Lancet. Author manuscript; available in PMC 2012 August 28.

Published in final edited form as:
Lancet. 2012 June 2; 379(9831): 2079–2108. doi:10.1016/S0140-6736(12)60435-8.

Shaping cities for health: complexity and the planning of urban environments in the 21st century

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Executive summary

The Healthy Cities movement has been in process for almost 30 years, and the features needed to transform a city into a healthy one are becoming increasingly understood. What is less well understood, however, is how to deliver the potential health benefits and how to ensure that they reach all citizens in urban areas across the world. This task is becoming increasingly important because most of the world's population already live in cities, and, with high rates of urbanisation, many millions more will soon do so in the coming decades.

The Commission met during November, 2009, to June, 2011, to provide an analysis of how health outcomes can be improved through modification of the physical fabric of towns and cities and to discuss the role that urban planning can have in the delivering of health improvements. The Commission began from the premise that cities are complex systems, with urban health outcomes dependent on many interactions and feedback loops, so that prediction within the planning process is fraught with difficulties and unintended consequences are common.

Although health outcomes are, on average, better in higher-income than in lower-income countries, urban health outcomes in specific cities cannot be assumed to improve with economic growth and demographic change. The so-called urban advantage—a term that encapsulates the health benefits of living in urban as opposed to rural areas—has to be actively created and maintained through policy interventions. Furthermore, average levels of health hide the effect of socioeconomic inequality within urban areas. Rich and poor people

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live in very different epidemiological worlds, even within the same city. And such disparity occurs in both high-income and low-income countries.

Through case studies of sanitation and wastewater management, urban mobility, building standards and indoor air quality, the urban heat island effect (the difference in average temperatures between city centres and the surrounding countryside), and urban agriculture, we draw attention to the complexities involved in the achievement of urban health improvement through urban planning policies. Complexity thinking stresses that the development of a plan that anticipates all future change for these issues will not be possible. Instead, incremental attempts to reach a goal need to be tried and tested. Such thinking suggests a new approach to planning for urban health—one with three main components.

First, there needs to be an emphasis on the promotion of experimentation through diverse projects and the use of trial and error to increase the understanding of how best to improve urban health outcomes in specific contexts. Localised projects can be sensitive to local circumstances and might use the resources of local communities and organisations to effectively deliver their goals. Urban planners need to be actively looking for windows of opportunity to promote such projects.

Second, this emphasis on learning from projects in turn suggests the need for strengthened assessment. However, a different kind of assessment is needed to that usually used for public health interventions. In line with ideas of social learning, such assessment should be based on dialogue, deliberation, and discussion between key stakeholders rather than a technical exercise done by external experts. It would also call on a wide range of sources of knowledge, combining statistical data with the insights of tacit and experiential knowledge held by practitioners and the lay knowledge and experience of local communities. The aim is to create a community of practice of all stakeholders around the incorporation of health concerns into urban development and regeneration to support hands-on learning. Available measures of assessment might prove useful, but only if they are used to support dialogue between stakeholders.

Third, consideration of the value-laden nature of policy interventions and the creation of forums to debate the moral and ethical dimensions of different approaches to urban health and city environments are essential. In-depth consultation, mediation, and deliberation are all processes that can be used to engage stakeholders in detailed and problem-orientated argumentation on potential solutions. They can also support the promotion of the urban health agenda itself, an agenda that often falls victim to powerful vested interests and, as a result, the needs of more vulnerable groups in urban societies are often forgotten. If health equity concerns are to be addressed, inclusion of the full range of community representatives within such deliberation and debate is essential.

The Commission’s five key recommendations

- City governments should work with a wide range of stakeholders to build a political alliance for urban health. In particular, urban planners and those responsible for public health should be in communication with each other.
- Attention to health inequalities within urban areas should be a key focus when planning the urban environment, necessitating community representation in arenas of policy making and planning.
- Action needs to be taken at the urban scale to create and maintain the urban advantage in health outcomes through changes to the urban environment, providing a new focus for urban planning policies.

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- Policy makers at national and urban scales would benefit from undertaking a complexity analysis to understand the many overlapping relations affecting urban health outcomes. Policy makers should be alert to the unintended consequences of their policies.
- Progress towards effective action on urban health will be best achieved through local experimentation in a range of projects, supported by assessment of their practices and decision-making processes by practitioners. Such efforts should include practitioners and communities in active dialogue and mutual learning.

