The Nature of Cities

Hurricanes, Earthquakes, Black Clouds:
An Urban Dweller's Guide to the Elements

By Ian Douglas

Cities are the places where people have most modified nature. Buildings protect people from extremes of heat and cold by air conditioning. Vegetation is managed by elaborate planting, watering and fertilization systems. Introduced and invasive species often dominate, if not overwhelm, native ones. Rivers are channelized, embanked and diverted. Water supplies are pumped from deep aquifers and piped from distant reservoirs, often hundreds of kilometers away. Health care systems, albeit variable in effectiveness and accessibility, protect much of the world's urban population from the worst communicable diseases.

Urban areas are often comfortable, congenial and civilized places in which to live, yet urban dwellers ignore nature at their peril. History shows that large modern cities are vulnerable to extreme events. To recall a few recent examples: Hurricane Sandy on the east coast of the United States in 2012; the 2011 Tohoku earthquake and tsunami in Japan; the fires in Dhaka in 2010 and in Manila in 2011; the Eyjafjallajökull eruption in 2010 that left an ash cloud over Europe; the list could go on and on. Meanwhile, every day nature affects our urban lives through disease vectors; rain, sleet and snow; floods and droughts; heat waves and cold snaps; landslides and subsidence; tree falls, weed and mold infestations and insect pests.

To cope with all these natural events, cities have to be well managed and well governed. The degree to which individual cities can provide security and protection for their inhabitants is in part related to the severity, magnitude and frequency of natural events; in part influenced by the extent to which buildings and infrastructure are able to withstand those events; and in part dependent upon the resilience of urban society. The latter comprises its ability to adapt to both abrupt major events and to the slower more gradual changes, such as the consequences of local urban growth and land-use change and of global economic,

▷ Smog crisis, Harbin, China, Oct. 21, 2013. *Cheng Qiang/Imaginechina/Corbis*

technological and environmental change, especially climate change. Improving urban conditions requires taking a holistic view, seeing the problems at a range of scales from the individual household to the whole metropolitan region, appreciating the relationship between an individual's daily activities and the changing character of the city, and realizing how altering one component of the urban environment affects a whole series of other aspects of the built-up area.

The Wu Xing

In modern municipal administrations, responsibilities are usually divided into strict professional departments, with planning and environment frequently separated from public health, education, finance and engineering. Addressing environmental issues usually requires cutting across these departmental divides. Today many urban managers, designers, planners and scientists are looking at cities as complex social-economic-natural ecosystems in which political, social, cultural and economic phenomena interact with the components of the natural environment.

Societies have long recognized the importance of such interactions for human health. In the eleventh century, the Persian scholar Avicenna (Abu Ali Al-Husayn ibn Abdallah ibn Sina) wrote in his *Canon of Medicine* of the four humors: hot, cold, moist and dry, which were related to the weather. Medieval Europeans described the four humors as blood, phlegm, yellow bile and black bile, again relating them to the seasons, but also to elements of nature.

This four-fold division may be compared to the five traditional elements of the Chinese Wu Xing: water, metal, earth, fire and wood, which are used as the natural subsystem framework for analysis of complex urban systems in China. In the United States, much recent research has explored the nature of coupled human-natural systems or urban socio-eco-biophysical systems, because the understanding of urban life gained from the social, behavioral and economic sciences has to be linked to ecological and earth surface processes; the latter to explain how nature works in cities under complex human influences. This approach helps to develop workable reactions to nature's responses to urbanization and the effects of environmental change on urban inhabitants.

In the current Chinese social-economic-natural complex ecosystem approach, which uses the Wu Xing in a modern context, the five natural elements form a physical subsystem, with economic, social and scientific subsystems as well. The core subsystem features three elements with which to deal with the Wu Xing: knowledge, culture and institutions. These three elements may be considered to represent the key human drivers of urban change and management. Knowledge embraces science and technology together with traditional understanding and community awareness. Institutions range from governments to corporations and professional and influential civil society

elites, and include urban management systems and non-governmental conservation and environmental organizations. Culture embraces lifestyles and family life (which dictates size and type of dwellings), as well as the way residential preferences and attitudes to nature affect the character of the built environment and the types and amount of urban green space. Human use of natural areas within and around cities varies greatly with social factors including age and ethnicity.

