city, it nevertheless offers a good basis for a sustainable settlement typology; it is precisely for this reason that it urgently needs to be reexamined and improved.

Within the compact city debate, we must put a stronger focus on quality of life, especially that of middle- and lower-income groups, both in the developed and the developing world. We must raise quality of life within the compact city while limiting the growth of its ecological footprint. Focus areas could be the development of more adequate housing options, more green areas, walking and cycling opportunities, noncommercial public space, and shared facilities. These are technical, social, and design questions that are best tackled by urbanists, architects, and landscape architects. Basing their research and work on adjacent disciplines in the social sciences, like psychology, geography, environmental science, and agriculture, these specialists will be best prepared to provide proposals to society, governments, NGOs, and private developers.

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Sprawl: A Strategy? From Closed System Dynamics to Open Systems Ecologies

Pierre Bélanger

Landscape architect Pierre Bélanger reviews the history of systems thinking in environmental thought and the idea of the sustainable city in particular. He argues that sprawl is inevitable and we must look beyond the parameters of our current debate to find the future of the city.

Urban population density is in decline, even as the world's population increases. As people migrate for a range of economic, political, and social reasons, urban areas sprawl beyond the legislative boundaries of their cities. The urban regions currently in formation simply do not conform to our traditional understanding of urbanism, which deals in cities and concentrated populations. These ground conditions contradict the assumption that compactness, verticality, and high density can contain the footprint of urban transformation.

Proponents of environmental protection and sustainable development have consistently promoted compactness and centralization. They characterize urban growth as a problem that should be regulated and restricted. With techno-scientific instruments of zoning, boundary demarcation, and density regulation, the practice of urban planning was professionalized in the twentieth century, becoming a major discipline largely premised on the control, optimization, and legislation of growth. Yet the underlying precepts of urban planning, like compactness and density, are seldom revisited. Our present-day discourse, dominated by concern for the environment, adheres unthinkingly to the concept of carrying capacity as the most important spatial factor for sustainability.

As the world's population grows, we must think beyond limits, footprints, and boundaries. We must change our notions of carrying capacity and move beyond the notion of spatial compactness and control through planning. Instead, we should explore urban processes through distributed structures, diffuse patterns, fluid formats, and flexible morphologies, working with the processes of decentralization rather than fighting them.

Compact City versus Sprawl

Looking at urbanization from a broader geographic perspective, rather than narrowly at just the city, gives us new perspectives on spatial, social, technological, political, and ecological change. These two ways of looking at urbanization recall the debate in the 1960s and '70s—when the notion of "the environment" was first gaining currency—between different models of systems thinking, particularly engineer Jay W. Forrester's "closed system dynamics" and ecologist Howard T. Odum's "open systems ecologies."

Forrester's model today represents the status quo in compact city thinking. Odum's alternative could help redefine urbanization as an open and fluid system—more complex, more nuanced, and more flexible—in which decentralization operates as a response to the predominant challenges of our time: migration, climate change, energy economies, and resource flows.

The Cold War Environment

At the core of the debate was the formulation of the "World Problématique," formulated by the Club of Rome, a global think tank for the future of humanity, in the late 1960s. This problematic was at the center of the club's 1972 publication *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. It crystallized the worldview of late-twentieth century environmental thought during a period of socio-technological change: the world had seen its first microprocessor in 1971, its first Earth Day in 1970, the first men on the Moon in 1969, and, in 1968, the first photographs of Earth from space, brought back by the crew of Apollo 8.

