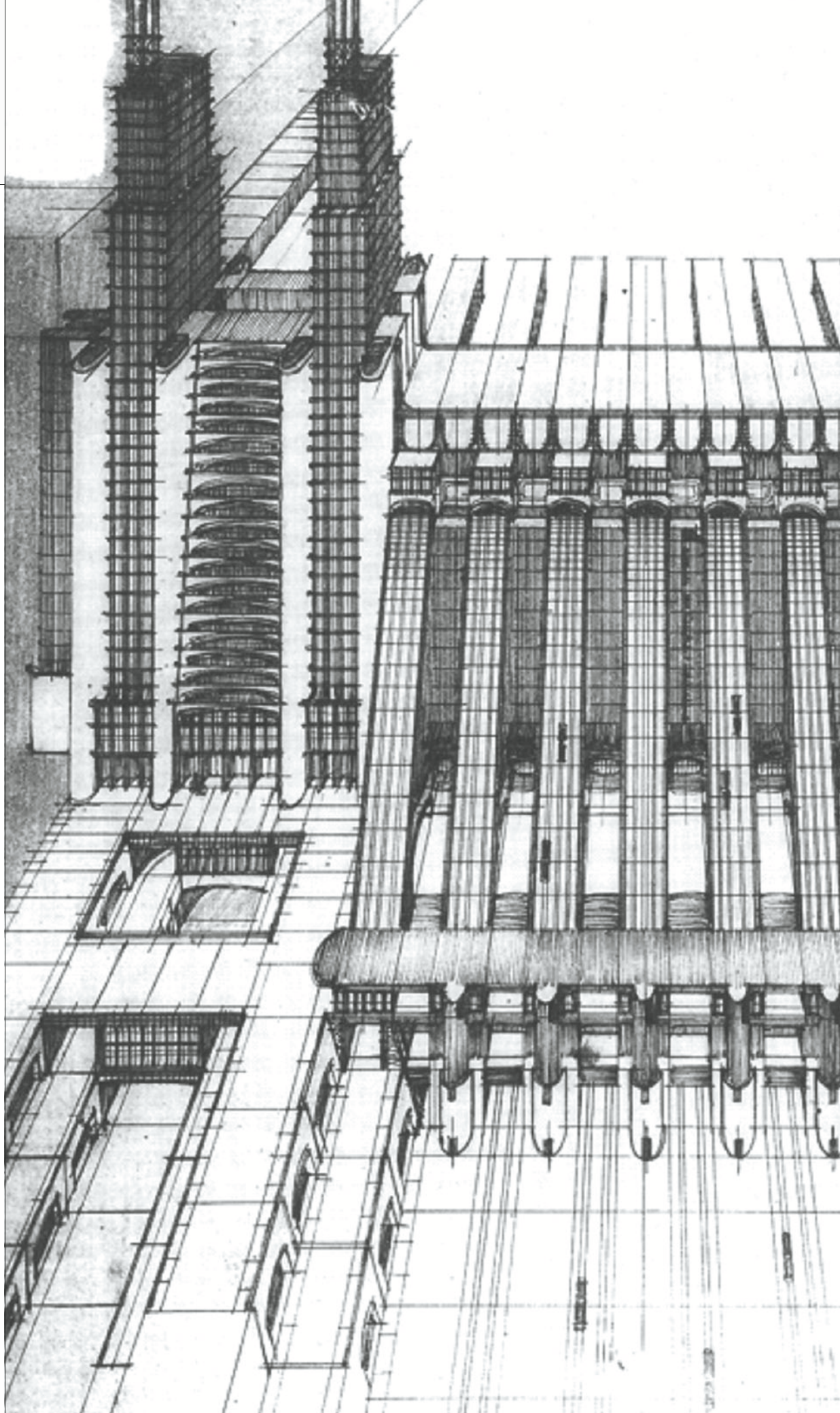
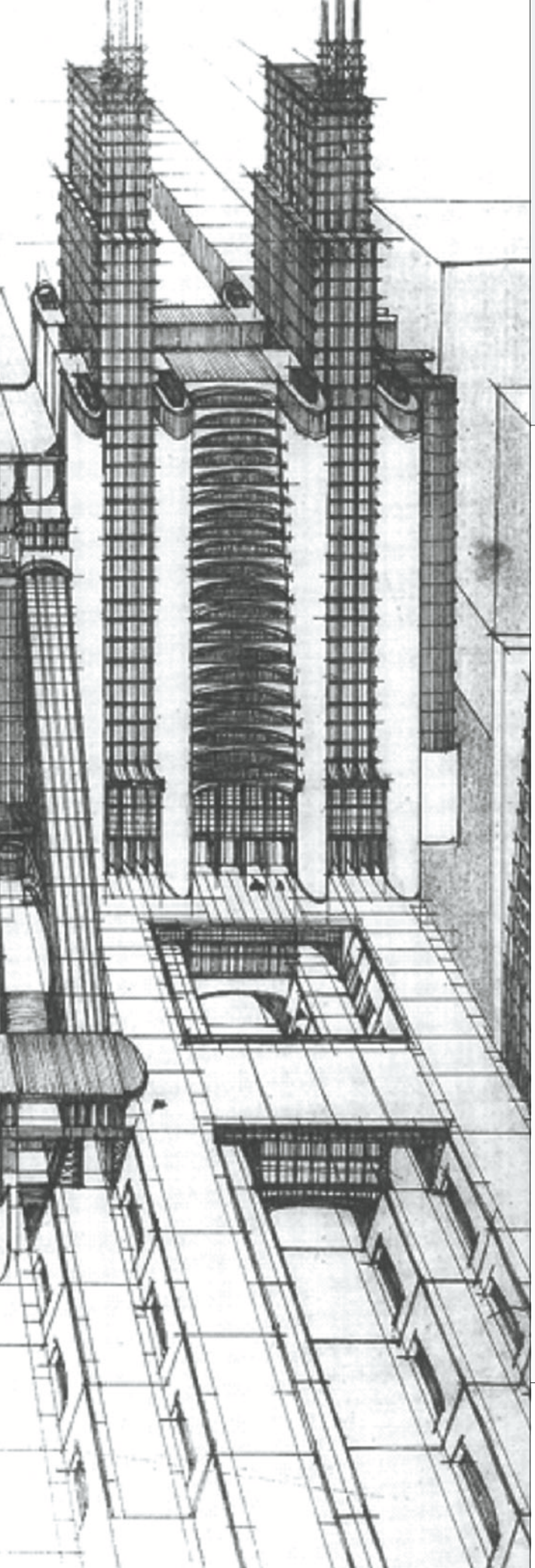
INTRODUCTION