The multiple environmental tests faced by modern cities need long-lasting sustainable responses that often require thinking over much longer timespans than those between democratic elections of mayors or municipal councilors. The knowledge available to municipal institutions is abundant, but not always in a form that busy people can rapidly assimilate.

The five Wu Xing natural components can be taken to deal with five critical spheres of urban and global change: the atmosphere (fire or energy), the biosphere (wood or life), the hydrosphere (water), the pedosphere (earth or soil) and the geosphere (metal or minerals). These spheres overlap; water, essential for all life, is found in the atmosphere, the pedosphere and the rocks of the geosphere. Nevertheless, they offer a workable framework within which to organize discussions about urban environmental challenges.

Element 1: Water

An essential factor in the location of urban areas is drinking water. Most ancient settlements were located on rivers or by springs. Many inhabitants sunk wells and found groundwater within a few meters of the surface,while the Romans constructed great aqueducts to carry water to the majority of their cities. By the twentieth century most large cities depended on remote sources, such as the surface water Mono Lake supply to Los Angeles; the 2,820-kilometer Libyan network of pipelines carrying fossil groundwater from beneath the Sahara to coastal towns, cities and farms; and the approximately 900-kilometer Ras Azzour to Riyadh pipeline, planned to convey one million cubic meters per day from the world's largest desalination plant, to be located on Saudi Arabia's Arabian Gulf coast. Even so, many cities have inadequate supplies, with piped water not available twenty-four hours a day, and many dwellings having, at best, a standpipe or well within a few minutes' walk. The quest for safe, clean, reliable, accessible, affordable water remains. Combinations of water sources, such as surface water from rivers, groundwater, rainwater harvesting, desalination and water reuse are being adopted in many Asian cities, both on a well-planned municipal basis (as in Singapore) or by a combination of public supply, private enterprise distribution, individual household and business rainwater harvesting, and well sinking (as in New Delhi).

Even more serious is the provision of safe sanitation. Over the period from 1990 to 2013, globally 1.9 billion urban and rural people gained access to sanitation. However,

around 2.4 billion people will be using unimproved, inadequate sanitation facilities in 2015: not much of an improvement over the 2.7 billion doing so in 1990. Although much of the improvement was in towns and cities, the trick is to do more than keep pace with the growth of global urban population.

The other side of the water challenge is to deal with water excess. As the world's urban population has become increasingly located in tropical regions—because the only areas in which they can find land to build homes are in floodplains prone to heavy thunderstorms, cyclones and rapid storm-water runoff—more and more people are becoming exposed to flood risks. That the urban areas are paved or roofed only increases the risk of local flooding within specific areas of the city. Such impacts are arising in cities everywhere, but ways of reducing them exist, particularly in terms of sustainable drainage systems, where the passage of water is slowed down and infiltration is encouraged.

Element 2: Metal

The Wu Xing element metal (or minerals) includes materials such as concrete, brick, glass and steel used to build, furnish, decorate and ornament urban areas. Concrete is particularly important as it is used for most of those paved surfaces that accentuate flood risks, but is also part of flood control systems in terms of urban drains and river flood walls. Abstraction of these minerals means new uses have to be found for quarries or gravel pits. Significantly, the topsoil from brick pits in China is put aside and later used to recreate agricultural land at a lower level after the brick clay has been removed. Success in reducing mineral raw materials use for urban institutions will require applying the available knowledge of alternatives to concrete drains and flood walls. This will involve particularly utilizing green infrastructure by installing green roofs, grassed suburban waterways and more natural urban rivers, including the converting of concrete channels or the reopening (or daylighting) of small streams that were diverted into underground pipes when the city first expanded.