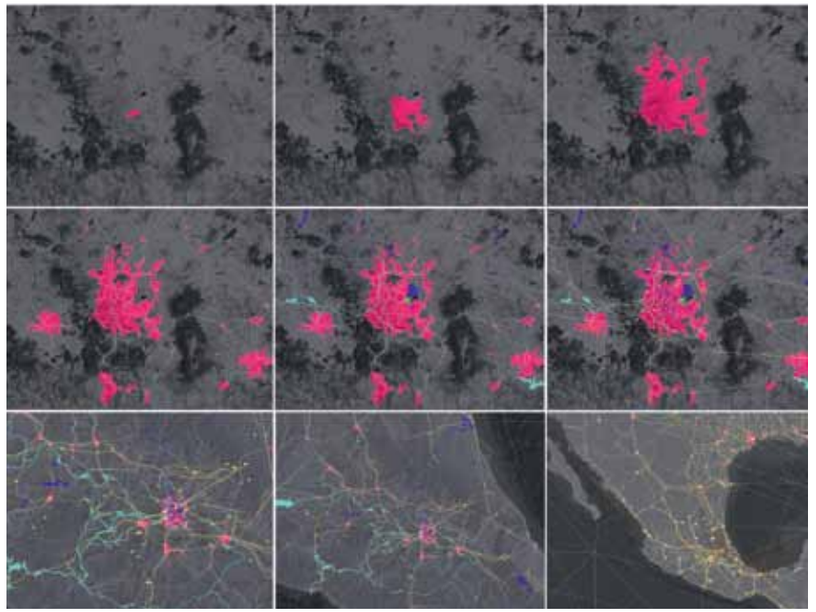
Newly aware of our place in the universe, we faced a perceived Malthusian dilemma of population outpacing resources and responded with the notion of carrying capacity. Two premises underlie it: that the resources of the world are limited and that the problems caused by population growth are universal. Supported by fear of nuclear annihilation and a sense of the smallness and fragility of Earth—the Blue Marble—in a vast universe, a new view emerged of the world as a closed and limited system of resources on the brink of potential collapse.

The Limits to Growth was published a year before the 1973 oil crisis, which greatly contributed to its cause; the visibility of *Limits* also grew significantly during the 1972 United Nations Conference on the Human Environment in Stockholm. *Limits* sounded an urgent alarm for a fragmented world threatened by pollution and poverty. In the 1970s, global inequalities were seen through the frame of the Cold War, which split the industrialized nations into two camps. *Limits* placed itself in the middle of a major social, political, technological, and economic divide across the world, challenging Cold War mentalities and establishing an intellectual foundation for environmental protection, resource conservation, and sustainable development. The cause of "the environment" fostered political solidarity among otherwise hostile nations during the Cold War.

The Limits of *Limits*

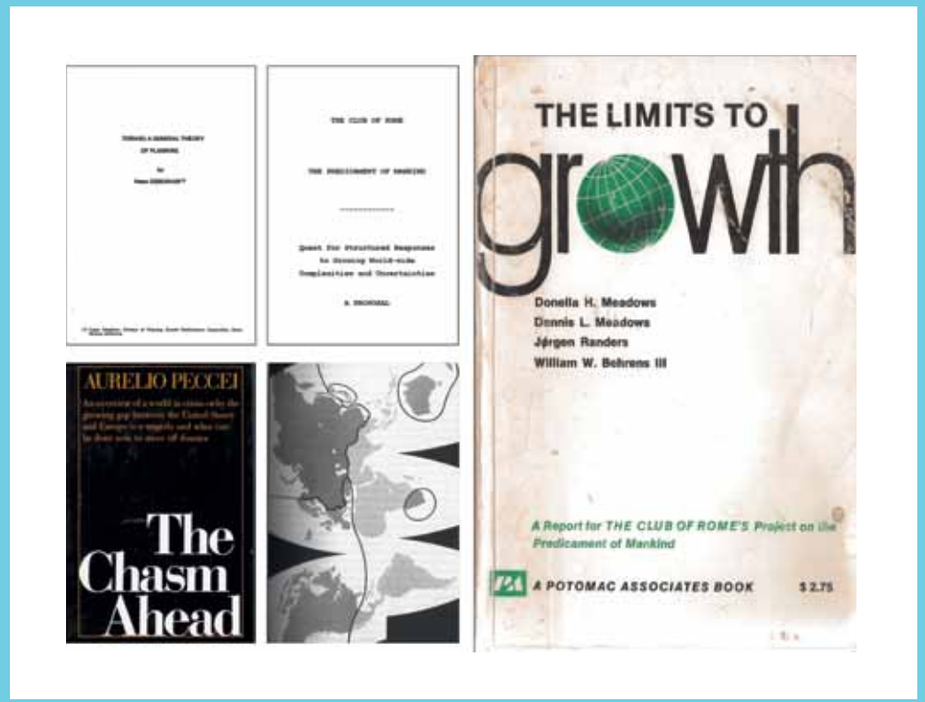
The Limits to Growth "examined the five basic factors that determine, and therefore, ultimately limit, growth on this planet—population, agricultural production, natural resources, industrial production, and pollution."[1] Basing their work on system dynamics in electrical engineering, the authors systemically modeled these five variables in order to "examine the complex of problems troubling men of all nations: poverty in the midst of plenty; degradation of the environment; loss of faith in institutions; uncontrolled urban spread; insecurity of employment; alienation of youth; rejection of traditional values; and inflation and other monetary and economic disruptions."[2] The authors of *Limits* employed a one-world system—a closed system diagram—to make projections through the year 2150 and exhaustively model the scenarios at which points of scarcity would be reached.

