leaf structure increases resilience by preventing rapid and catastrophic fluctuations from spreading quickly through the system and disorganizing it. A few long-range connections should be weak to prevent the spread of disrupting fluctuations. Weak connections allow the fluctuations to be absorbed. On the other hand, a great many strong short-range connections ensure the system's deformability.

When a branch of a tree is cut, all those that grew from it will die too. In a leaf, if a vein is interrupted, the redundancy of the network will allow the flow to get around the interruption via secondary paths. The flow will only be partly slowed by the degradation of the network. This is why cities structured like leaves are more resilient. Just imagine that a path is blocked by an accident: the flow is deviated onto other paths to irrigate the far side of the perturbation. A part of the leaf's network can be amputated and the leaf will go on living and converting light energy into nutrients. Nature has provided for redundancy on all scales to ensure the permanence of its structures. The simultaneous existence of small and big nervures having the same function contains a natural redundancy for living organisms that answers the objective of efficiency and resilience with an economy of volume.



Left: On this feng shui drawing for Zhifeng village, Jiangxi province, the mountains, water bodies, graves, and important structures are named as part of an auspicious composition. The positioning of the houses, their relationship to the landscape and to their neighbours, were all conditioned by the rigorous yet fluid demands of feng shui. This topographic configuration for the city as a whole and for all its parts orders space. Right: Eco-neighborhood based on a traditional urban texture in the Shanghai area, Françoise Labbé architect. The plan of the eco-district combines the geometric and organic. Its form is generated by dynamic forces. It grows organically like a leaf.



Left: Leaf veins. Right. Roma trident.

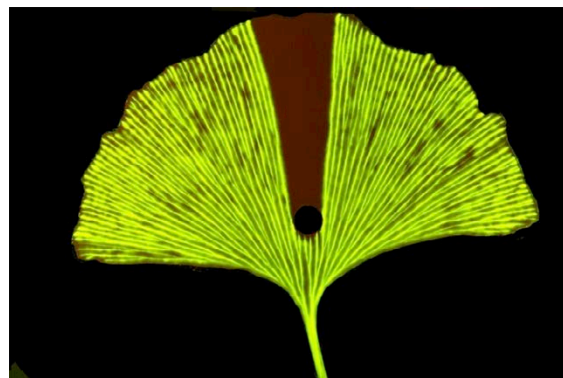
Town planners can learn from nature resilient systems such as leaves. A resilient neighbourhood infrastructure pattern and a leaf might just be variations on a single structural theme. Both are composed of a network for transporting resources and energy from one place to another. Roads, railways,

water and gas mains, sewage pipes and electricity cables all move energy and resources around in a neighbourhood. So, do the sap-carrying xylem and phloem of plants. If we understand the architecture of veins in plants, we will get a better handle on

photosynthetic efficiency, and on the resilience of networks to damage and fluctuation¹⁰.

A diversified system with multiple pathways and redundancies is more stable and less vulnerable to external shock than a uniform system with little variety. The self-similar structure observed in many natural networks has strongly stimulated the general investigation of optimal systems. For natural networks, their functional properties are intimately related with the patterning mechanisms by which they arise and evolve. Traditionally, biologists have celebrated the trunk, branch and twig system of a tree as an efficient

pattern. Many mathematical formulas¹¹ have suggested it is the best, least wasteful way to design a distribution network. But the very end of such a network, the leaf, has a different architecture: the veins in a leaf cross-link and loop. The delicate branching patterns show a complex network of nested loops – meaning loops within loops, within loops. This pattern can be found throughout nature and structural engineering: in the brain’s cerebral vasculature and the metal bracing of the Eiffel Tower, for example. Loop architectures, like redundant computer networks or electrical grids, make structures resistant to damage and to flow fluctuation.



Alternate Routes. Left: Thanks to the resilient structure of the loop network, fluid can reach all parts of a damaged leaf. Right: A ginkgo leaf has no loops to bypass the hole. Loops arose to handle damage and fluctuations in nutrient needs. Loops make the network redundant. If you have damage, flows can be rerouted to other channels. Loop networks can also better handle fluctuations in fluid flow as environmental conditions change. Source: Katifori et al. 2010.

Loops allow for a nuanced delivery system that can adapt to fluctuations¹². Flows can be rerouted in response to local pressures changes, such as different evaporation rates. When time variations or fluctuations are allowed for, a class of optimal structures distinct from trees is found: they share the hierarchical organization of trees yet they contain loops. These loops improve efficiency and help to withstand damage. No matter which piece of a leaf’s supply mechanism is disrupted, there is usually enough capacity in the rest to deliver water and nutrients¹³. This result in biology is also key for constructed

networks distributing goods over roads or electrical power over wires.

Most of the interconnections that make systems resilient and adaptive wholes operate through the flow of information. Like for trees and leaves, information holds cities and neighbourhoods together and plays a great role in determining how they operate and evolve. In a tree, signals allow one part to respond to what is happening in another part. As the leaves lose water on a sunny day, a pressure drop in the water-carrying vessels allows the roots to take more water.

¹⁰ Understanding leaf veins may also shed light on the vastly more complex vascular network on the surface of the brain, illuminating the close link between brain activity and blood flow.

¹¹ Research has shown that branching appears whenever there are economies of scale, so that combining two channels into a larger one reduces the ‘cost’.

¹² Francis Corson (2010) used computer models to examine why these loops exist. From an evolutionary point of view, loops seem inefficient because of the redundancy inherent in a looped network. Francis Corson’s models show, however, that this inefficiency is true only if demand for water and the nutrients it contains is constant.

¹³ Katifori et al. 2010.

Conversely, if the roots experience dry soil, the loss of water pressure signals the leaves to close their pores so as not to relinquish even more precious water. As the days get shorter in the temperate zones, a deciduous

tree puts forth chemical messages that cause nutrients to migrate out of the leaves into the trunk and roots. This weakens the stems, allowing the leaves to fall¹⁴.

MODULAR DESIGN ENHANCES RESILIENCE

Herbert Simon with his 'watchmakers' parable'¹⁵, has shown that complex systems can evolve from simple systems only with the creation of stable intermediate forms. The resulting complex forms will naturally be hierarchical. The parable of the two watchmakers was introduced by Nobel Prize winner Herbert Simon to describe the complex relationship of subsystems and their larger wholes. There once were two watchmakers, named Hora and Tempus, who made very fine watches. The phones in their workshops rang frequently and new customers were constantly calling them. However, Hora prospered while Tempus became poorer and poorer. In the end, Tempus lost his shop. What was the reason behind this? The watches consisted of about

1000 parts each. The watches that Tempus made were designed such that, when he had to put down a partly assembled watch, it immediately fell into pieces and had to be reassembled from the basic elements. Hora had designed his watches so that he could put together subassemblies of about ten components each, and each subassembly could be put down without falling apart. Ten of these sub-assemblies could be put together to make a larger subassembly, and ten of the larger subassemblies constituted the whole watch. The parable highlights the links between modular structures and resilience. An example is Venice (see below) and the traditional Chinese city described in detail in a case study.

CASE STUDY: VENICE MODULAR OPEN-ENDED ADAPTIVE ORDER

In Venice, the pattern is highly intricate while being structured. A complex order connects the large and the small. The city has grown organically through the aggregation of compositionally similar neighbourhoods ('*sestiere*' divided in '*contrade*'), each '*contrade*' being organized around a plaza ('*campo*') dominated by a church and linked by canals, bridges, and narrow streets to other '*contrade*'. Larger *campi* and churches serve as landmarks to each *sestiere*, while the city is ordered by the Grand Canal and Plaza San Marco. Venice is a modular city made bottom up of many cities sharing both a common highly legible pattern with endless variations. In Venice, the imageability does not derive from a fixed, limited, precise, unified, or regular hierarchy. It is established by scaling patterns linking the parts and the whole and created by centuries of gradual evolution.

¹⁴ Meadows 2008.

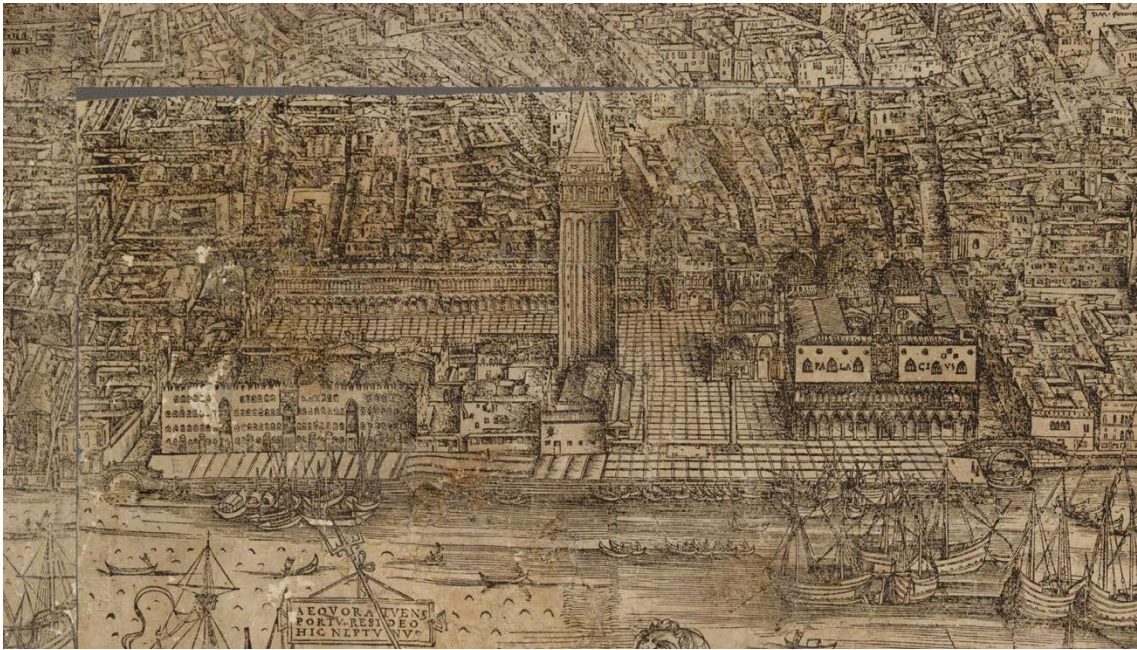
¹⁵ Simon 1962.