Recycling of construction and demolition waste is becoming widely adopted on a commercial scale, particularly in large cities where transport costs are high. On another scale, many poor rag-picking communities in South Asia are finding ways of using other people's waste materials to create building components, such as walls made of glass bottles or flooring made of broken crockery. More advanced materials reuse technologies including utilizing power station fly-ash for brick substitutes and making plaster board alternatives out of pressed and glued fragments of waste material. Although these forms of reuse are commercially viable, cultural constraints sometimes prevent their adoption. Several British supermarkets say they will not use recycled materials for fear of contamination in their buildings.

Element 3: Earth

Earth relates to soils and to the ground on which the city is built. Many cities experience geomorphological problems such as landslides, subsidence and soil erosion. Often these risks are not widely understood and purchasers of property may not always know of their existence, particularly in cities where the events happen infrequently, or generally only occur when the ground is disturbed and local conditions are altered by construction activity. Cities with frequent landslides, such as the Los Angeles and San Francisco areas, often have detailed landslide hazard mapping. Hong Kong has developed a highly sophisticated geotechnical control system to reduce landslide risk when building on steep slopes. Helped by detailed computer mapping systems and databases, this planning and building control system has reduced actual landslide damage considerably. Other cities with similar geology and deeply weathered rocks have begun to adopt some of the general principles, but elsewhere lack of information and building control means that unwise excavations on landslide-prone terrain continue to put urban lives at risk.

Subsidence is a persistent problem that is often aggravated by urban development, mining and groundwater extraction. Bangkok, Venice and Mexico City have frequently suffered flooding as a result of irregular lowering of the ground surface through groundwater removal. Restrictions on pumping and on unlicensed wells can help to alleviate the situation. Mining for coal, salt and other minerals also often leads to subsidence, long a problem in old coal mining areas in Europe and North America. More difficult to cope with is the subsidence due to subsurface cave collapse in soluble rocks such as the frequent sinkhole formation events occurring in limestone in Florida. Again, careful geological survey and building design can avoid the worst of these risks.

The major volcano hazards threatening many cities are partly predictable by close seismic monitoring of earth movements around the volcano. However, earthquake prediction remains difficult, but effective earthquake emergency response training and evacuation procedures can save lives. Good earthquake building codes and building control measures can help to save even more lives. Tsunamis caused by earthquakes are likely to become more threatening to coastal cities as sea levels rise as a consequence of global warming, making existing sea defenses less effective.

Element 4: Fire

Much of the current global warming is related to fire, to energy consumption—particularly the use of fossil fuels in all types of machinery including air conditioners and heating boilers—and the release of greenhouse gases and heat into the atmosphere. The extra heat keeps large city centers four or more degrees centigrade warmer than adjacent rural areas. However, large parks, such as Hyde Park in London, reduce the

heat island intensity locally. This suggests that by careful planning of urban green spaces, heat island temperatures can be lowered over larger areas. Many cities are encouraging the creation of green roofs and establishing more parks and street trees in an effort to reduce heat stress on hot days and to gain other health benefits through exercise and recreation in the open air.

Urban energy consumption has long had health consequences through air pollution. Much of the smoke and sulphur dioxide from coal burning that affected Western cities until the mid-twentieth century has gone, but has been replaced by new problems due to oxides of nitrogen and photochemical smog associated with the widespread use of oil and gas. Now extremely fine particles emitted from diesel engines are seen as a major health issue. Rapid expansion of motor vehicle numbers and traffic congestion has made such air pollution so severe in rapidly industrializing cities of Asia and South America that measures to restrict car use have been attempted. Urban traffic management remains a headache for most cities despite massive investments in urban rapid transit systems and bus services.

Congestion and long queues of vehicles with their engines running are common problems in Asia from Istanbul to Beijing and are growing in Africa from Cape Town to Cairo. Road pricing and congestion charging are unpopular, although often effective, because the private motor vehicle gives the driver the freedom to travel, but that is also the freedom to pollute.