By Michael Weinstock





SYSTEM CITY

INFRA-STRUCTURE AND THE SPACE OF FLOWS

Antonio Sant'Elia, *La Città Nuova*, 1914
Sant'Elia's imagination of the future city was characterised by an architecture of calculation, constructed with all the resources of science and technological systems to satisfy 'all the demands of our habits and spirit'.

Every generation must build its own city.

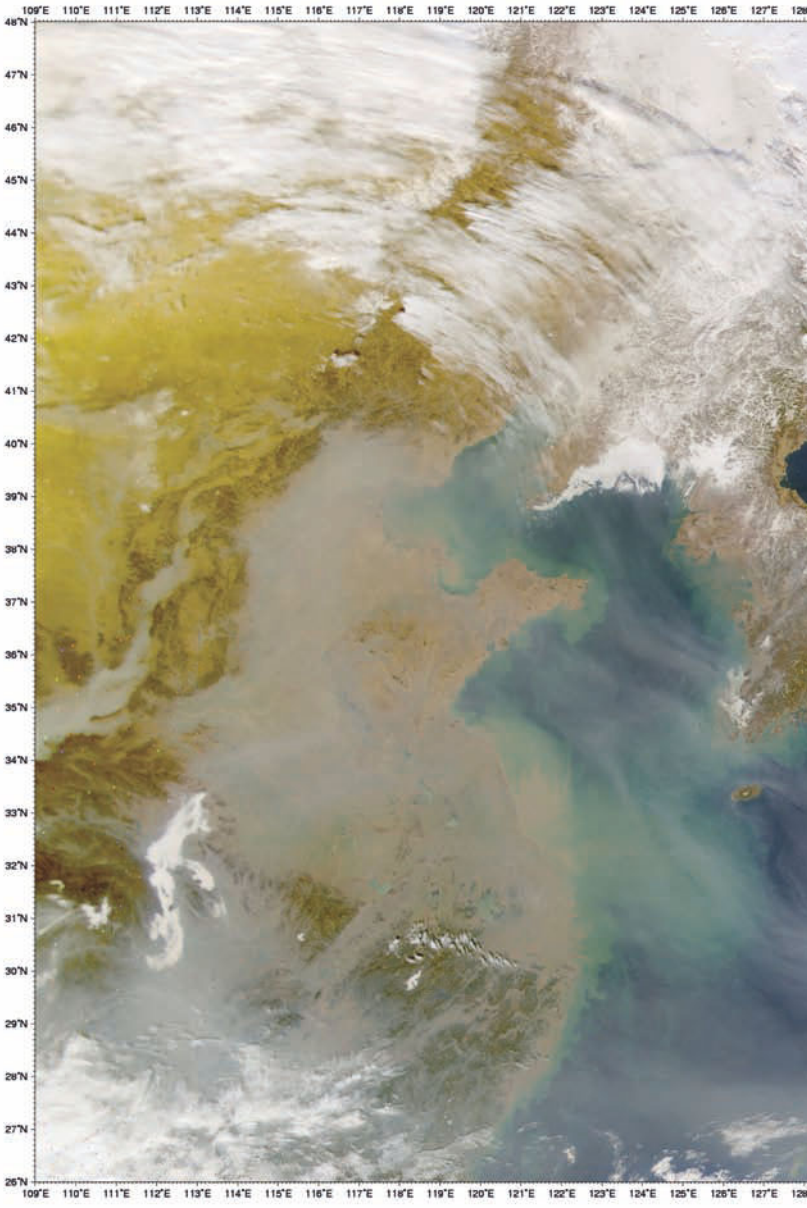
—

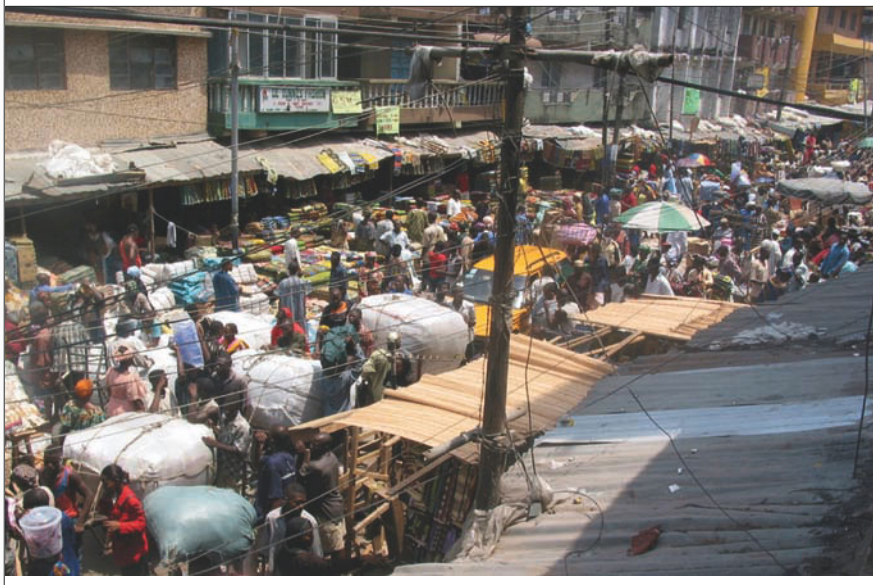
Antonio Sant'Elia
'Manifesto of Futurist Architecture'
1914 [1]