Introduction

3·4 billion people—about half the world's population--live in urban areas, and this number might rise to 6·3 billion by 2050.[1] The proportion of the global population living in cities will be 60% by 2030,[2] a 72% increase in 30 years (figures 1 and 2). Urban growth will be greatest in Africa and Asia, followed by Latin America and Oceania.[5] Even in long-established urban areas in Europe, urban population growth during that period will reach almost 5%.[5] This growth will not only result in more megacities (cities of more than 10 million people), increasingly concentrated in Asia, but also in more medium-sized cities, especially in Africa. UN estimates are that about 1 billion people, nearly a sixth of the global population, live in slum-like conditions. With the worldwide population predicted to expand to 9 billion by 2030, the number of people living in slum-like conditions could reach 2 billion.[5]

The understanding of how urban environments affect health outcomes and can produce health benefits is therefore an urgent priority, as recognised by WHO in their declaration of 2010 as the Year of Urban Health. From this perspective, there are reasons to be optimistic. The idea of the so-called urban advantage encapsulates the health benefits of living in urban as opposed to rural areas. However, factors such as economic growth and associated urban expansion cannot be relied on to drive improvements in health outcomes. Health improvements need to be actively planned for. The Healthy Cities movement has appreciated this fact and generated much action. Assessments have, however, pointed to a gap between aspirations and outcomes and limitations in the coherence of the models behind action.

In response to this problem, the UCL *Lancet* Commission met from November, 2009, to June, 2011, bringing together an interdisciplinary team of experts to under stand how better health outcomes can be delivered through interventions in the urban environment in cities across the world, and to generate policy recommendations. We began with the definition of health as both the absence of ill health and the presence of mental and physical wellbeing,[6] and the urban environment as the physical context within which urban activities take place, including the material fabric of buildings and infrastructure and their spatial organisation. The Commission focused on the potential for shaping the urban environment for better health outcomes; we explicitly did not address the issue of health-service provision within cities, but acknowledge that this is a key component of urban policy. We undertook expert-led reviews of available studies and desk-top research into the connection between urban planning and health in more than a dozen cities, with additional information provided by Commission members who have experience of working in many of these cities. The work informed discussions at monthly meetings with experts in public health, planning, architecture, building physics, engineering, development studies, anthropology, and philosophy.

The Commission developed an approach based on complexity thinking—an approach that looks at the interconnected elements of a system and how that system has properties not

readily apparent from the properties of the individual elements—and used this approach to develop proposals for an effective way forward. We begin by addressing the arguments around the urban advantage idea and then review the work of the Healthy Cities movement in the promotion of action for urban health. We then set out a complex systems approach for the understanding of how urban environments affect urban health, followed by five short case studies of urban interventions: the inter-related domains of sanitation and water management, building standards and indoor health, transportation and the links to mobility, urban form and the urban heat island effect, and the promotion of urban agriculture. We then turn to the implications of our analysis for urban governance if effective interventions to improve urban health are to be delivered, concluding with recommendations for policy and practice.

The health advantages of cities

Health is determined by many factors outside the biomedical domain,[7,8] even with the restricted definition of health as the absence of disease. This point is rein forced when the definition is expanded to the WHO vision of health as a "state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity",[9] the idea of health as the ability to adapt and to self manage,[10] and Amartya Sen's idea of justice entailing the ability to live a life one has reason to value.[11,12] Health is associated with social determinants[13]— nowhere more so than in cities,[14] and especially so when in conjunction with the increasingly important role of climate change.[15] But for more than 150 years, a large and continually expanding body of research has shown that the way in which cities are planned and managed can make a substantial difference to the health of their residents.[16] Long-term projections of global health outcomes now explicitly include factors such as unsafe water, poor sanitation, urban air pollution, and indoor air pollution.[17]