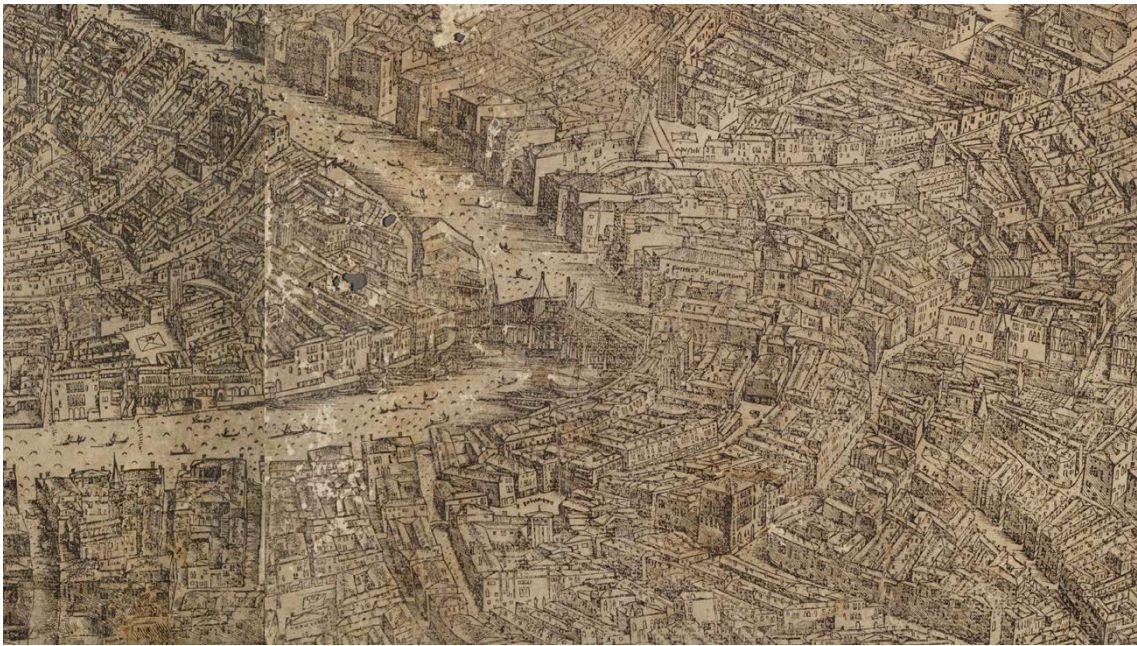
Venice. Google image.



Detail, Venetie, ca.1514. Anton Kolb/Jacopo de' Barbari. Anton Kolb/Jacopo de' Barbari. This map illustrates the modularity of Venice. It must have been prepared from dozens, perhaps hundreds of bell tower sightings. Jacopo's view is neither a giant landscape drawing made in the field, nor a carefully compiled, foreshortened plan, it can only be a studio fabrication. It must have been assembled mosaic fashion at the drawing table from a myriad of small view details. Each of them has been made from heights throughout the city.



Detail, St. Mark's Square



Detail, Rialto Bridge



Close detail, Santa Maria dei Frari Monastery.



Detail, Murano.

EVOLUTION

Historical cities achieved a high degree of complexity and resilience because they were never established on a clean slate. All new divisions of space were embedded in prior divisions. 'The new replaces, modifies and coexists with the old. There is always an 'already there', an older form of occupation to compose and compromise with, one that presents a material

existence that must be considered.'¹⁶ The key is the composition of successive urban spaces in a single place, the genealogy of urban space. A living city is the continual transformation of fragments and strata in an ongoing movement of redevelopment that alters them without ever erasing or destroying them. The urban composition is the search for coherence between

¹⁶ Riboulet 1998.

multiple realities, while maintaining respect for their heterogeneity. Composing the city means expanding and transforming it without disrupting its cohesion. Composition involves walking the thin twisting line between two extremes: on one side, spontaneous growth; on the other, order imposed by planning. Historical cities maintained a balance on this crest line. The piazza del Campo in Siena in Tuscany resulted from two centuries of debates and projects. The cupola of Santa Maria del Fiore now defines the form of Florence. It was debated for sixty years, between proponents of gothic and Renaissance styles. And discussions

continued throughout the decades of construction when Brunelleschi gradually gained control. the complexity of historical cities is not a disorder; it is rather the result of sometimes carefully considered decisions over centuries by communities that have settled into the long-term. This composition presupposes an authority in a position to plan the city but an authority that negotiates with reality. This is in contradistinction to modernist urbanism, which crushed reality beneath a utopian dream and resorted to calling on the authorities to impose its vision¹⁷.



Arles and its Roman layout highly deformed but still visible. Source: Urban Morphology and Complex Systems Institute.

Historical cities could absorb successive transformations without losing their essential structure. In Paris, deemed capital of the 19th century by Walter Benjamin, no more than half of the buildings predating 1900 subsist within its historical boundaries. Yet the city has managed to maintain its character thanks to the tenacious hold of the structure created by Baron Haussmann. In the historical European city, the extremely complex substrate, the subdivisions and the

street grid can be traced to the Middle Ages and sometimes even to the Roman empire¹⁸.

Contemporary cities lack this flexibility and elasticity. Sustainable approaches must enable physical transformation when required by social and economic shifts, while keeping continuity and identity in the pattern and form. Sustainable neighbourhood design should achieve a dynamic stability, simultaneously permanent yet ever-changing. Evolving

¹⁷ Salat et al. 2011.

¹⁸ Salat et al. 2011.

neighbourhoods are dynamic fields of interrelated forces rather than static entities. They should not be designed once and for all. They are ‘sets of mutually independent variables in a rapidly expanding infinite series’¹⁹. ‘Any order introduced within the pattern of forces contributes to a state of dynamic equilibrium – an equilibrium that will evolve in character as time passes.’²⁰ Once built, neighbourhoods take a life of their own. The initial planning and design ideas that have generated them are constantly challenged by shifting uses, tastes, and competing priorities.

Functions and technologies change faster than places. If we design cities and buildings to fulfil a function or to optimize a technology, they are in danger of becoming quickly obsolete. A street may have longevity of 2000 years, as shown by Mediterranean cities inherited from the Roman Empire. The existence of a traditional building is about 200 years. Utility and building services may have a life of just 25 years. The lifespan of ITCs technologies is accelerating and cycles of innovation tend to renew technologies and value chains in less than 5 years.



Cities constitute a world in themselves. The city is something that endures beyond metamorphoses. In ‘On Collective Memory’, Halbwachs writes: ‘The group not only transforms the space into which it has been inserted, but also yields and adapts to its physical surroundings. It becomes enclosed within the framework it has built. The group’s image of its external milieu and its stable relationships with this environment becomes paramount in the idea it forms of itself’ (p. 132). The city is the ‘locus’ of collective memory.

Left to right:

Rome. Piazza Navona. The monument as a persistent urban phenomenon. Square 400 m.

Rome. Via del Giubbonari. The complexity of the serpentine medieval streets. Square 400 m.

Rome. Via del Corso. The trident and the straight street are symbols and footprints of Sixtus V papal power. Square 400 m.

Source: Urban Morphology and Complex Systems Institute after Google, images © 2011 Geoeye.

Neighbourhoods should be flexible enough to accommodate these different overlapping cycles of innovation. Victorian boroughs in London, Haussmann ‘arrondissements’ in Paris, and New York grid still largely filled with brownstone houses built in the early 19th century, have seen successive industrial revolutions. They have changed household sizes and building functions several times. They have adapted to cars, better than many areas engineered for cars. Today, they are places where the AI and deep tech economy thrive.

To incorporate the flow of time in design, we must shift from ‘master plan’ to ‘master programme’, since the latter term includes a time dimension. Given a set of goals, the master programme suggests several alternatives for achieving them, the implementation of one or the other being decided by the passage of time and its effect on the ordering concept. As a physical correlation with the master programme are ‘master forms.’ Examples are the Stockholm inner city block typology and assembling patterns used in the development of Hammarby Sjöstad. They provide a formal pattern language that can evolve with time.

¹⁹ Maki 1964 and 2008.

²⁰ Maki 1964 and 2008.

CASE STUDY: KEEPING THE MASTER PLAN FLEXIBLE IN KING'S CROSS, LONDON²¹

King's Cross is a mixed-use, urban regeneration project in Central London around a major multimodal transport hub. Two master planning teams and four independent design review panels led to a highly tailored scheme. It responded to the needs of multiple stakeholders. Planning balanced the developer's long-term aspirations to create and manage a long-term asset and the local authority's desire to integrate it into the deprived communities that surrounded the area through urban regeneration.

The master plan unifies the site with a comprehensive vision, but it is flexible enough to accommodate revision. This flexibility will enable King's Cross to adapt to transformations in social and technological trends. Development is not functionally locked into the requirements and technologies of today but has been left enough margin to evolve with needs and market fluctuations. Changes in uses proportions and buildings' transformation can respond to shifts in market conditions. Time has been integrated in planning conceived more as an ongoing process than as a once and for all exercise.

To balance this adaptability and maintain continuity, order in space, and identity, key physical aspects of the site were anchored. Streets and public spaces, the most resilient features of neighbourhoods, were specified. To create visual order in space and avoid out-of-proportion construction that would obstruct views and the flow of well-defined public space, maximum and minimum building heights were fixed in various zones. These standards ensure consistency in density and scale throughout the site. To provide a sense of unity, uniqueness, and harmony while permitting for diversity and variety, design guidelines describing building techniques, materials, and how they can be used were also established.

Planners have been careful not to be too prescriptive about the tone, character, and feel of the area. Instead, details of the new district have been enabled to emerge over time, aided by a master plan that allows room for flexibility, negotiation, change, and experimentation with occupiers and activities²².

The constant cycle of decay in cities can make them more resilient if managed well. The rapidity with which the urban systems expand suggests the need for linking newly established or projected parts of the city to existing ones. Cities must evolve with 'open linkages' permitting them to grow with both coherence and variation. If all dwellings in an area become unsuitable for use at the same time, urban renovation usually clears all the area and builds new housing. This erases place memory, continuity and mix of people and activities. This destroys correlations between old and new. Quite the opposite, if managed well, the cycle of decay can be a cohesive and entwining force. It can provide the opportunity to transform neighbourhoods by replacing incrementally old edifices in an old environment by new buildings, still in a partially old setting. Such diversity in age – applied, for instance, in

London's King's Cross through retaining and repurposing 19th-century brick industrial structure – is a form of temporal linkage. It gives a morphological demonstration of the city's ever-changing nature and enriches people choices and perspective – as they can live or work in 21st century buildings while moving into layers of history.

Italian historical cities are such examples of living cities. They preserve traces of their millenary past. Their very high variety and complexity proceeds from the stratification of time. Historic towns are most often complex by sedimentation of centuries, by fires, by reconstructions, changes in power and sometimes in civilizations, modification of customs and cultural values. Across their metamorphosis, something from the past remained, it was the pattern of streets,

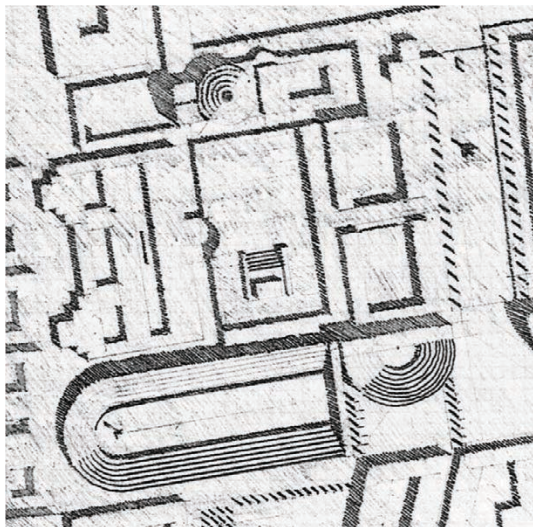
²¹ This box draws on Salat and Ollivier 2017.

²² ULI 2014.



Florence. Santa Croce area. Photo: Photo: © Françoise Labbe.