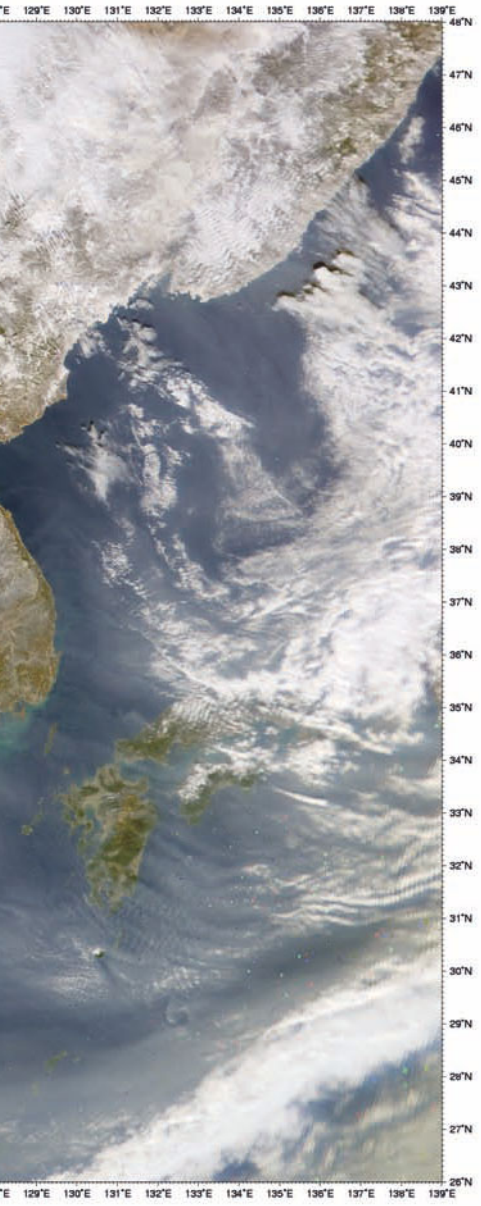
A century has passed since these words were written, and much has changed in the world. For Sant'Elia, as for architects today, the future city was a project of the imagination as much as it was of calculation, and his descriptions of a dynamic city constantly being reinvented and rebuilt, of rapid movement and change, and new ways of being, resonates most strongly today. The city is 'both real and imaginary, something lived and something dreamed, the most complex artefact of human civilisation, an object of nature and a subject of culture'.[2] It is our culture that determines the way we think about the city, and mediates our experience of it. New ways of thinking about the city and new methods of design and making it are once again emerging, engaging both the means and the imagination of our culture. *System City* brings together scientists, architects and engineers from disparate fields whose work and thoughts converge on contributing to the societal endeavour of building the 'future city'.

The need for new imaginations and new configurations of the city is more pressing now than at any previous time in human history. Two major phenomena are driving changes in the geographical distribution of populations: the migration to cities from dispersed territories, and the rapid acceleration in the growth of the number of people in the world. Migration to the city was a gradual historical phenomenon in Europe and North America, but is now a much more rapid process underway in Africa, South America and Asia. Population growth follows the same geographical distribution, being slow in the West and much faster in Africa and Asia. The centuries-long evolutionary processes that took place in the West have taken only two or three decades in Africa and Asia, and will continue to accelerate in these regions.[3]

The world is also currently in a regime of rapid climatic and ecological change, and there is widespread concern regarding the ability of the global system to cope with the array of changes that are underway or anticipated.[4] It is clear that the accelerating informational complexity, extreme velocity and volumes of fuel and food energy flowing immense distances across continents and oceans, and high but inequitable energy and material consumption[5] strongly correspond to the multiple causality of disruption, societal transformation and collapse of the past.[6] The city is critical to the capacity of society to adapt to a future of uncertainty and change.





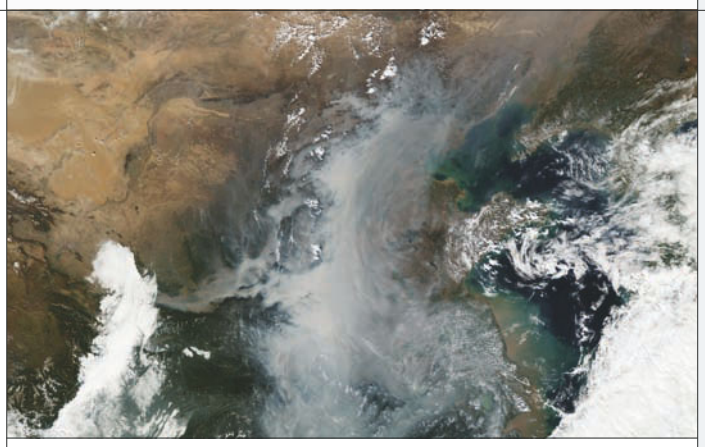


Wax Market, Lagos, Nigeria
left: While population growth and the development of the city networks of the West evolved over a period of centuries, cities in Africa and Asia are under immense pressure to adapt to the rapid rates of population growth over only two or three decades.

Climate, Ecology and the City

Considering the city as a dynamic complex system places emphasis on the interactions and connectivity of the flows through its infrastructures, and of the feedbacks and critical thresholds that drive the emergence of new spaces and urban morphologies that are animated by new modalities of culture. Complex systems are composed of elements that are interconnected, and causation is iterative so what is an effect at one scale may also be a cause at a higher scale.[7] In this domain cities are regarded as emergent phenomena that exhibit characteristics of complex systems, are embedded within the systems of the climate and ecology, and have reciprocal interactions between them at a variety of spatial, temporal and organisational scales.