However, despite important studies such as those undertaken by Takano and colleagues,[18] a comprehensive methodology for analysis of the associations between aspects of the urban environment and residents' health is not available. The absence of such a methodology is largely attributable to the complex nature of urban systems, in which many factors affect social and health outcomes, compounded by the scarcity of consistent data available at the urban scale. Instead, data have been used to show the existence of a shift from an urban disadvantage, or penalty, to an urban advantage, in which health outcomes in cities have historically first decreased and then improved compared with rural areas. Some evidence exists that growing cities in industrialising countries in the 19th century initially accounted for the poorer improvement in mortality rates than might have been otherwise expected from urban and economic growth.[19] Infant mortality rates were generally higher in urban areas than they were in rural areas and remained so until the so-called sanitary awakening[20] in the late 19th century. Thereafter, though, urban settlements tended to have better health outcomes than their rural counterparts. In low-income countries, urban mortality rates fell below rural rates by the mid-20th century.[21]

The difficulty with the idea of an urban advantage is that it is based on a broad transitions model, which assumes that further economic growth and urbanisation will bring health indicators into line with those of higher-income countries.[22] Much of the public health discourse has been underscored by the idea of such linear transitions with time. The mortality transition, as proposed initially by Samuel Preston,[23] showed a positive association between life expectancy and national income per head—the Preston curve.[23,24] The demographic transition described steady reductions in death rates accompanied by decreases in birth rates, so that populations have aged and their growth rates have fallen with economic growth.[25] The epidemiological transition**,** proposed by Omran[26] in 1971, postulated that, with time, degenerative diseases and anthropogenic disorders would displace

infections as the main causes of mortality and disease. This has subsequently been reframed into a more positive term—the health transition—that encompasses the effects of sociocultural, behavioural, and health-service factors, rather than being reliant on only economic output to drive health outcomes.[27,28] More specific versions of transitions thinking are provided by the following terms: the nutrition transition—the shift in the nutritional profile of the population from undernutrition (in macronutrients and micronutrients) to overnutrition as income rises; the energy transition—the replacement of locally sourced biomass[29] for energy production by more modern fuels,[30] with immediate health consequences;[31-33] and the environmental transition—the inverted-U-shaped relation between environmental pollution and per-head income posited by the Environmental Kuznets Curve.[34]

A few conclusions can be drawn about urban health. First, transitions analysis does not fully explain changes in health outcomes. In Preston's mortality transition, income growth explained at most only a quarter of the increase in life expectancy between the 1930s and the 1960s; understanding of the remaining 75-90% is still poor.[35] Mechanisms other than national economic growth clearly exist, although debates have not always recognised this fact.[36-38] Second, there has been much criticism of the assumption of linearity in health out come trends with time. For example, in relation to the epidemiological transition, the pattern of changing causes of death has been challenged,[39-45] and the emergence and reemergence of infectious diseases, especially in urban contexts,[46-51] has undermined the overall argument. This pattern is clearly shown by studies such as that of Frenk and colleagues in Mexico,[52] in which an analysis of changes in morbidity patterns showed that the stages of the epidemiological transition tended to overlap and were reversible (counter-transition), that transitions could be protracted, and that pretran sitional and post-transitional disease could coexist in the same population.

Similarly, the Environmental Kuznets Curve[34] does not always hold up to empirical scrutiny, especially within cities that are not economically homogeneous. For example, in terms of air quality, environmental pollutants associated with industrial sources fit the model, but others associated with urban transport do not.[53] Again, the theory does not hold for the effect of water-borne and food-borne disease in some low-income groups.[54] In the case of energy transitions, fuel replacement will not always be sustained; in the face of changes in availability or price of fuels, low-income urban households might slip back down the so-called energy ladder to cheaper, more polluting fuels, or might reduce their total fuel consumption with adverse health effects.[55,56] Finally, the speed at which nutrition transition is taking place in some communities, especially in low-income and middle-income countries, has led to the coexistence of undernutrition and overnutrition.[57] Instead of the nutritional status curve moving to the right, it has widened, which has particular resonance for urban populations in low-income countries, where the shift from ancestral and early-life undernutrition to relative overnutrition[58,59] is implicated in the increasingly heavy burden of cardiovascular disease and diabetes.[60,61]