The Roman Empire planning has created cities able to evolve for 2,000 years. Their square blocks and street patterns dating from their foundation are still found in the centres of most Italian cities, such as Rome, Turin, Bologna of Florence.



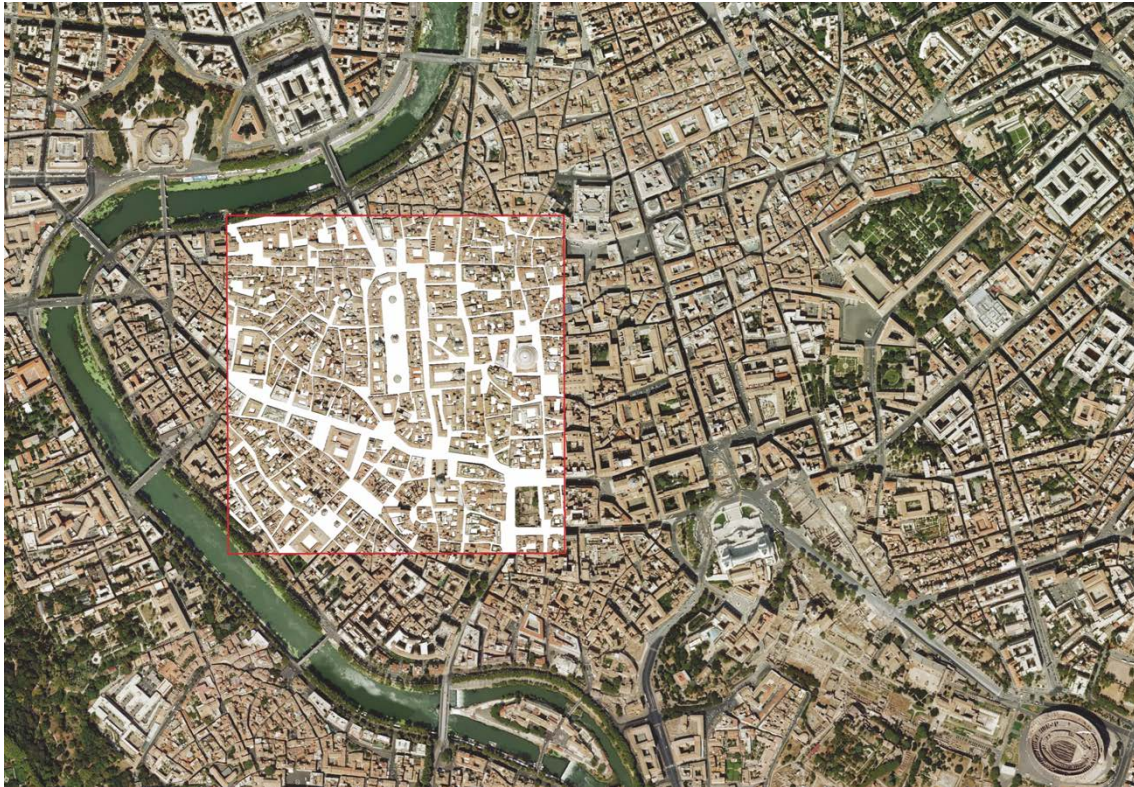
The Campus Martius was Imperial Rome's monumental core. Only the Pantheon, recognizable by its round stepped dome, survived intact into the Renaissance. A millennium of stone scavenging and piecemeal reconstruction has disintegrated the Baths of Nero, the Odeon, and the huge stadium of Domitian whose elongated imprint is still visible in the Piazza Navona. Source: Kostof 1999.

To survive, a city has to be able to reshape itself in a continuous metamorphosis. Adapting to new needs necessarily implies deformations to its original plan. The evolution of cities shows that successful urban developments are based on an interaction between urban planning and processes of self-organization that

make the overly regular aspects of the initial organization more complex. The original form of the founded city must be able to deform successfully. The capacity of urban structures to last over time depends on the complexity of their organization, the intricacy of their network, the richness of their connectivity. To

withstand, they need a flexible order presenting the same level of complexity on several distinct scales. A city can be said to be resilient if the idea of its form is preserved through successive transformations but not fixed in an unchanging order. Cities like Turin, Florence

and Rome survived the centuries and civilizations. With each metamorphosis, enough of their different forms was maintained to keep their memory alive while leaving their future open²³.



Rome urban fabric. Source: Urban Morphology and Complex Systems Institute.

Grids and Modular Evolution from Miletus to Manhattan²⁴

The streets in Greek cities of the Archaic period were not laid out according to a preconceived plan. They developed as narrow interstices between dwellings. Houses constituted the basic unit in the organic growth of the city-state. But if Athens grew this way, this was not the case for the cities founded during the Greek colonization of the Mediterranean and Asia minor. With the reconstruction of Miletus after its destruction by the Persians in 494 BCE, we have an example of Greek urbanism in a new rationalization age.

Hippodamus redesigned Miletus according to a grid plan. It was made up of two squares differently sized. The main religious and civic edifices stood at the centre, at the junction of the two grids, and formed a complex composition characterized by rotations and

translations of axes. On either side of this monumental centre, the grid constituted a system of land division rather than of circulation. This was the case much later with the 1811 Commissioners' plan for Manhattan. In both cases, the grid is an abstract pattern, a rational instrument of spatial organization.

Aristotle²⁵ tells us that Miletus was composed of 10,000 citizens. They were divided into three classes – artisans, husbandmen, and defenders of the state. Hippodamus divided the city into three zones – one sacred to honour the gods, one public for the defenders of the state and one private for the husbandmen. The articulation of the two grids with the sacred sphere works, however, to attenuate by its regularity the functional division of society. In opposition to incremental organic growth,

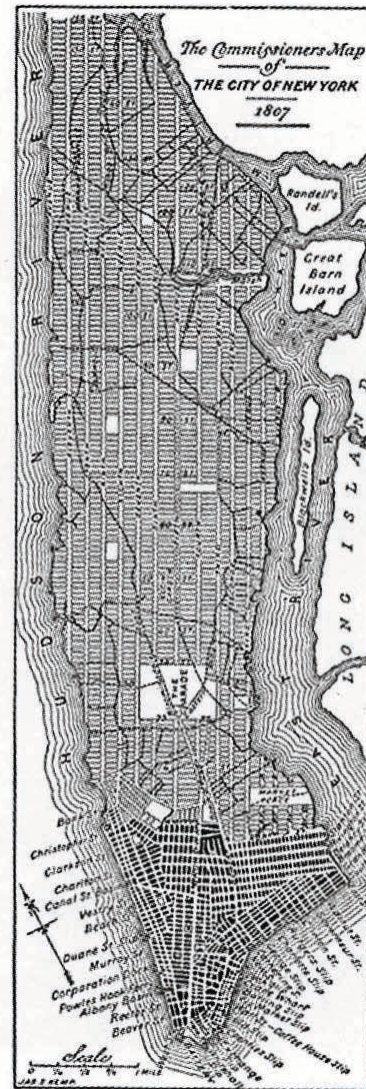
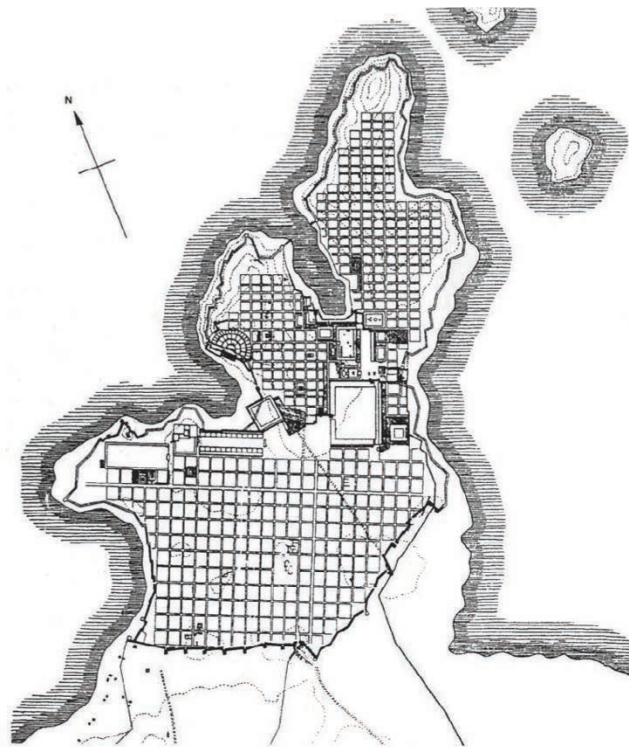
²³ Salat et al. 2011.

²⁴ This section draws on Salat et al. 2011.

²⁵ Aristotle, Politics, II:VIII.

the grid represents a total preconception. But this preconception is not a set order. To the contrary. It encourages the emergence of internal complexity within the network of its regularity. Even after several centuries and well before the Roman period, many blocks defined by the grid remained unoccupied. The example of Miletus, and later of Manhattan, suggests

the importance of leaving room for growth and evolution. In Manhattan, nearly 120 years went by before the Commissioners' plan was filled by such urban compositions as Rockefeller Center, started May 17, 1930 and completed in the 1970s. Manhattan continues to be transformed and recreated today within the grid designed two centuries ago.



Left: Source: Franchetti2008. This plan is derived from archaeological research at Miletus. The city was probably laid out based on a design by Hippodamus of Miletus. In Archaic Greece, the original labyrinth by accretion (archaic Athens resembles a medina) remains small. It is expanded in the form of a grid during the Greco-Persian Wars and the classical period. All the Roman colonization cities around the Mediterranean follow a grid pattern. The augur in a ritual fixed the orientation of the city, the cardo and the decumanus, the templum and the mundus. This linked the city to the cardinal points and, at the same time, connected vertically the subterranean, terrestrial and celestial worlds.

Right: The Commissioner's Plan of 1811 for Manhattan

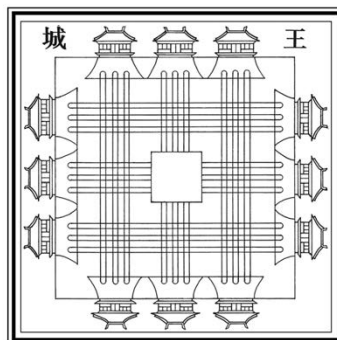
The grid plan for Manhattan was more an instrument to regulate land use than a system of circulation. Manhattan demonstrates the incredible anticipatory power of the grid. The night skies were still studded with stars. Steam engines, locomotives, trains, electricity, automobiles, and elevators were merely nascent nightmares about a future that appeared in nobody's dreams. The island was a marsh through which native American tribes travelled. It was during the Napoleonic Wars, a year before the disastrous invasion of Russia in 1912, that the plan was developed at a time when the two fundamental technologies that were to make New York the capital of the 20th century did not yet exist: the automobile and the elevator, instruments of horizontal and vertical speed. They were unthinkable at the time because the energies and motors needed for their functioning had not yet been

invented. Nonetheless the plan for a city of 2.5 million formulated by the commission designated for this purpose ensured the city's growth with prodigious possibilities of differentiation and substitution.

James E. Vance²⁶ draws a comparison with the periodic table of elements. The underlying system of the table could be established before all the elements that now comprise it were known (and with others still remaining to be discovered) because the fundamental relationships were understood. Similarly, Hippodamus understood the Greek urban system and designed its physical form so that it could grow. Indeed, his principal contribution is to have designed an urban form sufficiently adaptable to be able to grow and be transformed over a long period of time.