In 'Local Climates of the City' (pp 100–105), Iain D Stewart examines how regional-scale climate produces effects on the thermal and morphological properties of urban and rural surfaces. Urban climate phenomena exist across a continuum of scales that connect the city surface and its roughness elements to the enveloping atmosphere, driven by inputs, throughputs and outputs of energy, and set out a new classification of urban microclimates. Regional-scale climates also affect the flow of energy through the ecological system of the rainforest. Evan Greenberg and George Jeronimidis' 'Variation and Distribution: Forest Patterns as a Model for Urban Morphologies' (pp 24–31) analyses the rainforest's morphology, and traces how it emerges from the interaction of climate with the flows of energy and genetic information through its individuals. The distribution patterns and growth strategies produce sectional differentiation in the forest and its microclimates, and this provides a conceptual model for the generation of urban forms organised by patterns of distribution, local height differentiations and density gradients. In turn, stratified urban microclimates are produced that can be linked to the network of green spaces and productive surfaces at the ground level.



Satellite images of smog and dust clouds over China
top and left: The city is a dynamic and complex system embedded within environmental flows across a variety of scales. Smog and dust systems, for example, emerge from the combined processes of the productions of cities and conurbations and creating regional-scale climate phenomena.

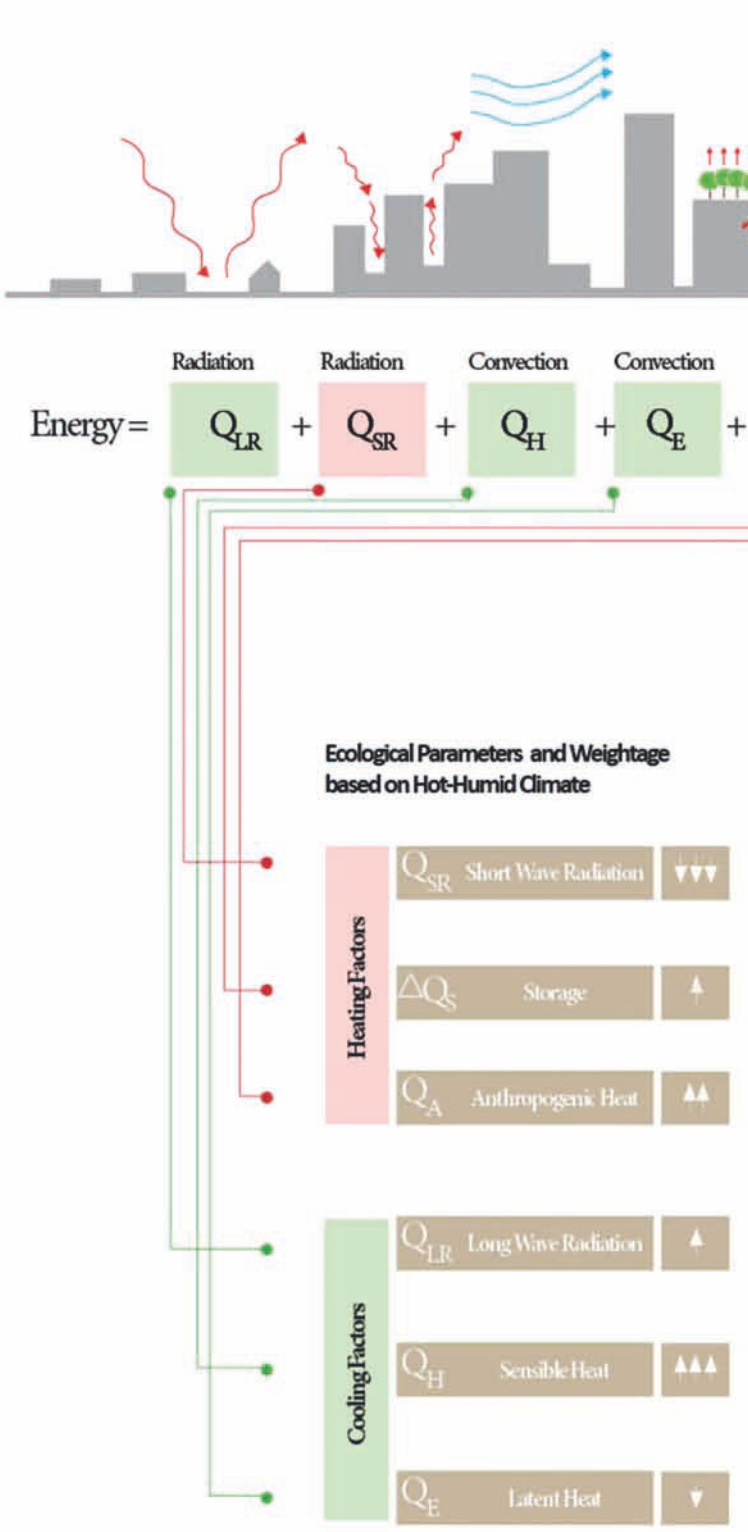
In 'Scales of Metabolic Flows' (pp 86–93), Keith Besserud, Mark Sarkisian, Phil Enquist and Craig Hartman of Skidmore, Owings & Merrill (SOM) elucidate how the understanding of the differing scales and metrics of metabolic flows through cities drives their analytical and design processes. At the regional scale, the SOM study of hydrological and ecological complexities informs their 100-year vision for the Great Lakes and St Lawrence River region. The large urban project in Chicago on the Lake Michigan shoreline is integrated with the existing systems of the mature city, and emphasises the necessity for multi-scalar connectivity of hydrological and movement systems. Their urban information model of the city of San Francisco has been developed to collate the data of these flows in relation to the morphology of the city.