Urban air pollution affects all living things within urban areas and far beyond, having significant impact on agriculture as contaminated soils and plants will affect food supplies. Further afield it has damaged forests, corroded iron work and acidified lakes. In this way we can think of cities as having a pollution shed, or contaminant fallout zone, extending well beyond the metropolitan boundary, especially where carried away by the prevailing wind. The spread of acid rain across northwestern Europe in the 1950s and 1960s showed how urban emissions can become a transboundary problem, with the consequence of energy consumption in one country being felt in another. International agreements can sometimes cope with such issues, but the difficulties of getting a global agreement on lowering greenhouse gas emission show just how hard this task can be, regardless of how urgent the problem is. Some international coalitions of city mayors already indicate a greater willingness of some municipal authorities to collaborate than their national governments have done.

Such external impacts of urban environmental problems now extend to the heart of the Pacific Ocean, where a great gyre of finely comminuted plastic, dubbed the Great Pacific Garbage Patch, threatens marine life. Some estimates say the debris field is twice the size of the continental United States. Reducing these far-reaching externalities is a collective urban problem that may be forgotten among more immediate

local issues, particularly as the voices of the small Pacific Island states most seriously affected by damage to life in the oceans and by rising sea levels are seldom listened to in international meetings.

Element 5: Wood

The Wu Xing element wood implies the whole biosphere and all forms of life. The main environmental concerns faced by city administrations often relate to human well-being and social care, public health, to the avoidance of epidemics and the impacts of disasters such as earthquakes. World Health Organization environmental standards help urban managers to recognize when problems such as air pollution are most severe, but sometimes economic and social considerations make the adoption of the most effective alleviation and control measures difficult. Measures such as mass immunization, avoiding contact with zoonoses (infectious diseases, such as rabies, that are transmitted between species, sometimes by a vector, from animals other than humans to humans) and preventing the transmission of viral infections are not always effective in every major city. The zoonosis West Nile virus appeared in the United States in 1999 in the New York City area and spread rapidly across the country in 2002. Urban practices and conditions such as the sale of live animals in many Asian markets greatly affect the transmission of zoonoses. With malaria and dengue fever remaining problems in many tropical areas, despite large international campaigns, climate change may lead to such diseases moving poleward, reappearing in cities from which they have long been eradicated. Urban authorities and health institutions must be able to detect and control such events rapidly.

Urban environmental conditions and diseases also affect other urban animals and plants. Bird and mammal survival in urban environments is affected by collisions with manmade objects, food acquisition, predation and disease. Over decades, many urban animals adjust to urban conditions, showing physical, behavioral and genetic differences from their rural cousins. Small creatures adapt and evolve more quickly than larger organisms. The way that dark peppered moths (*Biston betularia*) survived in the soot of industrial cities demonstrates how selection and evolution in cities can lead to distinct differences between urban and rural animals. Changes can be difficult to spot; for example, white blood cell (monocyte) counts are higher in house sparrows (*Passer domesticus*) in urban areas than in rural areas, suggesting immune system adaptation to the urban environment.

The food urban people put out for birds and other animals helps to stabilize small bird populations and to make predatory mammals more numerous. Nonetheless, urbanization tends to reduce the numbers of large mammals, such as coyotes in the United States. This allows meso-predators, such as domestic cats, more opportunities

to hunt, leading to the deaths of many of the most abundant urban birds, with feral cats hunting more often than free-ranging domestic cats. At the same time, there are concerns about the impact of agricultural chemicals in the urban environment, with pesticides and herbicides influencing bird populations, both directly and indirectly, by affecting birds' growth, development and survival. Some insecticides have had profound effects on predatory bird populations, such as the sparrow hawk, but others have been used for decades with no apparent impact on non-target organisms.