CASE STUDY: TRADITIONAL CHINESE CITIES MODULAR COMPOSITION

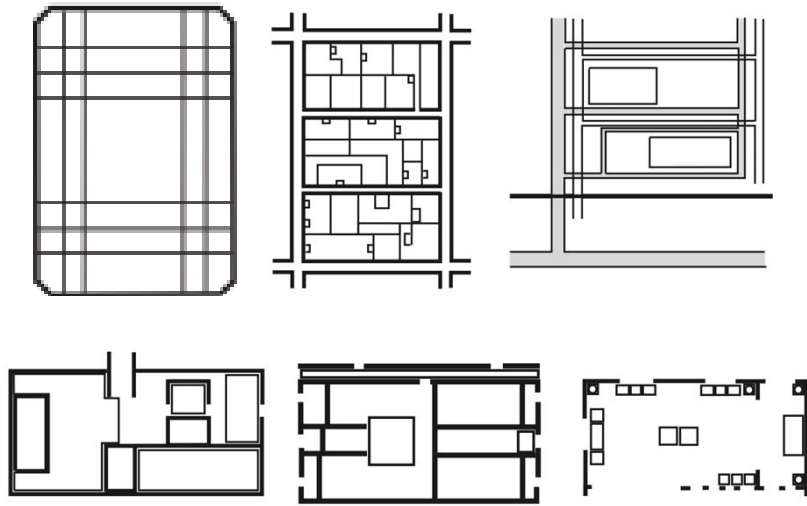
Chinese traditional cities were ordered yet able to evolve incrementally with endless diversity. A mathematical grid regularizes the whole pattern of subdivisions with streets of different widths. Within this grid, variations in the size and in number of courtyards all belonging to the quadrangle house type introduce flexibility and capacity for change. The great palaces of the aristocrats were on the south side, the smaller houses of the commoners on the north side. The grid was not filled and crops could be grown right in the heart of the city. Chang'an was both dense and green.



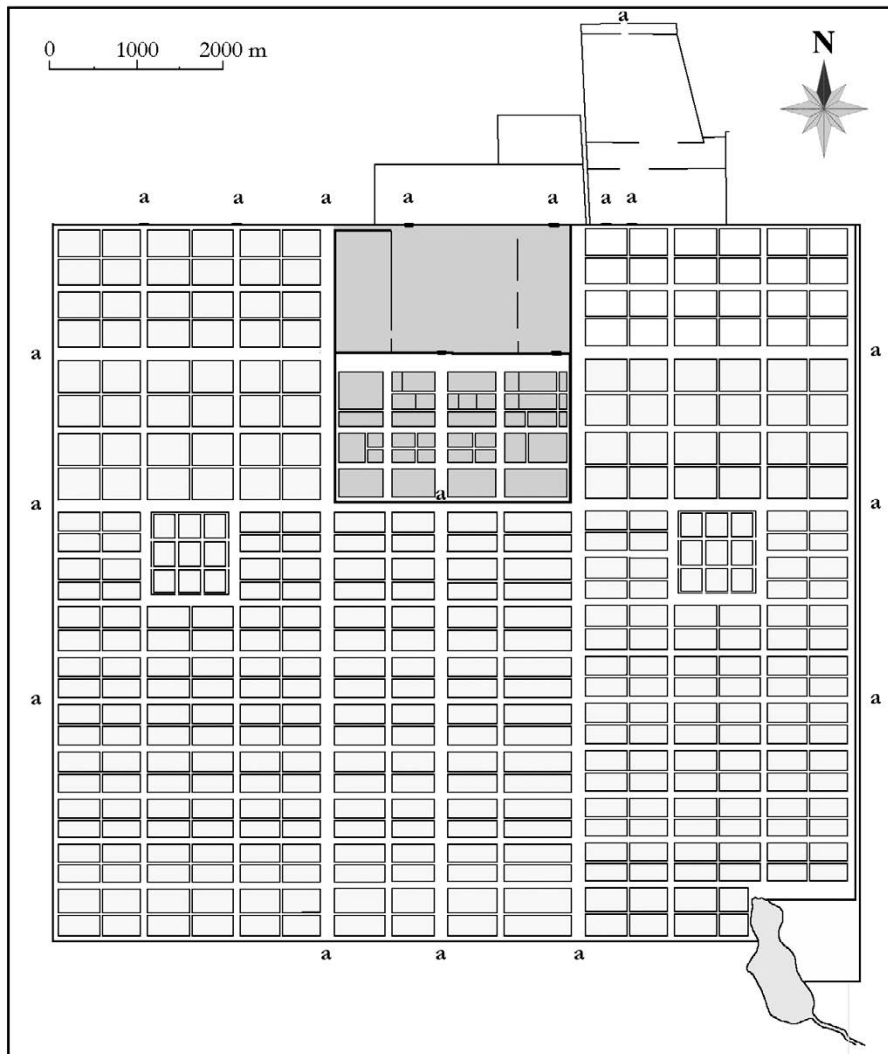
Map of Wangcheng in Kaogong Li. 'When the builder constructs the capital, the city should be a square, nine li on each side, with three gates on each side. Within the city are nine longitudinal and nine latitudinal streets; each of them nine carriages wide. On the left (i.e. east) is the Ancestral Temple, on the right (west) are the Altars of Soil and Grain, in front is the Hall of Audience and behind, the markets.'

Source: Heng Chye Kyang 1999.

²⁶ Vance 1990.

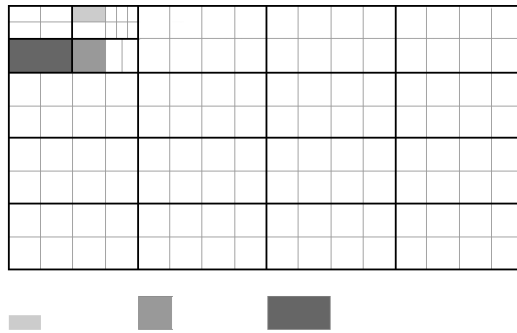


Modular scaling properties in Chinese cities and architecture. From left to right and from top to bottom: urban, district, neighbourhood, house clusters, house and room scales²⁷.

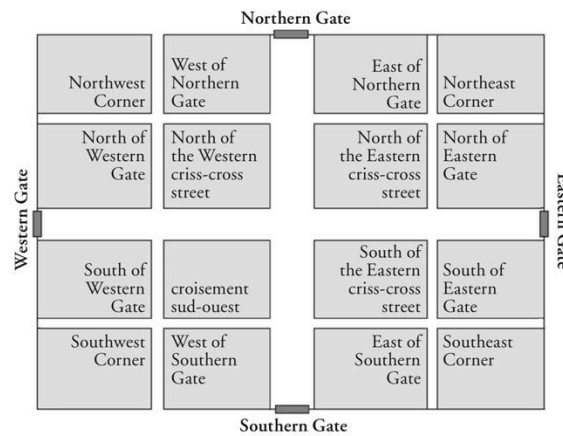


Chang'an and its 'Six Streets'. Source: Heng Chye Kyang 1999.

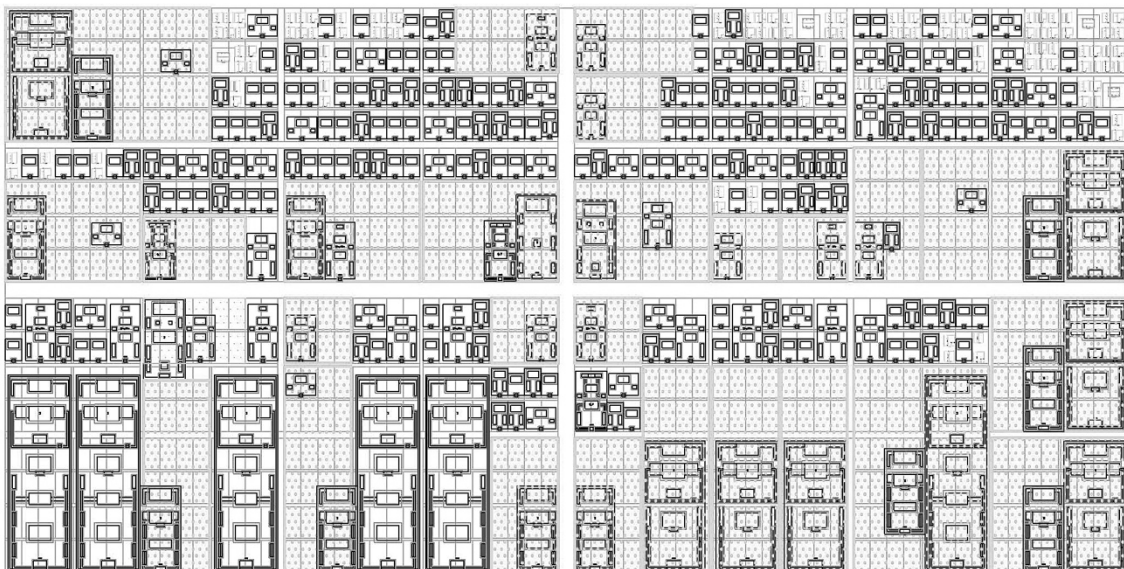
²⁷ Salat et al. 2011.



From left to right: 1/16 cho, 1/4 cho, 8 mu. The division algorithm of Chang'an districts ensures the continuous scaling of the urban structure and a perfect numerical unfolding from smaller scales to larger scales and vice versa. Source: Heng Chye Kyang 1999.



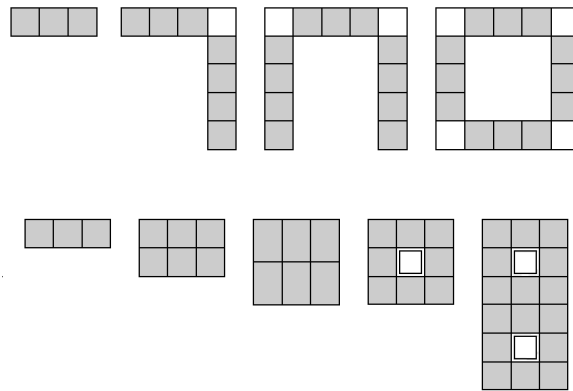
Street layout of a residential neighbourhood. Source: Heng Chye Kyang 1999.