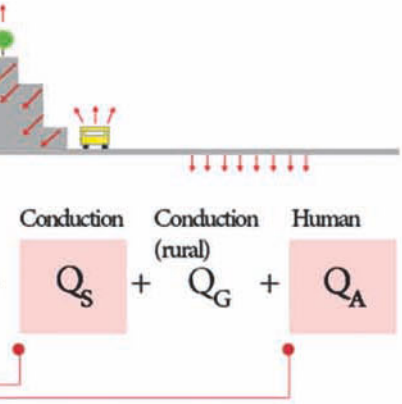
Daniel Segraves has also worked on the problems of collating the 'big data' of energy flows through the centre of Chicago, and in 'Data City: Urban Metabolic Decision Processes' (pp 120–23) proposes that a working model of the city will consist of numeric representations of all the flows and physical compositions of its parts in the context of the atmospheric conditions and fluctuations. Such a complete set of data would require the development of a regional-scale sensory system. The manipulation of these data during the process of city design is addressed in 'Ex Silico Ad Vivo' (pp 106–11) in which Francis Aish, Adam Davis and Martha Tsigkari of Foster + Partners explain how the existing competencies of analysis and modelling of urban environmental flows can be augmented by 'population thinking'. In this approach, a family of design options is produced, sharing genes of expressed parameterised variation that enable the evolution 'in silico' of systems via simulation processes that can also incorporate intuition and experience.

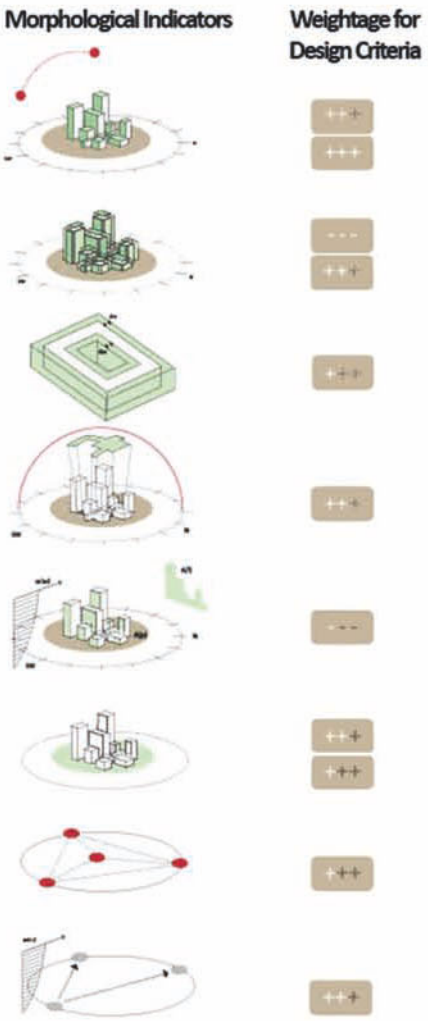
The integration of ecological, hydrological and city systems are the design drivers for new urban morphologies in the work of Eva Castro, José Alfredo Ramírez and Eduardo Rico at Groundlab. In 'The Grounds of a Renewed Practice' (pp 78–85) they present the manifestation of this approach in Ground Ecologies, a masterplan proposal for 200,000 inhabitants in the Jiading District of Shanghai. In their Paisajes Latentes project the analysis of the hydrological systems of Mexico City are coupled to the topology of Valle de Chalco's street networks to produce a synthesis of landscape infrastructure and architecture, developing new spatial patterns and adjacencies.

Cultural Systems

As humans are incorporated within the complex system, there is an increasing area of studies of the cultural aspects of the complex systems of cities. Over the last decades, the study of the city as a complex system has grown from a little-known specialised field of physics to an established and widespread collaborative research that crosses disciplinary and domain boundaries in the sciences and humanities. Culture is the collective memory of society; it encodes ways of being and the means by which each generation is bound into society and through which they contribute to it. Cultural systems are embedded in the intricate choreography of the evolution of cities and inflect their evolutionary dynamic.