Complex chemicals in the urban environment remain a major problem, with huge quantities of pharmaceuticals being used every day. The world's chemical and biomedical companies are constantly searching for new products, materials and medicines. The outcomes of their research and development help people everywhere to improve their lives, avoid and recover from disease, grow higher-yielding crops and manage plant and animal pests and diseases. Many characteristics of these chemical compounds alter other chemical and biological processes and these substances can enter food chains, particularly those of aquatic ecosystems, into which they are carried by rainfall, sewer overflows, and releases from unregulated manufacturing and farming activities. Not all pharmaceuticals are removed in normal sewage treatment and their residues may be consumed by microorganisms in river waters and thence by invertebrates that eventually are eaten by fish, which may be caught for human consumption, or eaten by larger fish that are harvested for human food. Evidence of serious problems for human health from such contaminants is patchy, but their effects on fish are well-documented.

Chemicals are becoming a significant problem for water supplies and for the management of fisheries in waters (lakes, ponds, reservoirs, canals or rivers) in and around towns and cities, particularly those close to megacities, and large industrial and transportation complexes. These chemical compounds are part of the urban circulation of chemical elements, but many national or municipal environmental monitoring agencies do not yet have either the means to test for them or sufficient aquatic sites at which to monitor their concentrations. Many of these compounds are known as persistent organic pollutants (POPs) and have been found in high concentrations in fish off river mouths. They are also carried by winds to agricultural areas so that the global extent of food transfers means the POPs entering a food chain in one region may be carried to urban areas remote from both their source and the locality where they first accumulated in plants. Each individual city and each individual chemical user in that city, at home or in industry, has a potential impact on the global movement of potentially harmful chemical compounds.

The task is to raise awareness of this invisible environmental problem and to take measure to avoid accidental or unintended releases to air, water or soils. This

again is in part an issue of personal freedom to use pharmaceuticals, beauty products and other toiletries against reducing the risk of contaminating the environment and affecting food chains. Governments can only legislate to curb the most severe risks, but other impacts, such as the careless disposal of chemical compounds, have to be reduced through education that enhances individual responsibility and awareness of potential side effects.

Another important aspect of biota in the urban environment is the use of greenspace for physical and mental health improvement. Contact with greenspace, even viewing it from a hospital window, can improve mental health and feelings of well being, while physical exercise in open space is sometimes prescribed by doctors as an alternative to taking more pills. These health benefits are one reason why local authorities in countries such as the United Kingdom have set open space accessibility standards, suggesting criteria such as there should be a green area within ten minutes' walk or 600 meters of every home. Public housing developments are often good at providing some open space, for example Singapore features open-space facilities for children's play within all its public housing developments. Open-space requirements may be imposed on private developers, but sometimes the space they provide is awkwardly situated, near road intersections or relatively inaccessible, and not suitable for children's play or human relaxation.

Multiple benefits are gained from well-located urban open spaces, particularly those with trees and other vegetation. They improve health, reduce the urban heat island effect, trap some pollutants, provide habitat for animals, support biodiversity, can be parts of sustainable drainage systems and enhance the visual attractiveness of towns and cities. Ideally such green spaces are parts of green networks, or the green infrastructure of urban areas, helping to provide a series of interconnected patches and corridors facilitating the movement of both wildlife and pedestrians, be they walkers, cyclists or horse riders. In many countries the principle of having such greenways or green infrastructure plans is well developed, excellent examples being found in the Netherlands and in Germany.

Our Grandchildren's Children

The consideration of the five Wu Xing elements has led us to see that they are indeed highly interconnected. Living in the city means that we are constantly using the benefits, and sometimes the disservices, that they bring. We cannot ignore the character of the air above us, the vegetation, animals and insects around us and the ground beneath us any more than we can ignore the changes of the traffic lights or the ringing of our cell phones.