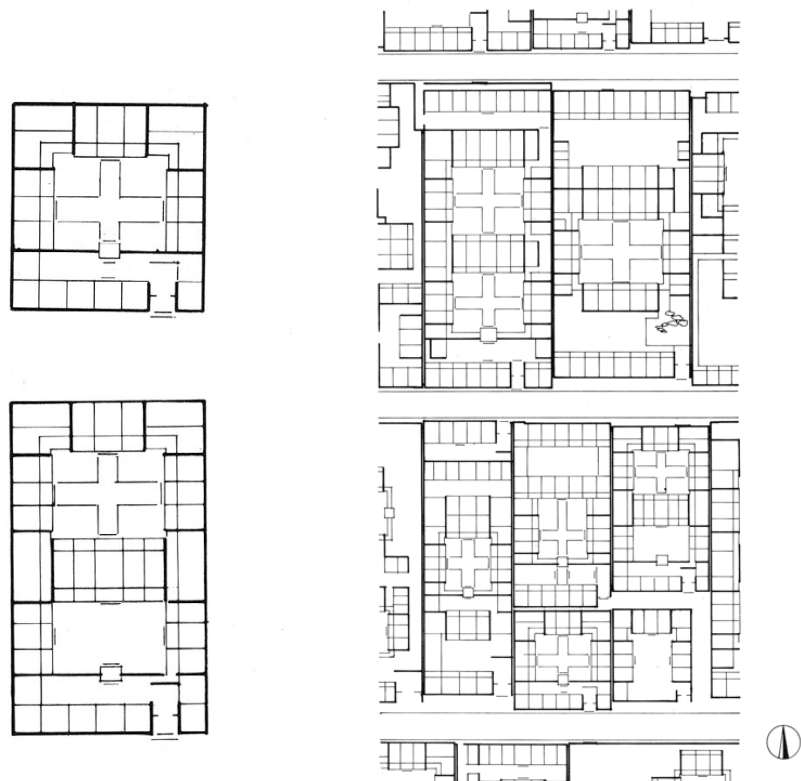
Reconstitution of a Chang'an district. Source: Heng Chye Kyang 1999.

In the historic Chinese city, the complex urban fabric consists in unending variations on the courthouse (*siheyuan*). All the same and yet each different, they establish a rich carpet connected on many scales. The square courtyard is an internal and private microcosm, protected from the cold northern winds in winter, below the shadow of a tree in

summer. It is not closed at the corners. Between the houses, passages on alternating sides create high connectivity in a complex network of paths.

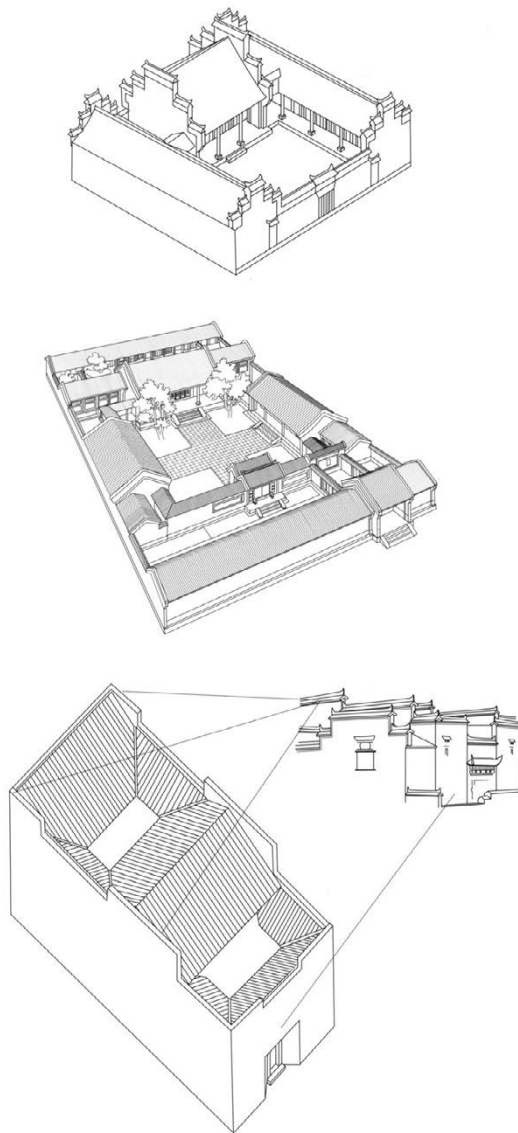


Chinese houses modularity. Over a period of time as a family's circumstances improve, dwellings tend to grow from a three-bay rectangle shown here on the left, to more complex shapes. The top drawing shows the common pattern in Northern China where, first, an L-shape emerges and then an inverted U-shape, before full enclosure of a courtyard within a rectangle. In Southern China, as the bottom drawing reveals, additions are sometimes made to the front or back with small "sky wells" situated within the growing mass. Top: Northern China. Bottom: Southern China. Source: Knapp 2005.

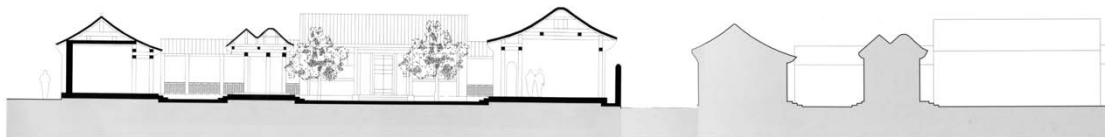


Left: Source: Werner Blaser 1979.

Right: Strips of houses between two narrow streets (hutong). Source: Werner Blaser 1979.

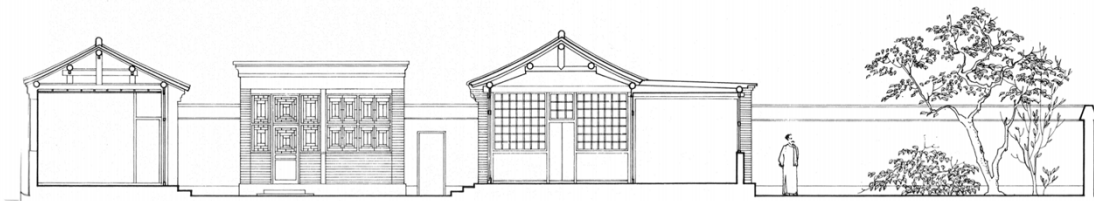


Traditional Chinese courtyard forms. While differing in detail, the dwelling types shown here all include the fundamental elements of Chinese architecture: enclosure, axuality, hierarchy, and symmetry. The central image is that of a classic Beijing siheyuan or quadrangular courtyard house. Chinese building forms, which took shape thousands of years ago, have displayed remarkable resilience down to the present. On the other hand, striking variations in architectural style are geographical. The latter reflect responses to differing regional environmental conditions, underscoring the extraordinary adaptability of the traditional Chinese house – one by its principles, and multiple by its metamorphoses.

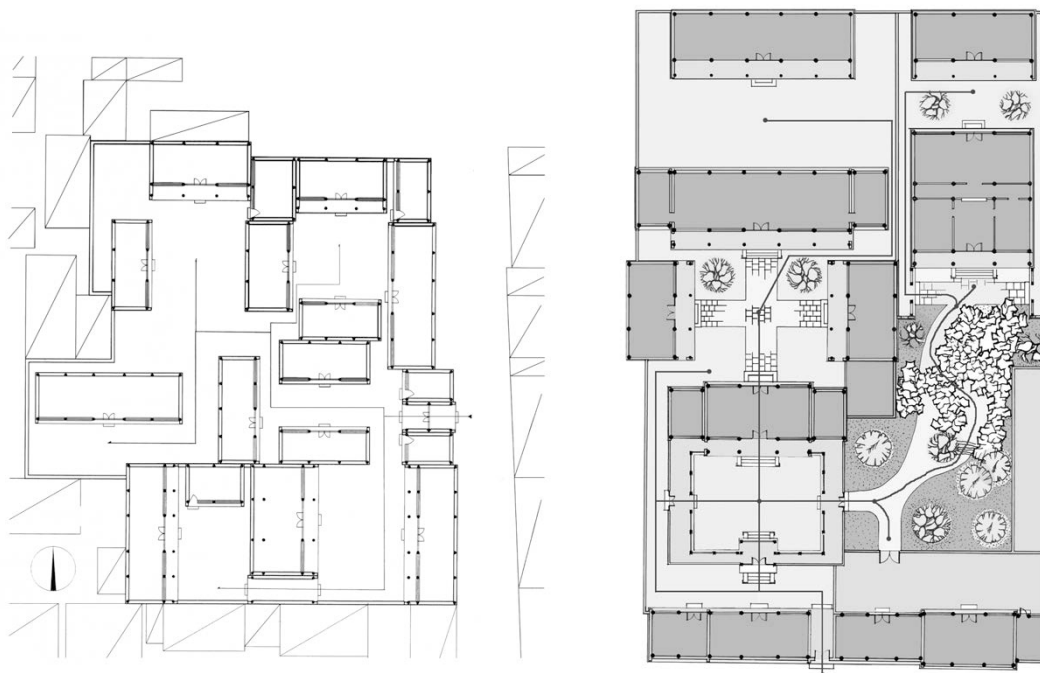


Section of a siheyuan. The square courtyard of the house is an internal and private microcosm.

Source: Firley and stahl 2009.

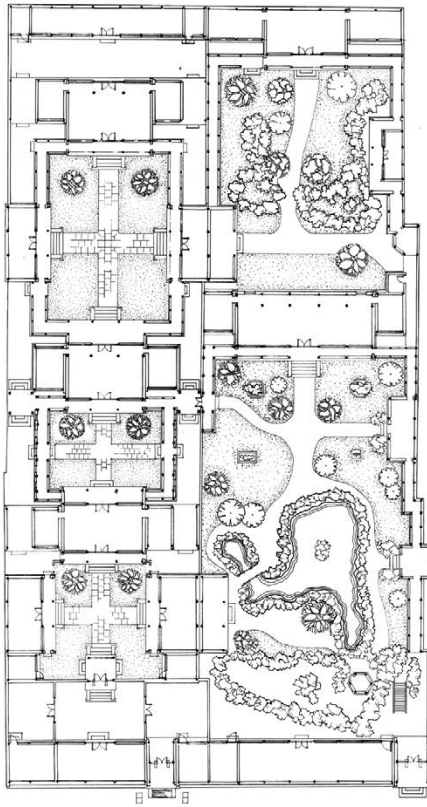


Above. Section of a siheyuan. Source: Chao-Kang Chang and Blaser 1988.



The square court is not closed at the corners. Between the houses are passages on alternating sides. They create a high degree of connectivity and a rich, complex path pattern. Source: Ma Bingjian 1997.

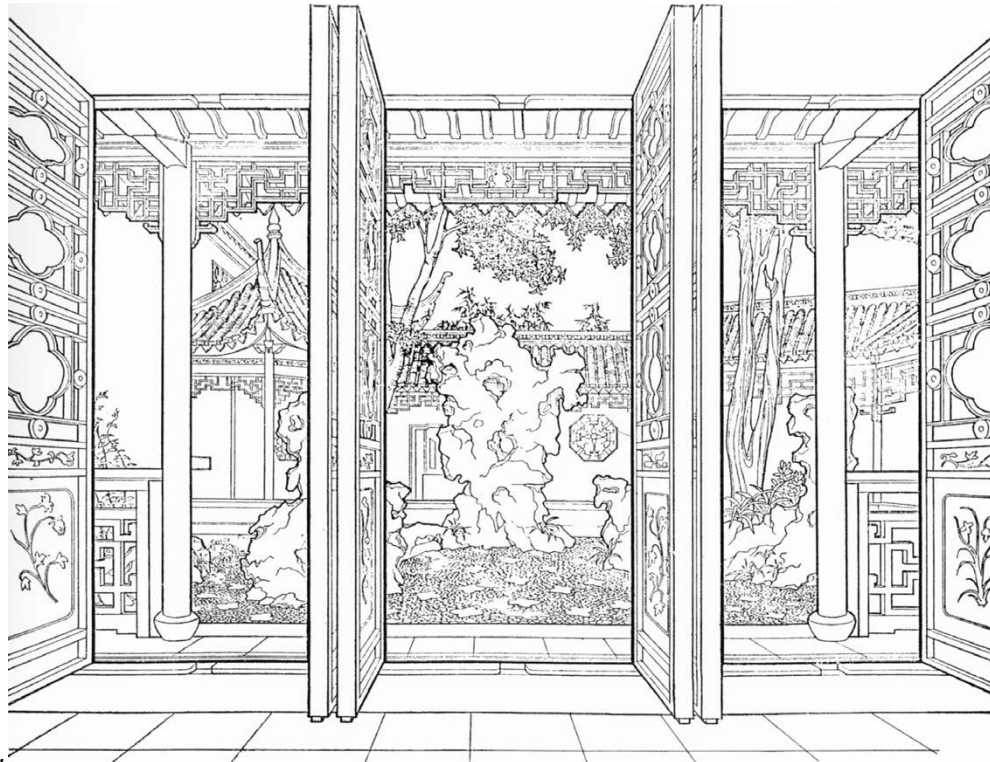
Right. Movement pattern analysis in a siheyuan with a garden. Source: Salat et al. 2011.