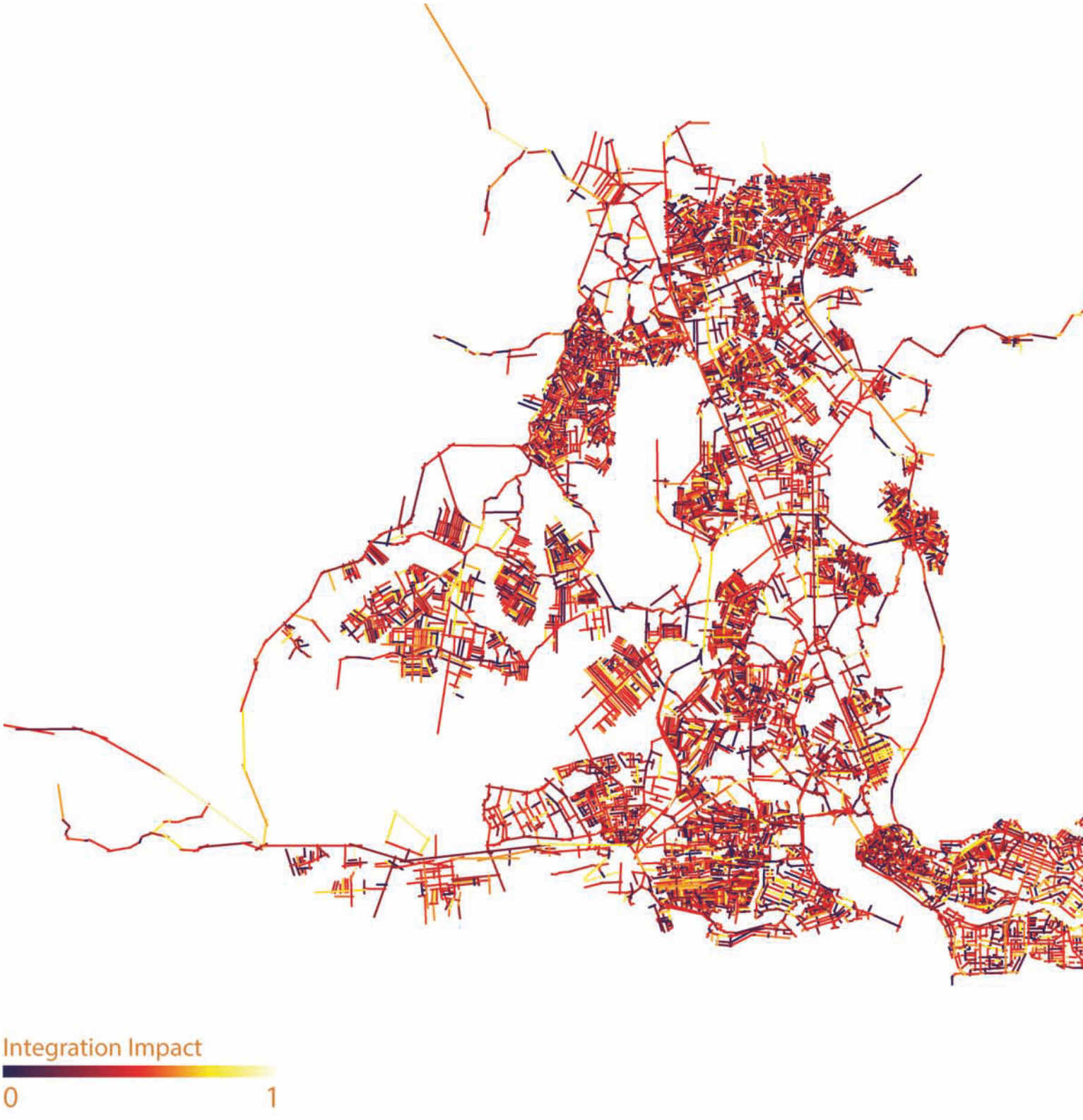


Sebastiaan Leenknegt, Lei Liu and Aarathi Muralidharan, Ecological Parameters Affecting the Environmental Performance of the City, AA Emergent Technologies and Design (EmTech), Architectural Association, London, 2011–13
Simulations of the environmental performance of urban morphology have to encompass a series of intricate interactions of several parameters. Differential weighting of these parameters is dependent on cultural and social values.

Marina Lathouri's 'A History of Territories, Movements and Borders: Politics of Inhabitation' (pp 32–7) explores the relationship between people and territory, expanding from the scale of the intimate to the scale of geography. In her account, borders are the interfaces between the private and the public, the individual and the collective. This is also where new cultural practices play out the articulation of indeterminacy, and where the spaces of the social are created and defined. The construction of social spaces is the critical concern of Cristina Díaz Moreno and Efrén García Grinda of AMID.cero9. In 'Third Natures: Incubators of Public Space' (pp 46–55) they argue that public space is not just defined by the buildings that enclose it, but also by the interactions of people and technology as they inhabit space. What they describe as 'third natures' are self-assembled communities that construct social space through their cultural practices. In Jack Self's view, the city is a multiplex superposition of evolved network infrastructures whose origins may be traced far back in the distant past. In 'Darwin Among the Machines' (pp 66–71) he argues that contemporary informational technologies augment the social practices of the city's inhabitants, and free them to engage with public space in new and often startling ways.

Cultural evolution is intertwined with genetic evolution,[8] but neither can be neatly mapped onto the other. Humans became behaviourally modern when they could reliably transmit accumulated informational capital to the next generation, and do so with sufficient precision for knowledge to be preserved and accumulated. However, there are many differences between the evolutionary processes of culture and nature. The pace of cultural evolution is quite different to that of biological evolution, as the paths and modes of information transfer in culture are more frequent and have a far more rapid proliferation through populations than genetic transfers of information from one generation to the next. What is common between them is that both are situated, so that when changes occur in the collective behaviour of humans it tends to bring about changes in the environment, and that in turn has set up changes in the regime of natural selection.

Cultural evolution is intertwined with genetic evolution, but neither can be neatly mapped onto the other.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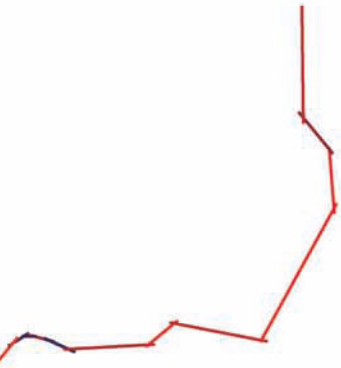


The Systems and Spaces of Flows

'Infrastructure' is the collective term for the systems and spaces of flows[9] that provide the 'services' of the city; its transportation, water, energy, information and communications, waste collection and disposal, public spaces including the 'green' spaces of parks, gardens, open woodlands or nature reserves, and the social programmes of health, education and recreation. The study and design of infrastructures is conventionally focused on the separate physical artefacts of the networks, and in recent times there has been strong focus on the architectural renewal of stations, bridges and terminals, but less on how infrastructural systems interact with their local tissues.

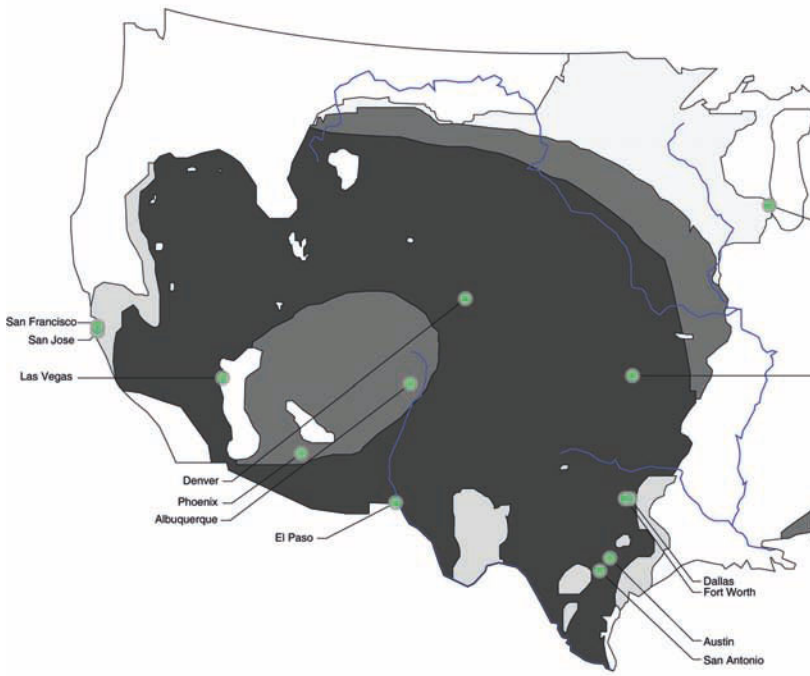
Wolf Mangelsdorf's 'Metasystems of Urban Flow' (pp 94–9) comments on a recent shift in the design of urban infrastructures that is based on the recognition of how multi-scalar patterns and variable speed of flows can produce emergent spatial configurations. He presents an argument for flow systems that have a measure of indeterminacy in their relations to immediate context to allow sufficient flexibility for future change. Buro Happold's approach is demonstrated in the High Line in New York City, where the reworking of the old railway infrastructure has acted as a catalyst for urban regeneration along its path. In the XRL terminus in West Kowloon the flows are more constant, but the building itself provides the gradation of spaces and programmes that mediates the transition from high-speed train to pedestrian flow into the new waterfront developments of the West Kowloon Cultural District.