↑ 1. Flexible urbanization: Okobaba Sawmill and the 200-year-old fishing village of Makoko on the shores of the Lagos lagoon, Nigeria.

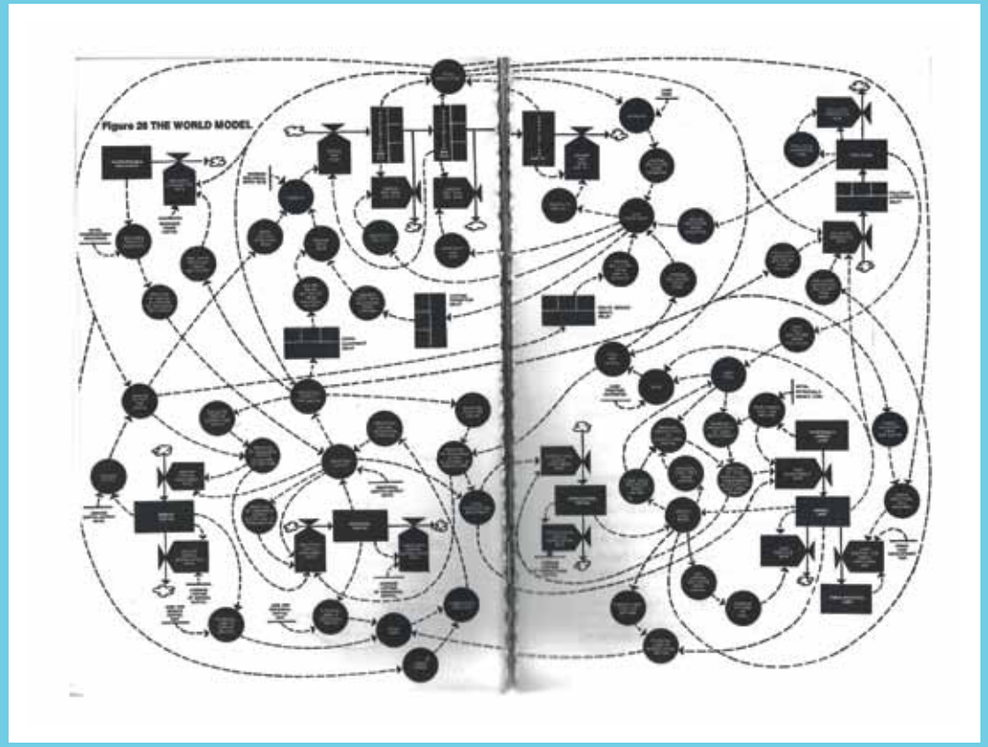


↑ 2. Dispersal and dispersion: the decentralization of urban Mexico—the region with the lowest per capita consumption of water in the world—between 1524 and 2012.

↑ 3. Environmental institutionalization: the United Nations (1946), the Club of Rome (1969), and the United Nations Environment Programme (1972).