A complex composition of siheyuan with gardens. Source: Ma Bingjian 1997



Suzhou gardens. Photo: Serge Salat.



Room: articulation of inner space and gardens, opening to nature from within the most interior spaces.



Suzhou gardens. Photo: Serge Salat



Suzhou gardens. Photos: Serge Salat

CASE STUDY: KYOTO: 1,200-YEAR EVOLUTION OF A CITY FABRIC²⁸

Kyoto (originally Heiankyô) city fabric evolution manifests a unique Japanese form of interaction between human beings and their environment.



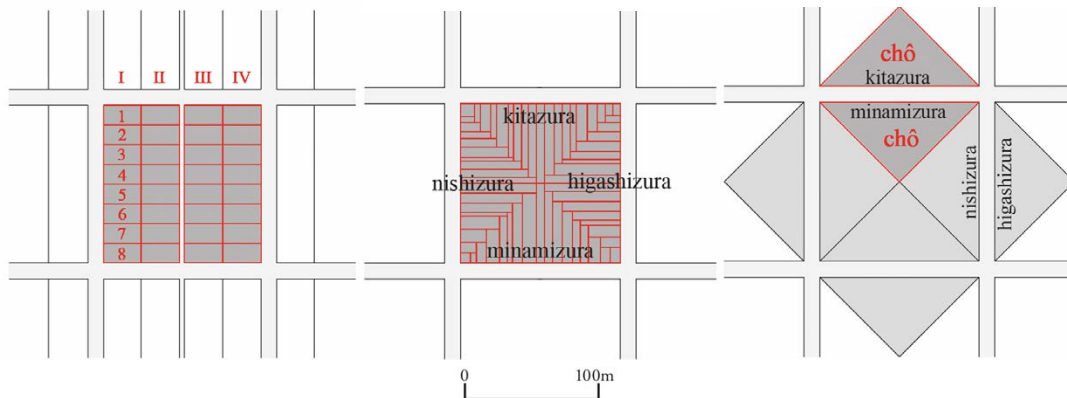
The grid plan of Kyoto has become more complex and denser over time. Source: Google, Gray Buildings © 2008 ZENRIN © 2011 ZENRIN, Image © 2011 DigitalGlobe.

When the city of Heiankyô was founded in AD 794 as the Imperial capital, its construction and street layout were informed by the same Chinese *feng shui* principles that had been applied to the Chinese capital, Chang'an. The Tang dynasty capital was laid out on a north-south axis in a grid pattern; the imperial palace was centre north and commanded the two main streets running north-south and east-west, while the districts were distributed along the grid, subtly varying the size of the mesh. The Japanese did not choose this model for its economic or social virtues but rather to symbolize spatially the hierarchical order corresponding to the imperial dynasty. Initially Kyoto had to deal with a reduced population and it adapted the original Chinese principles to the conditions of the site. Architectural traditions subsisted and were adapted to the plan. Walls surrounded estates, which formed miniature towns, housing merchants, residents, and servants.

²⁸ This case study is based on Salat et al. 2011.

which secondary streets provided access. The buildings occupying these plots had different architectures corresponding to the status of their inhabitants and to different functions (residential, commercial, storehouses).

Toward the end of the Middle Ages (1185–1573), after the devastation caused to Heiankyô by the civil wars, and with the rise of the merchant class, the walls that ran along the streets and delimited the enclosures disappeared. They were replaced by rows of *machiya*, mixed commercial and residential homes, open onto the streets. This modified the morphology of the *chô*: the district straddling both sides of the street (*ryôgawa-chô*) supplanted the old square block (*Katagawa-chô*). This new organization enriched the earlier one, enhancing the connectivity and complexity of the Japanese street layout rather than destroying it.



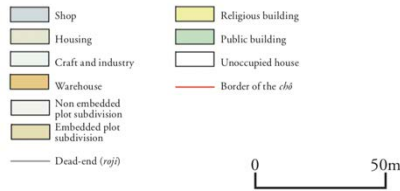
Despite the urban structure shift from a juxtaposition of walled-off invisible interior spaces to a perimeter of *machiya*s facing the street, and despite the many fires throughout the medieval period, the basic street layout was not destroyed. Its main north-south orientation and its orthogonal plan are still visible.



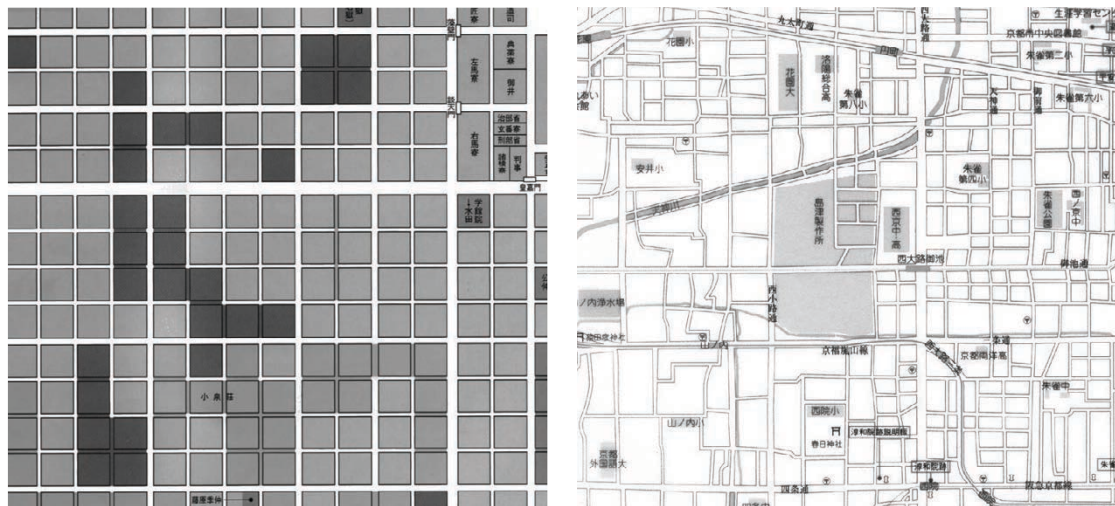
Old ryôgawa-chô of Bukkôji-Shinmachi.



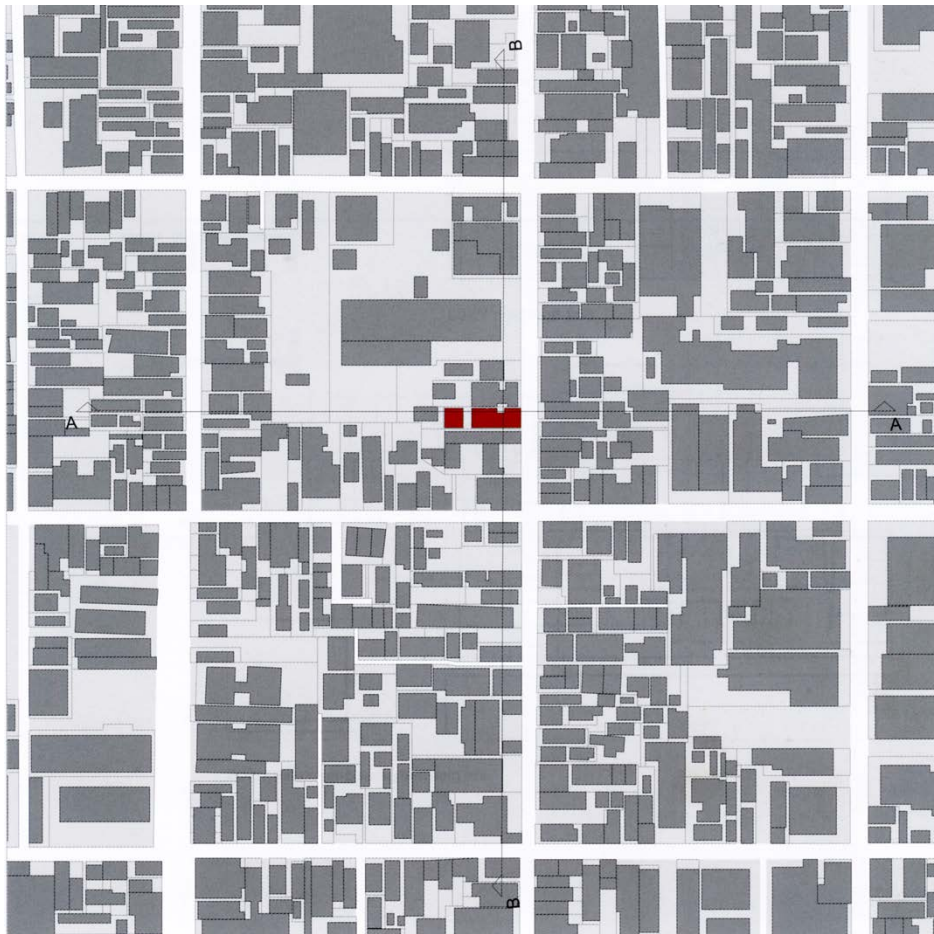
Old Katagawa-chô (with a central alley) of Gojô-Shinmachi.



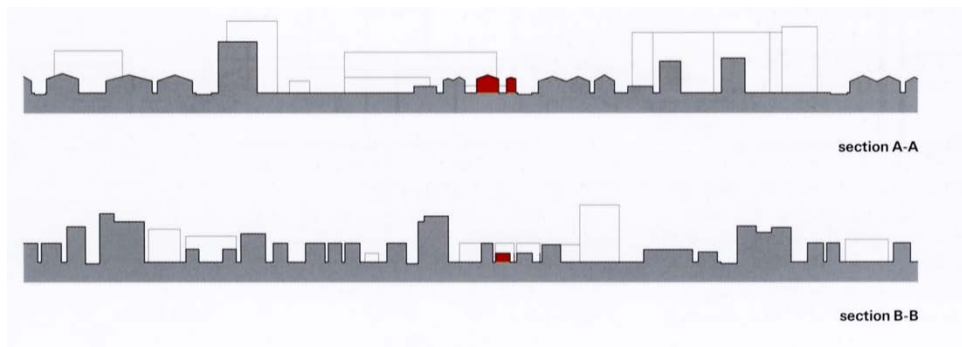
Kyoto today patterns mix the regular and the organic: be it the grid that remains highly visible in Gion or that has become more complex in Nishijin, or in the more organic development in Yamashinaku. Short distances between intersections that facilitate walking characterize these street networks. Indeed, the grid still structures the main roads but these are often connected to secondary streets. These provide access to the interior of blocks. They are sometimes hard to locate on maps as they lead deeper and deeper into semi-private and private spaces. This network even continues branching out right into homes themselves since the *machiya* are composed of interior 'streets' providing access to the different rooms and gardens of a single house. The density of intersections is high, reaching very high values.