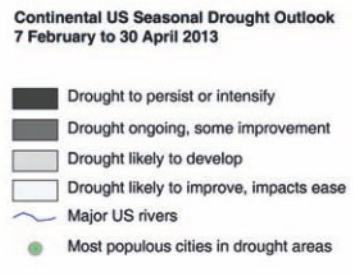
In 'Cities and Grids: In Search of New Paradigms' (pp 72–7), Joan Busquets shows a taxonomy of the distinct variations of grid system street patterns of cities, each producing different spatial orders and widely distributed across historical time and geographical distance. He argues that though grid systems produce urban coherence, they have also enabled adaptations to new city functions that emerge as urban societies have evolved. He suggests a new paradigm is emerging in contemporary urban projects, a multilayered three-dimensional grid system differentiated at territorial, urban and finer-capillary scales.

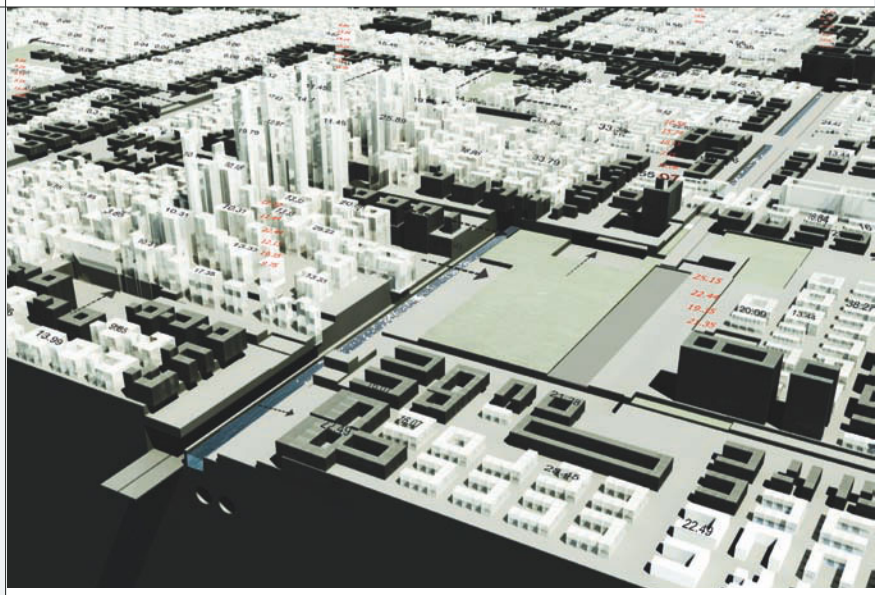
Javier Cardós Elena, Dennis Goff and Mary Polites, Adaptation of the Transportation Network of Lagos, Nigeria, AA Emergent Technologies and Design (EmTech), Architectural Association, London, 2011–13
The existing infrastructural networks within the city are highly stressed and must be adapted for rapid acceleration in population growth.

The topology and dynamics of network systems is a major area of research in complexity studies, but as yet is rarely focused on the interdependencies between differing infrastructural systems and their potential integration. However, it is now clear that developing strategies for the adaptation of existing city systems, and the design of new systems adapted to the accelerating changes of climate and population, requires integrated system analysis. Infrastructural networks do exhibit some characteristics that appear to be similar to those exhibited by the branching metabolic networks of living forms, of which the most frequently studied is the 'scale-free' power law ubiquitous in nature. Power laws describe empirical scaling relationships that are emergent quantitative features of the underlying physics of biological processes, and so are also applicable to artificially constructed network systems. Sergi Valverde and Ricard V Solé in 'Networks and the City' (pp 112–19) show that the reason that many biological and artificial networks share common features is because they operate under similar constraints, including spatial embedding, optimisation and self-organisation. The streets of the city are organised into networks, and buildings are themselves reticulated networks embedded in other networks that sustain our lives in the city.

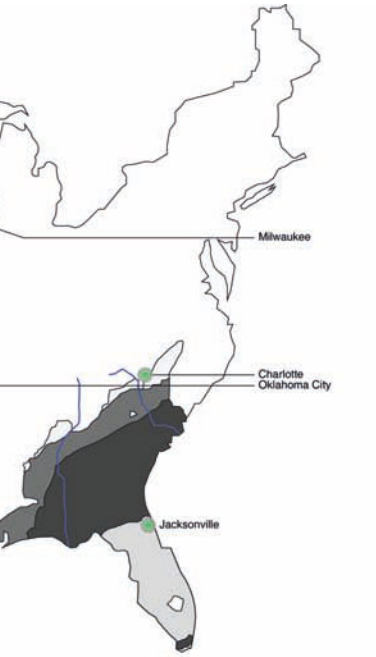
It is thought that biological and artificial networks both grow by the addition of new nodes or hubs, and that these tend to preferentially attach to nodes that are already well connected. Flow patterns are dominated by the highly connected nodes, through which flows the maximum volume and velocity of energy, information or material. This preferential connectivity makes the networks robust as the greater majority of nodes have few links, so a random failure of any one node will only affect a local area of the network. However, if a node with a high number of connections fails, the scale-free characteristics of the entire network will be affected, and it may fail altogether.[10] The scaling patterns in city infrastructures and their relation to the periodicities, velocities and quantities of flows through their systems are related to the size of city, and the larger the city the faster all of its processes are. This has effects on the pace of life and has led to shortening cycles between major urban reconfigurations and renewals, now estimated to be shorter than a human lifetime.[11]