↑ 4. Plans, problems, and predicaments: *Towards a General Theory of Planning* (1968), *The Chasm Ahead* (1969), *The Predicament of Mankind* (1970), and *The Limits to Growth* (1972).



↑ 5. Closed system: a diagram of the world model interrelating the five variables of population, natural resources, capital investment, capital investment in agriculture, and pollution.

↑ 6. Jay W. Forrester: the engineer as industrialist, urbanist, and globalist.

↑ 7. Projections and biases: the Apollo 8 images As08-14-2384 and As08-16-2593, taken by Bill Anders and released in 1969, appeared widely in media and literature.

↑ 8. Circuitry: Jay W. Forrester (left) pioneered the development of magnetic core memory (bottom right) and led Project Whirlwind (top right) for the US Navy.

The Club of Rome published the book with two objectives in mind: establishing the ideological platform of "an informal, non-political, multi-national group of scientists, intellectuals, educators, and business leaders" and establishing a series of scenarios related to global problems.[3] Alarmist and catastrophic, these scenarios of overproduction and overpopulation modeled cataclysmic levels of pollution and plummeting food availability that would result in mass starvation and death within 150 years. The linear forecasts and modeling procedures suggested disastrous relationships between inputs of industrialization, throughputs of production, and outputs of pollution. These scenarios seem preposterous today, in a world of relative abundance where the more pressing questions of urbanization are much more about distribution and equity than scarcity or depletion, but they shaped our thinking about conservation and sustainability for decades.

From Engineering to Urbanization

The authors of *The Limits to Growth* were students of Jay W. Forrester, a pioneer of closed-systems thinking. With his graduate students, Forrester developed and operationalized theories of system dynamics across a range of applications, using a simulation language and software respectively named DYNAMO and World3. The latter was designed to understand and track complex parameters and subsystems through nonlinear relationships and feedback look structures. Forrester had been working for almost a decade with the US Navy at MIT's Lincoln Laboratory on the development of SAGE (Semi-Automatic Ground Environment), a radar-detection system for intercontinental ballistic missiles. At the Lincoln Laboratory, he also developed technology for the most significant problem of the digital era: data storage. The magnetic-core memory he developed was among the earliest forms of random-access memory, or RAM, which is now found in every computer in the world.

In a series of three books, Forrester developed a computational model for analyzing social systems and predicting their future implications. Funded by the Ford Foundation, *Industrial Dynamics* was written in 1961 "to understand and to design corporate policy."[4] *Urban Dynamics*, completed in 1968, extended Forrester's system-dynamics approach to problems of urban blight and renewal. At the invitation of an MIT colleague, Club of Rome member Carroll Wilson, and with funding from the Volkswagen Foundation, Forrester then applied system dynamics at a global scale with *World Dynamics*, completed in 1971. Although the computational power of Forrester's simulation work was significant, the scalability of system dynamics is equally astonishing. Within the space of a decade, Forrester was working at three scales: the industrial, the urban, and the global.

Whole with Holes

Forrester's pioneering research on the theories of system dynamics was widely read, but, though his ideas were easy to work with under laboratory conditions, they were difficult to put into practice. For corporate policymakers and city organizations, system dynamics was hard to understand or incorporate into established practices. Forrester encountered prejudice and outmoded thinking; the application of his modeling methods and system theories resulted in no real-world projects.

For all their brilliance, the digital innovations at the core of Forrester's work also resulted

in a technocratic view of urban society. Closed systems had their own practical limits. Style, design, perception, opinion, bias, media, and politics—though seemingly unquantifiable and subjective—actually mattered. During a period of considerable social and economic transformation, as cities like Detroit, Newark, and Philadelphia were torn apart by racial strife and industrial decline, the very basis for system dynamics and for future scenario planning seemed to be flawed. Cities presented considerable complications to modeling, let alone to actual implementation.

Cities as Circuits?