What we also have to be aware of is that ways of meeting these challenges do exist. In rapidly developing urban areas, opportunities to forestall problems are found both

in the construction of new urban areas (as in the Tianjin Eco-city in China that is being built in collaboration with Singapore) and in the way old cities (like Freiburg, in Germany) have been converted into much more sustainable places through a series of planning measures and retrofitting old buildings.

The brilliant 2008 Brunel Lecture by Peter Head demonstrated that existing technologies could make existing urban areas more sustainable and cut greenhouse emissions by 80 percent, by retrofitting buildings and changing transportation, water, energy, and waste management systems. Cities would have comfortable zero emissions mass transport; water collection, storage and recycling systems with separate potable and grey water mains. Organic waste fed to biodigesters would create both energy and compost for urban food growers. Buildings would be heated and receive hot water through district combined heat and powers systems, while much renewable energy would be generated by large scale desert solar, tidal power and wind turbine installations. Distribution of goods and many human needs would be greatly assisted by smart information systems. The ideas and technologies exist, the willingness to change behavior, make appropriate political decisions, and to act collectively for the benefit of future generations is less evident.

The key to the urban future is first of all to ensure that new developments are more environmentally friendly than in the past and that the mistakes already made are not repeated. Secondly, we have to retrofit both for sustainability, and to mitigate and adapt to global climate change. The technologies are there, from household solar panels to community-combined heat and power, from window boxes to urban greenways. Integrated, holistic lateral thinking is required, along with political emphasis on solving present problems through techniques that will make urban living better for both present and future generations. Sustainability is all about thinking of our grandchildren's children.

Thinking about and addressing urban environmental problems has to occur at all levels, from the individual and the household to the local community, the individual district or local authority, the metropolitan government and the whole urban region including the surrounding countryside intimately linked to the major city. Improvements are achieved through both small things and major schemes.

Changes in habits—such as levels of home cooling or heating, reusing goods or recycling of things no longer required, walking rather than driving—contribute to better health, urban heat island effect reduction, slashing greenhouse gas emissions and cutting back on use of raw materials. Achieving similar behavioral change in the workplace adds to the benefits. Community schemes for recycling furniture, composting garden waste, growing vegetables and even removing litter from drains all assist in reducing some of the problems of materials use, energy consumption and

storm water flooding. This emphasizes that people can do things for themselves and often can take a lead that prompts local government into action.

Equally important is the initiative taken by individual elected councilors to promote environmental action through their local authorities. Mayors have been particularly effective in some cities, exerting political leadership to reduce the environmental impact of their municipality's operations and encouraging local businesses and the community to do the same. Some introduce fines to discourage practices such as increasing paved areas around homes: Hamburg charges for every square meter of extra impermeable paving put in place, in order to reduce storm water flooding. Governments can show similar leadership. Taxes can be used positively, for example the UK Landfill Tax has forced local governments to greatly improve recycling rates. Charges for plastic bags in supermarkets reduce plastic waste while deposits on bottles encourage reuse and feed-in in tariffs for renewable energy encourage non-fossil fuel electricity generation and prompt power companies to use biomass. Equally, the planning of urban green space and green infrastructure can change the character of urban areas and provide multiple benefits for local climate, water management and biodiversity.

Such measures can be found in many cities, sometimes as part of an integrated move toward sustainability, but too often they are piecemeal responses to a series of initiatives. Local biodiversity action plans are not necessarily linked to climate change adaptation plans which in turn are not connected to transport infrastructure policies and to public health strategies. Meanwhile, there are many cities in which the imperatives of public order, water supply, health, education and housing are so great, and the financial resources so small, that little forward planning is possible. There are persistent differences between successful growing cities with adequate investment and those with few financial resources, whether in declining industrial areas or in regions where millions of poor people are migrating from rural areas to cities in search of better livelihoods.

Knowledge is not simply that held by the technocrats and in libraries, it is also the community understanding of local conditions and ways of coping with them. Neither top-down nor bottom-up schemes alone will deal with all situations. There has to be mutual respect, understanding, sharing and will to tackle the challenges on all fronts.