Two views of the street network show the same site in Heian-kyō and in Kyoto 1,200 years apart. The hierarchized square network of the old imperial capital became more complex. However, it remains the underlying framework of the city. Kyoto today combines its original connectivity with the complexity and fragmentation created by the passage of centuries.



The contemporary urban fabric in Kyoto in a square 350 m side shows both the grid order created 1,200 years ago and the complex modular fabric of small land plots and buildings created by urban evolution. Source: Firley and Stahl 2009.



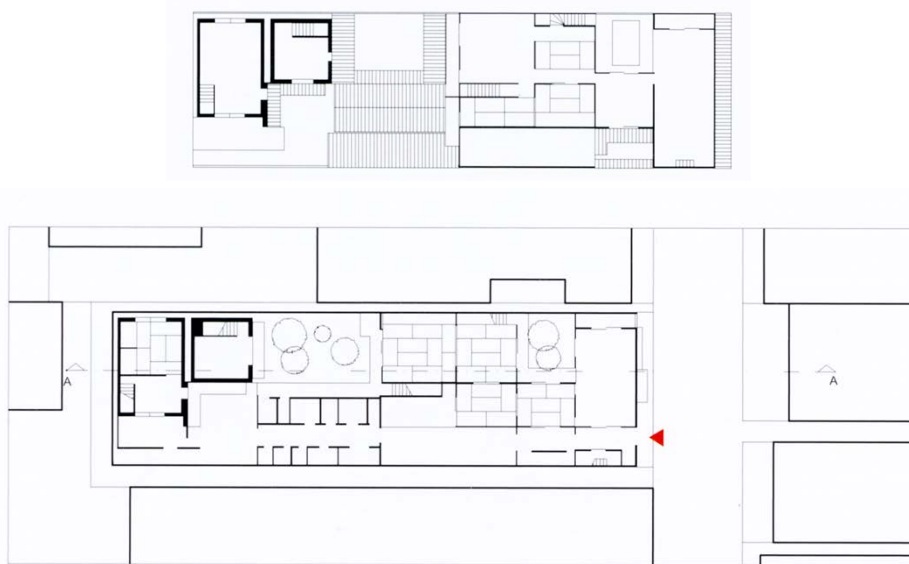
Two sections on the above urban fabric showing the human-scale rhythm of small buildings in Kyoto. Source: Firley and Stahl 2009.

The *kyo-machiya*, the traditional houses of Kyoto, are exemplary by their complex internal organization. On a relatively small surface of around 250 m², each house integrates up to five functional and architectural elements. It comprises a shop, a residential area, one or more courtyards, a warehouse and a large passageway. Each house is a micro-urbanism. The *machiya* fabric had a high plot coverage ratio (69%). The urban density²⁹ is 2 for two- to three-storey houses. This continuous dense fabric achieves high density while offering a variety of inner gardens.

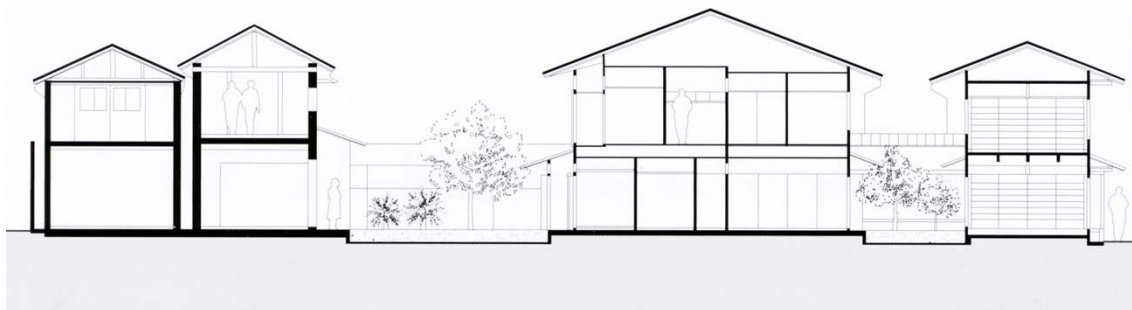
The orthogonal geometry of the *machiya* offers great flexibility and fluidity. It combines nature and artifice: it juxtaposes a long corridor on the ground floor (*toriniwa*) and elevated *tatami* rooms, with interior gardens surrounded by rooms

²⁹ Floorspace divided by gross land area.

and not directly linked to the main circulation. This layout creates a complex, stratified world, with multiple degrees of interiority in parallel and in depth. Space is differentiated with distinct levels of intimacy and sociability based on a principle of spacing (*ma*) and enveloping interior spaces (*oku*). The spatial logic is complex despite the prevalence of right angles. Geometry is allied with compositional flexibility on all scales, from the texture of the material assemblage to the layout of the room, the house, the *cho*, and the entire city.



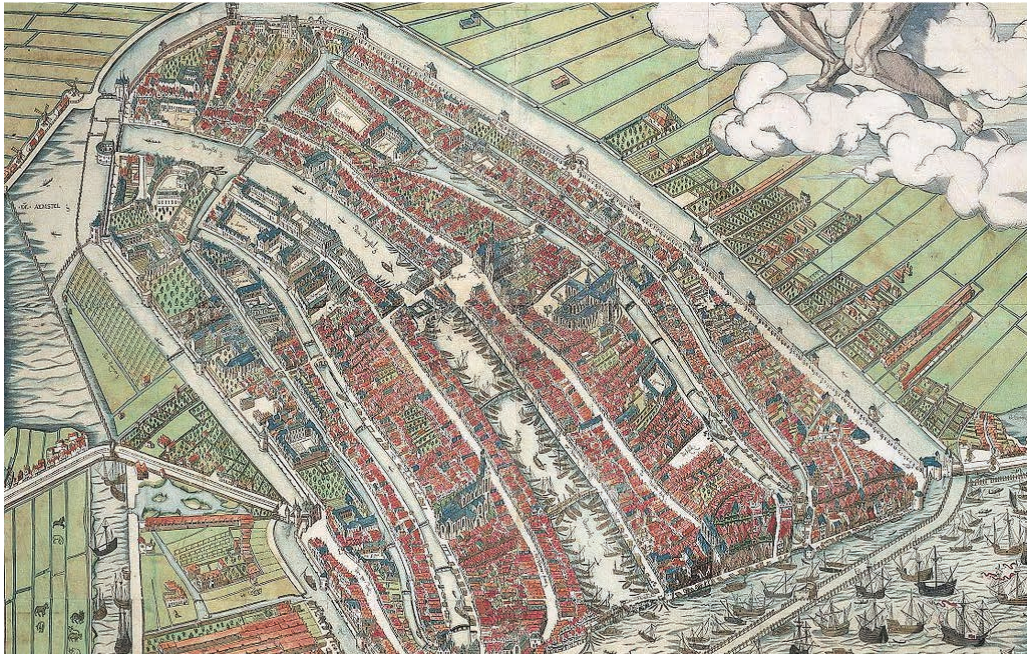
Top: First floor plan. Bottom: Site plan and ground floor plan. Surface area of the ground: 252 m². Source: Firley and Stahl 2009.



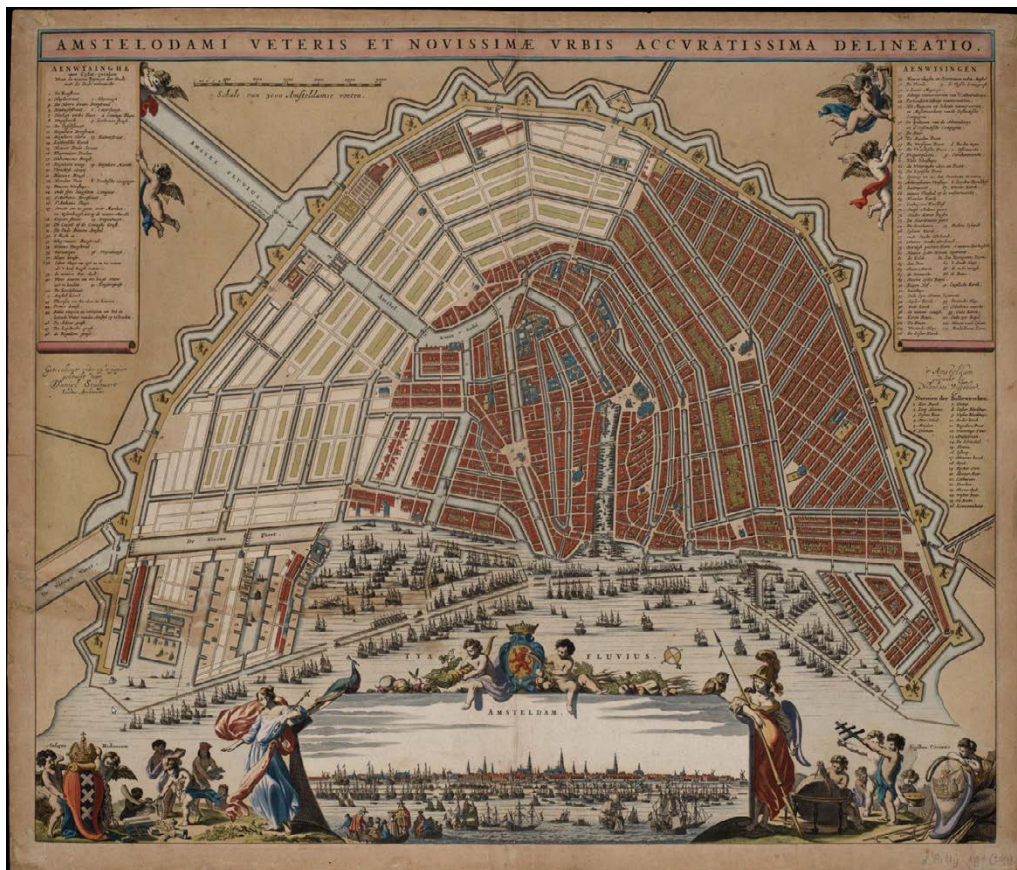
Section.

Originally, the *machiya* had more width than depth and covered only a narrow strip on the perimeter of relatively small blocks. Then during the Edo period, because of the growing wealth of the merchant class and the high taxes on façade width, they became narrower and deeper. The house form continually transformed – from the palaces of the Heian period to the diverse *machiya* of the Edo period – within an unchanged square grid. This demonstrates the resilience of complex urban grids. They survive centuries while renewing their built contents.

CASE STUDY: AMSTERDAM, EVOLUTION OF AN URBAN FABRIC BETWEEN ORGANIC AND PLANNED



Amsterdam in the 16th century.