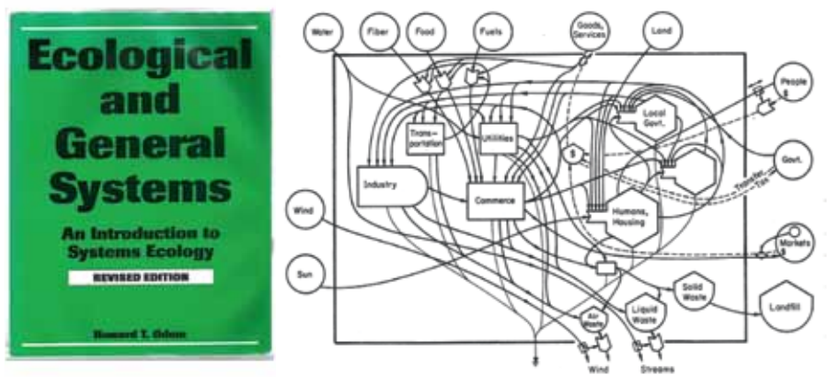
Together, these problems of modeling and implementation point to a much deeper, more fundamental flaw with Forrester's work. With its roots in theoretical dynamics and electrical engineering as well as convergent ideas from the social sciences and cybernetics, the Taylorist-influenced systemic approach to urban problems had limits. Like any other problem, it required boundaries and the isolation of variables, yet urban spatial models resisted pure, rational, or quantitative simplification, let alone comparison to problems associated with electrical networks. Cities simply did not work like circuit boards.

However, the relationship between corporate and urban scales present in the genealogy of Forrester's work is useful to consider. In the 1920s, cities were incorporated one after the other, at a very rapid pace, in order to collect tax revenues; legally, they emulated corporations in their governance structure: hierarchical, multidivisional, bureaucratic, and closed. System dynamics worked in the corporate environment, so it seemed appropriate for urban policy as well. Furthermore, since large multinational corporations—from Volkswagen in Germany to Battelle in Ohio—were underwriting the Club of Rome's research, the relevance and applicability of systemic research to urban problems went unchallenged there. The club viewed the world through an industrialized lens, seeing problems chiefly among the nonindustrialized other, the so-called third world.

From Problématique to Process

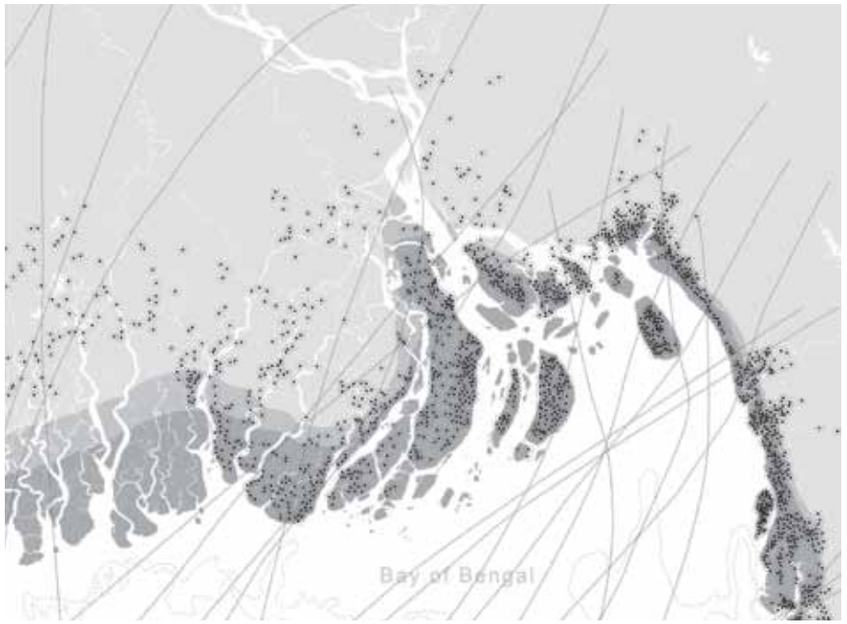
Systems ecology—a holistic approach that views natural systems at an aggregate level, studying the interactions among their components and their relationships with other systems—offered an alternative to closed-systems thinking. Among the pioneers of this interdisciplinary field was Howard T. Odum, who, starting with coastal and estuarine systems in the early 1960s, developed models for mapping and understanding natural systems through flows and exchanges of energy. He worked for the Atomic Energy Commission (AEC) at the Puerto Rico Nuclear Center (PRNC) between 1963 and 1970, researching the effects of radiation on plants, specifically, and forest systems in general. The PRNC was an ecological stress test, and the island's tropical rainforest was a laboratory: given their high sensitivity to atmospheric radiation, pine trees served as bio-indicators, guinea pigs of radioecology. The AEC project was the foundation of Odum's work on complex ecologies as open systems, moving systems thinking beyond metaphors of electrical networks and circuitry.