Mehran Gharleghi, Model of the City, AA Emergent Technologies and Design (EmTech), Architectural Association, 2013–14
right: The morphological model of differentiated gradients and densities is connected to numerical models of network infrastructures and their dynamic flows, and to mathematical evaluation of environmental performance to test adaptive reconfigurations under development.



Major US cities by population located within projected drought areas, 7 February to 30 April 2013
All major city systems within the zone, and the continental-scale water distribution network, are in need of development and adaptation strategies to cope with changes in local and regional climatic conditions.

Imagining and building the future city is central to the future of humans

Society has already begun to transit through the long-anticipated threshold of an explosion in 'information' and associated new technologies, and the social and economic consequences have made substantial transformations of cities. Public and social space were once strongly linked to the traditional neighbourhood of the historical city, in which 'local' was a bounded space, defined by proximity – what is 'local' is more difficult to define today. We are more mobile, and our social and work relations are spread over a larger area than in the past. There is, in consequence, an emergent sense of locality as something more personally constructed, a patchwork of people and places united not by proximity, but by our ability to move between them. They are assembled into coherent wholes by our physical and digital journeys, and it is these journeys that constitute the network of connections that animate our individual lives and synthesise societal dynamics with the spaces of the city. Liam Young and Kate Davies explore and document the emerging landscapes from which the materials that support the mechanisms of contemporary life are extracted and which flow across the earth. 'A Distributed Ground: The Unknown Fields Division' (pp 38–45) presents a narrative account of a speculative supply chain that begins 1 kilometre (0.6 miles) below the surface of the Western Desert in outback Australia, continues to the Arctic 'Northwest Passage' and on to London. It is a dialogue between the immediate and the remote, a means of conveying the logistics, trajectories and distributed territories of the contemporary and future city.

The Future City

Imagining and building the future city is central to the future of humans in the regime of rapidly accelerating population growth and declining resources, climatic and ecological change, and accelerating complexity of the global system. In 'Intelligent Cities and the Taxonomy of Cognitive Scales' (pp 56–65) I have set out, with the help of Mehran Gharleghi, an outline of the specifics of the intelligence required for integration of sentient urban infrastructural systems into an intelligent 'metasystem' that is sensitively coupled to the lives of its citizens. It is a preliminary conceptual schema of cognitive categories in ascending order of complexity: the 'situated city', 'reactive/responsive city', 'adaptive/attentional city' and the 'self-aware city'. The future city is fully intelligent. It is self-aware and 'conscious' of both itself and its citizens, and able to synchronise the city systems with climatic and ecological phenomena at the regional and local scales. Its spatial patterns are culturally appropriate to its citizens, and it adapts itself to the fluctuations of its flows, and to the emergent phenomena of its cultural practices by expansions, contractions and reconfigurations of its infrastructural systems, its spatial patterns and the morphology of its architecture. AD

Notes

1. Antonio Sant'Elia, 'Manifesto of Futurist Architecture', in 'Messaggio', the foreword in the catalogue of the 'Città Nuova' exhibition, Milan, 1914 (thought to be later appropriated and edited by Filippo Marinetti).
2. Claude Lévi-Strauss, *Tristes Tropiques*, Librairie Plon (Paris), 1955, trans John Weightman and Doreen Weightman, Jonathan Cape (London), 1973, p 155.
3. World population is projected to be over 9 billion by 2050. From the 2010 Revision of the World Population Prospects, Population Division of the United Nations Department of Economic and Social Affairs of the United Nations Secretariat.
4. Paul Ehrlich and Anne Ehrlich, 'Can a Collapse of Global Civilization be Avoided?', *Philosophical Transactions of the Royal Society of London* B 280, 2013.
5. Karl Butzer and Georgina Enfield, 'Critical Perspectives on Historical Collapse', *Proceedings of the National Academy of Sciences*, Vol 109, No 10, 2012, pp 3628–31.
6. Michael Weinstock, *The Architecture of Emergence: The Evolution of Form in Nature and Civilisation*, John Wiley & Sons (Chichester), 2010, pp 261-9.
7. Peter A Corning, 'The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory', *Complexity* 7 (6), 2002, pp 18–30.
8. Herbert Gintis, 'Gene-Culture Coevolution and the Nature of Human Sociality', *Philosophical Transactions of the Royal Society of London* B 366(1566), 2011, pp 878–88.
9. The phrase 'space of flows' was first used by Manuel Castells to describe the effect of information networks as transforming society, a change from 'spaces of place' to the 'space of flows'. Manuel Castells, *The Informational City: Information Technology, Economic Restructuring, and the Urban Regional Process*, Basil Blackwell (London), 1989, p 146.
10. Ricard V Solé and José M Montoya, 'Complexity and Fragility in Ecological Networks', *Proceedings of the Royal Society* B 268, 2001, pp 2039–45, and Marti Rosas-Casals, Sergi Valverde and Ricard V Solé, 'Topological Vulnerability of the European Power Grid Under Errors and Attacks', International Journal of Bifurcation and Chaos, 2007, pp 2465–75.
11. Luís MA Bettencourt, José Lobo and Geoffrey B West, 'Why are Large Cities Faster? Universal Scaling and Self-Similarity in Urban Organization and Dynamics', *European Physical Journal* B 63, 2008, pp 285–93.