A map of Amsterdam from the 17th century. With plans for expansion.



1. Amsterdam 14th century

2. Amsterdam, 16th century.

In the 12th century, where Amsterdam now stands was a swamp, the Amstel river still flowed into the Zuiderzee Inland Sea. The history of Amsterdam started with a fishermen community. They decided to build a 'Zeedijk' (dike) to protect themselves from the tides. Not far from this dike, a passage called 'Dam' was constructed. The village, which was growing little by little, was initially named 'Amstel-Dam'. In 1300, Amsterdam obtained city rights. Its real expansion then began. First, the eastern part of the city developed. Amsterdam was a merchant city. It lived from fishing and trading. Its location was perfectly chosen. It was a strategic position, as the flow of merchants was obliged to stop by Amsterdam to unload the goods and ship them inland. In the 14th century Amsterdam was still modest in size, but the Duke of Burgundy called it 'the most commercial city in the country'. With the port area as the city's pediment, only one canal crossed Amsterdam, the left and right bank being still the same size. The other canals circling the city outside the ramparts were used to irrigate crops.

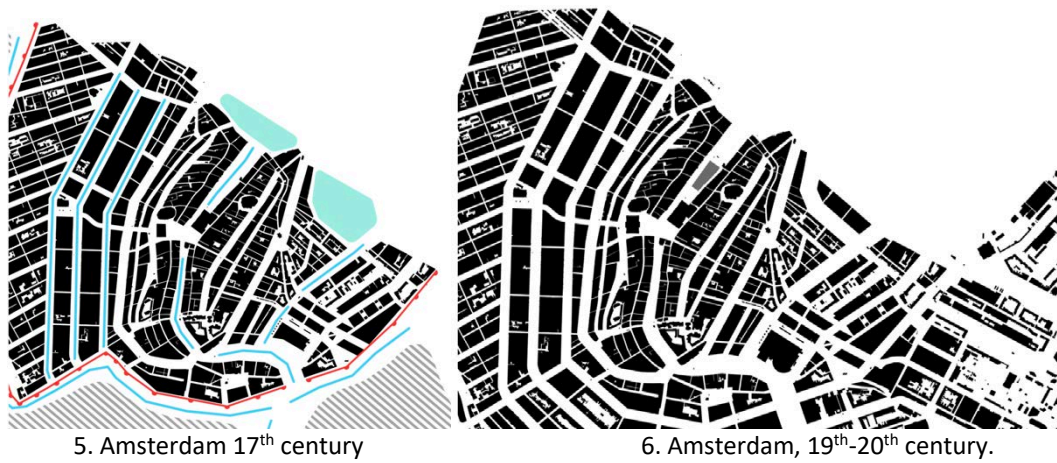
In the 16th century, the ramparts of the city 'Singel' retreated further, the outskirts of the city expanded. Amsterdam was crossed by a multitude of canals. On the right bank, Spuistraat en Nieuwezijds Voorburgwal emerged. On the left bank was Oudezijds Voorburgwal. Even beyond the ramparts, the city continued to expand. Plantations and farms began to develop. The port area also expanded and grew in size. The lock systems and the 'Damrak' inner port started their construction.



3. Amsterdam 17th century

4. Amsterdam, 17th century.

The 17th century was the city's golden age. The cessation of hostilities allowed Amsterdam to improve its trade with the Baltic Sea. The 17th century was also a critical time in the urban fabric transformation. The city now had its inner port and lock systems that were used to regulate the level of the Amstel, but also to clean the canals. The ramparts from century to century are an indicator of the city growth. Once again, they have retreated and encompass the agricultural area to the east. With prosperity, the city expansion accelerated. A ring was added. It became the limit of old Amsterdam. A radical transformation of the urban fabric began. During this century, what is now called 'Centrum' gradually developed. Around 1600, works to extend Amsterdam started. From 1600 to about 1614, the new enclosure was built. Once the enclosure was finished, the old enclosure was demolished and the work on the houses could commence. While the blocks of old Amsterdam are organic, a precise organization was put in place. The residences which are built there, are intended for the rich and follow a grid plan with large planted interior courtyards. Only in 1620, construction of this city part was completed. In Dam Square in 1648, a fire destroyed the old Gothic town hall. The city decided to build the current Royal Palace from 1648 to 1665. The city also extended east from 1660 to 1700.



5. Amsterdam 17th century

6. Amsterdam, 19th-20th century.

- █ City wall
- █ Canals
- █ Port
- Fields

Amsterdam morphological time line. Drawings by Louhann Brocard. École Spéciale d'Architecture, Paris.



Amsterdam urban fabric, 1625.



Amsterdam urban fabric, 1724.



Amsterdam urban fabric, 1876.

CASE STUDY: HILLSIDE TERRACE, TOKYO

Fumihiko Maki, Architect



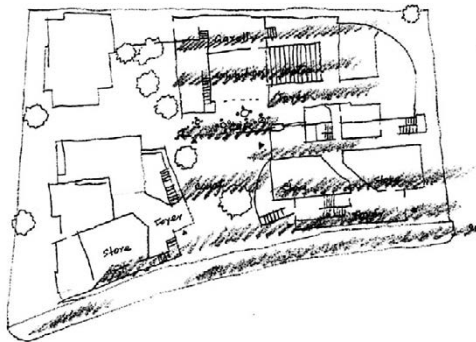
Hillside Terrace interplay of indoor and outdoor public space. Fumihiko Maki, Architect. Photo: © Françoise Labbe.

Located in Shibuya ward, Hillside Terrace is a medium-density mixed use development of apartments, shops, restaurants, and cultural facilities. The ensemble was constructed and evolved overtime, with increasing refinement while keeping a clear identity and coherence. The composition has changed, adapted and grown, as a result of new elements added over time. 'Although their architectural expression has varied in response to the times, the buildings of phases one through six share a consistent scale of massing, using a combination of staggered, cubic volumes, generally one and two stories tall, with apartment blocks frequently lifted above street level on transparent and/or recessed ground-floor volumes. Several unifying spatial elements, such as corner entrances and interior stairs echoing exterior topography, are repeated in different guises to create a sense of continuous townscape while allowing localized variations. Within such an evolving framework, I have viewed each individual building design from the perspective of its urban presence and meaning – aiming to discover in this process a modern language for the creation of group form.'³⁰

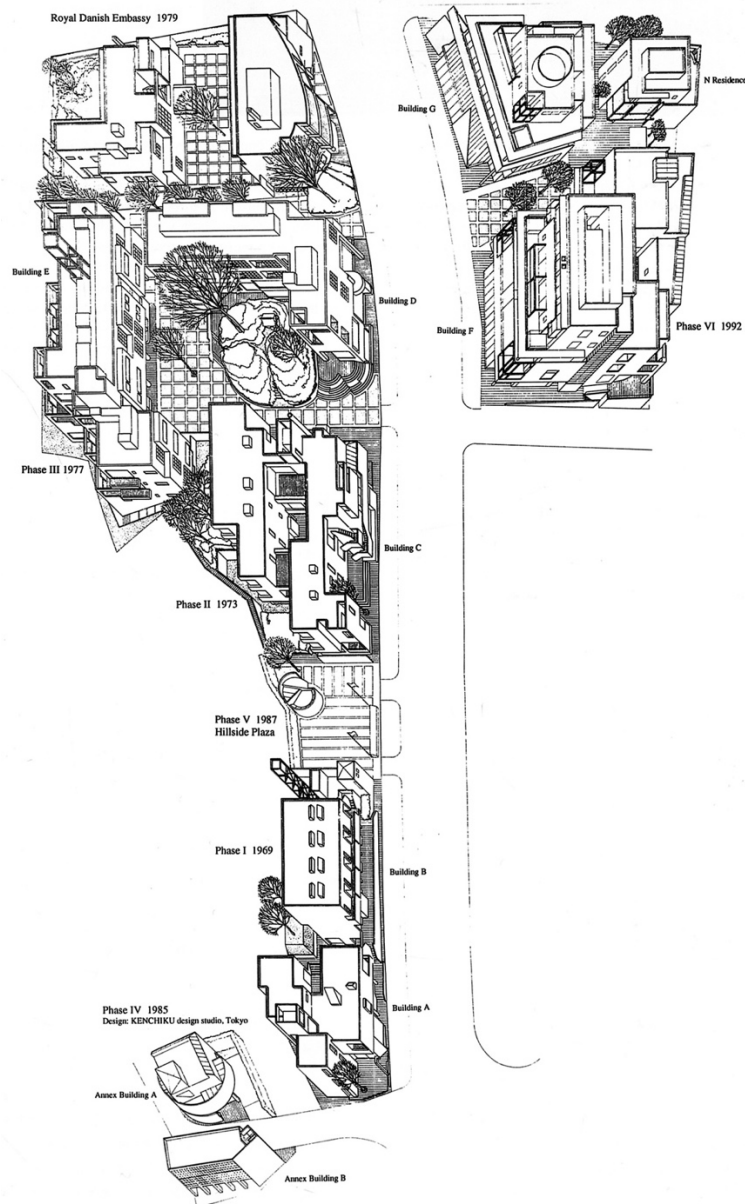
³⁰ Maki 2008.



Left: Hillside Terrace. Phase VI (1992). Right: Hillside West (1998). Fumihiko Maki, Architect. Photos: © Françoise Labbe.



Layers of buildings and public space in Hillside Terrace, Tokyo. Fumihiko Maki, Architect. Photos: © Françoise Labbe.



Hillside Terrace, Tokyo. Fumihiko Maki, Architect.

At each stage, each composition was not an unfinished totality in progress but a complete whole greater than the sum of its parts and possessing both wholeness and linkage. Each successive whole became more complex when adding new elements. Over time, the plural form of Hillside Terrace has been unified by many factors other than Maki's design. It has included several buildings in between or behind the development, designed by other architects. These have respected the serenity and sense of layered complex public space infused from the very beginning by Maki. These common design strategies have allowed a strong consistency in the diversity provided by the interventions of different agents, clients with different purposes and programmes. In other terms, plural agents in Hillside Terrace have created a plural but coherent urban form over a span of a quarter-century.



Continuity and evolution over a quarter century. Hillside Terrace. Fumihiko Maki, Architect. Photos: © Françoise Labbe.

‘The singular sense of place that people strolling among the various buildings and outdoor spaces of Hillside Terrace feel is no accident. It is the result of a deliberate design approach that has created continuous unfolding sequences of spaces and views, taking advantage of the site’s natural topography and, indeed, enhancing it with subtle shifts in the architectural ground plane. The various green areas, plazas, sunken gardens, exterior stairs, sidewalks, and transparent entrance halls are interconnected by views to one another, giving an impression of substantial depth and extent across the site. One does not physically experience urban space by simply gazing at buildings or looking at them from above – space is experienced only through sequential movement. Like music, movement in space can be a source of elemental joy, something to which one can give oneself up entirely.’³¹ ‘At Hillside Terrace, long views pass through multiple spatial boundaries created by topography, stairs, roads, trees, and low walls. Several possible loops are offered for passage through the site and back to the street, and glimpses of greenery seen around the corner are just as important as fully transparent views for suggesting a path.’³²

³¹ Maki 2008.

³² Maki 2008.

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