Through an understanding of ecological emergence and temporal indeterminacy—in lieu of the integration and insularity of closed systems—Odum graphically and spatially demonstrated the biological and metabolic structures of plant life—and associated linkages and loops, from

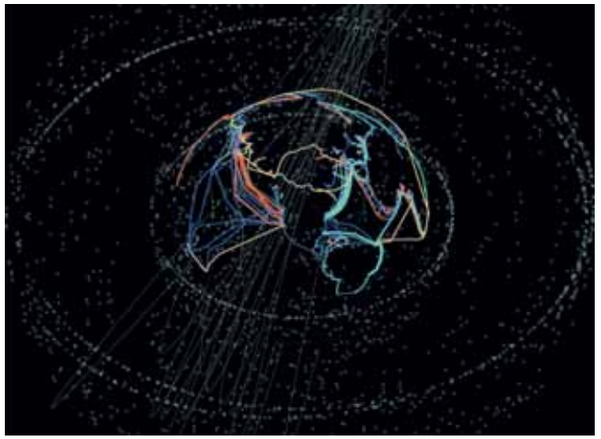


↑ 9. Open systems: Odum's post-modern concept of open systems is seen here in a representative diagram of an urban region, showing fluidity and flows, animated through vectors, fields, inputs, outputs, energies, exchanges, patterns, and processes.

↑ 10. Island to archipelago: often touted as a model for sustainable cities, Hong Kong's vertical density relies heavily on an extensive horizontal hydrologic network consisting of freshwater reservoirs, river water from the Dongjiang River in the neighboring Guangdong province, and the use of seawater for toilet flushing.



↑ 11. Flexibility and contingency: the distribution of storm shelters and evacuation systems on the coast of the Bay of Bengal in Bangladesh. The South Indian Tropical Storm Basin is one of the most extreme, most hazardous urban regions identified by the United Nations.



↑ 12. Altitudes of urbanization: submarine cable systems, lower and outer satellite orbits, and space junk.

microbial to animal—in tremendous detail. He developed his notion of ecology through media including maps, diagrams, aerial photos, and charts, demonstrating that open-ended systems could be communicated quantitatively and qualitatively.

Flow as Form: Systems Ecologies

Odum's models were scalable and easy to understand, reproduce, and manipulate; it was likewise easy to translate them from biology to urbanism. Odum was less interested in problematizing urban environments than in studying and transforming them. His modeling of complex systems through flows helped position the urban as a landscape of processes and patterns, extents and intensities, economies and ecologies. In *Environment, Power, and Society* (1971) and the revised edition of *Ecological & General Systems* (1994), Odum proposed applying his studies of ecological systems to urban regions, significantly widening our understanding of the complexity of the urban landscape.

Applying ecological knowledge to urbanization reveals its basic, indivisible flows: waste and water, food and fuel, flora and biota, mobility and energy. Scalable and constantly seeking new morphologies, they provide room for growing complexity. Waste ecologies, for example, could be understood as an infinite multitude of backflows, overflows, reflows, leakages, impurities, spillovers, discards, residues, and secondary energies. Odum understood that systems need to change structurally over time, through substitution: "Systems in nature are known that shift from fast growth to steady state gradually with programmatic substitution, but other instances are known in which the shift is marked by total crash and destruction of the growth system before the emergence of the succeeding steady state regime."[5]

Odum's reformulated understanding of urbanization as a form of ecology moved beyond the centrality and singularity of infrastructure, which had typically dominated the engineering of urban environments. In contrast to Forrester, Odum moved beyond merely asserting solutions, beyond the limits to growth, and instead drew on the work on others—like landscape ecologists Richard T. T. Forman, Ernst Neef, and Zev Naveh—to make room for existing social forces and geospatial formations.

Decentralization as Decompaction

The global phenomenon of urbanization is a process of decentralization. Decentralization is persistent and pervasive thanks to the rise of the middle class throughout the world. Geographic sprawl is its most visible effect; a distinctive pattern of low-rise urbanization is prevalent around the world. What those who dismiss sprawl as unsustainable do not understand is that decentralization stems from the leveling of global socioeconomic structures and the increase in world population. It is a process of self-actualization that has been underway for the past two thousand years and is unlikely to reverse. This process is rendered visible as conventional, top-down economies dominated by production are supplanted by new consumer-oriented economies. Conventional economies find their origins in societal structures where large populations were governed by small elite classes: monarchies, military dictatorships, and industrial monopolies. Extremely hierarchical, vertical, and autocratic, these structures dominated much of the world's history. The recent flattening of these hierarchical structures

is the evidence of decentralization's relentless influence.[6] This structural transformation was enabled by several major shifts during the twentieth century: the democratic organization of large populations; an increase in individual purchasing power, individual access to housing, and personal mobility; the availability of consumer goods throughout the world, made possible by global transportation; and the ubiquitous spread of real-time communications. As a result, large populations are now better informed, better organized, and more able to make decisions, instigate change, and place demands on their governments.

Flexibility, Contingency, Risk

When seen through a geographic lens, the ecologies of urbanization reveal patterns of flows and processes of consumption, production, and exchange across vast distances, in relation to planetary processes that are dynamic, temporal, and contingent. This broad view transcends the legislative and political borders that modern-day nations inherited from their imperial and colonial masters or established through warfare, industrial planning, or land-use engineering. Living, dynamic processes counteract the paradigms of control, compactness, and containment found in engineering-based planning practices.

In this expanded field, the designation, delineation, and direction of ecological and urban processes become a new priority. As the vertical, hierarchical differences between engineering as a technological discipline and ecology as a scientific subject break down, a new set of projective questions can emerge from the gradual de-problematization of the urban landscape: Can decentralization bring spatial flexibility? As cities like Detroit go bankrupt, can we look to patterns of decentralization—instead of the city as the central unit of urban development—to unlock more flexible infrastructures?[7] Could we then see sustainability in the flexibility of super-urban geographies such as slums or suburbs?[8] Can large-scale ecological change be achieved without legislative planning, through incremental hacking and continuous readjustments?

Through systemic modeling of real-time decision making (guesses, estimates, bluffs, or approximations) and geospatial representation, can we draw ecology and economy closer together? Through feedback from consumption patterns, capital flows, market structures, and resource exchanges, can we better defend ourselves against the unpredictability of environmental hazards and economic risks?[9,10,11]

Infrastructural Ecologies

Moving beyond the notions of compactness and density by which we currently define and measure cities, we can propose several other projective models that reformulate the challenges historically associated with pollution, poverty, and population:

Altitudes and latitudes of urbanization: Patterns of urbanization can be best projected in section, revealing new dimensions and extents, from the bottom of the oceans to outer space. While population increases but growth rates taper off, we will not only have to plan for the global population's spread and waste, but also for its growth and shrinkage in different areas. From processes of suburbanization to super-urbanization, from the subterranean to the orbital, we must design infrastructure that supports the world we live in.

Material markets and scrap economies: Imagine the planet as a big brownfield. Consider it less as a virgin resource to be protected or a sensitive system to be saved and more as a big ball of oscillating waste, which keeps moving and circulating. Everything—from the oxygen in the atmosphere to the water in the ocean—has been used, abused, and reused. Materials and fluids in different concentrations, whose varying distributions are in constant motion, are powered by existing Earth processes—arrested, attenuated, and accelerated by methods of extraction and evolving technological processes; adjusted, layered, and thickened by urban change. Our ecological predicament must be the impetus for cleaner production, smarter consumption, and intelligent exchange to reduce waste. Brown is the new green.

Littoral landscapes and coastal sprawl: With half of the planet's population already living within 60 kilometers of the coast, we must look beyond the natural contours of urban geography—deltas, estuaries, lagoons, river mouths, and gulfs—for space into which coastal cities can grow.[12] These present-day landscapes can be seen as the starting point for development out onto the ocean: facing climate change and the tropicalization of the planet, the dry-land economies that have formed the basis of trade and exchange in the twentieth century must give way to wet, fluid ones. Taking to the seas will provide incidental advantages to our safety and security as well as to wealth generation and the health of the planet.

Together, these alternatives frame "the urban" not as a category of problems but of strategies. From here, processes of spatial decentralization—political denationalization and the weakening of states—can open new spatial distributions and zones of development thanks to interdisciplinary reconfiguration, technological proliferation, increasing social equality, and cross-border mobility. From a distance, historically and geographically, we begin to see horizontal spread—whether expressed through the prevalence of slums, suburbs, or skyscrapers—as one of the world's most important spatial strategies across all different dimensions of urban life and action, from the planetary to the personal.

Notes

This graphic essay is the condensed version of a paper titled "The Strategy of Urbanization: A Preliminary Review of the 'World Problématique' and the Club of Rome's 1972 'Limits to Growth,'" delivered at the 4th Holcim Forum in Mumbai on "The Economy of Sustainable Construction." The original version, including notes on the original interview with Jay W. Forrester and full references, can be downloaded here: http://src.holcimfoundation.org/dnl/60234c0a-f496-4c6f-b495-86817f917398/F13_GreenWS_Belanger.pdf.

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Lessons Learned from Mumbai: Planning Challenges for the Compact City

Rahul Mehrotra

Can density alone be used to judge the sustainability of a city? Rahul Mehrotra, principal of Mumbai-based RMA Architects, encourages us to consider social factors as well as economic and ecological ones: a truly sustainable city will give rich and poor alike good access to mobility, infrastructure, and opportunity.

Historically, formal and informal cities have formed a sharply juxtaposed binary. Though these cities have been totally interdependent in their evolving relationship, the economic and physical characteristics of each were distinguished and thought to be fixed. The people that engaged in the informal economy were imagined to reside in the informal city and vice versa. However, in the messy, mutinous democratic condition of Mumbai, and indeed in most parts of India, this relationship is not so neat. In Mumbai, people employed in the formal sector often reside in the informal city and vice versa.

Although the informal city has come to epitomize the compact city, the densities of the informal and formal cities are similar.[1] Informal city is celebrated for its economic efficiency and human resilience in the face of extreme infrastructural and sanitary deficiencies. Mumbai has been at the center of the world's imagination in the last few years for all the wrong reasons.[2] While its economic energy has been celebrated, what has not been adequately articulated is its failure to cope with infrastructure, housing, and governance. One of the reasons for this skewed focus is that the metrics that we use to measure density are inadequate. Measured in terms of floor area ratio, which compares a building's total floor area to the area of its site, density of urban form often does not account for intensity of use, which would provide a more accurate estimate of the amount of people actually using a space and thus of its infrastructural requirements. The notion that greater density equals greater economic equity is often a red herring in discussions about the compact city and its failure to provide equitable access to infrastructure (sanitation, water, and mobility) to a majority of the population. The manifestations of these failures in the form of slums, the informal city, garbage on the streets, overcrowding, and bizarre adjacencies have become the new mythical images through which the city is celebrated globally.

The current fetishizing of informal cities has shifted the focus of planning from avant-garde approaches to rearguard actions. In the last few years, architects and planners have developed strategies of incremental growth and upgrades to the existing built environment rather than opening up land and planning new urban centers to disperse growth, as was done when Navi Mumbai was imagined in the 1970s.[3] Like the preservation debate before it, this limited narrative