Our greatest concern about the idea of an urban advantage, however, is that it hides the diversity of health outcomes within cities. As the recent WHO-UN Habitat report Hidden Cities[14] details, in many urban areas, rich people and poor people live in different epidemiological worlds, and the burden of ill health is highest in the poorest groups.[62] The double burden of communicable and non-communicable diseases is borne predominantly by poor people.[63-65] In the informal settlements that house poor people in many cities in low-income and middle-income countries, the conditions that spread infectious disease, such as unclean water, poor sanitation, and overcrowding, con tribute to epidemics.[66] Evidence exists that in some high-income countries with growing income inequalities, cases of infectious diseases are increasing in socio economically deprived subpopulations.[67-69] For

example, New Zealand has a rising prevalence of chronic diseases, and rates of close-contact infectious diseases in indigenous Māori populations and Pacific Islanders are also rising.[70] The nutrition transition is also strongly socially determined. In the early stages of development, wealthier people become overnourished whereas the poorest populations remain undernourished; after a specific point—and especially in urban areas in low-income and middle-income countries[71]—deceleration at the wealthier end and acceleration at the poorer end is seen, and poorer people end up more overweight. Work on the social determinants of health during the past decade has strengthened the evidence of the link between social and health inequalities, at urban as well as international and national scales.[14,16] The Commission on Social Determinants of Health[72] drew attention to how transport patterns, access to green space, pollution effects, housing quality, community participation, and social isolation are all structured by social inequality.

Although, on average, health outcomes are better in cities in wealthy countries than they are in less wealthy countries, economic growth cannot be assumed to lift all urban citizens into a zone of better health. Similarly, continuing urbanisation cannot be relied on to bring more people within the remit of the urban advantage in terms of improved health outcomes within cities. We need to be aware of the continual effect on health inequalities of social inequalities and diversity within cities. Low-income populations in cities might face an urban penalty of poorer health and wellbeing compared with their rural counterparts, even as their richer, urban neighbours are benefiting from an urban advantage.[73] Any understanding of these associations, therefore, needs to combine the recognition that, on average, urban populations in high-income countries fare better than those in low-income countries and better than rural populations, with the acknowledgment of the persistence of intra-country and intra-urban inequality. Unfortunately for much of the world, information about intra-urban health differentials is scarce and the available statistics are aggregated at too high a level to draw conclusions about local patterns.[74]

Every city has a range of health burdens related to social inequalities and the effect of social determinants. Thus, a particular epidemiological profile could be associated with two different socioeconomic groups in two different cities (figure 3). However, the fact that the greater share of the world's population lives in lower-income cities should be borne in mind. The priority from a global perspective is to improve health outcomes for the many people at the bottom of the socioeconomic spectrum in cities in low-income and low-to-medium-income countries. But from a national and urban perspective, a need exists to recognise urban inequality and to tackle the health problems of the poorest population in all cities, no matter how wealthy the country.

The urban advantage in health, therefore, has to be actively promoted and maintained through policy measures and planning. Little doubt exists that medical interventions have contributed to the decreases in mortality from cardiovascular disease since the 1960s (along with high taxation and regulatory policies to reduce tobacco smoking),[19] to improvements in survival rates in low-income and middle-income countries,[75] and to the increasing longevity of people living with non-communicable disease. But public health interventions such as changes in water and sanitation infrastructure have also contributed substantially to decreases in infectious disease mortality,[76-79] and regulation has had a major effect on environmental quality in specific locations, although disentanglement of the relative contribution of technological change and policy frameworks is often difficult.[80,81] Neither can we assume that the urban advantage is irreversible. Drastic reductions in investment in the construction and maintenance of basic infrastructure, especially as population density increases and household incomes drop or remain stagnant, can lead to increased morbidity and even mortality. The task for urban planning and management in the delivery of urban

health is continual. The Healthy Cities movement has recognised this and the next section reviews the activities under this umbrella initiative.

The Healthy Cities movement

The Healthy Cities movement originated in Toronto, Canada, in 1984, with the Beyond Health Care conference, building on the work of Leonard Duhl and Trevor Hancock.[82] 2 years later, the Ottawa Charter on Health Promotion was adopted, and WHO held the first Healthy Cities symposium in Lisbon, Portugal, to launch the European Healthy Cities Project.[83] The European project proved popular from the outset.[84,85] It has been divided into a series of 5-year phases.[86] Phase one focused on new organisational structures, creating agents of change (such as dedicated units or officials) and introducing new working practices focused on health. By comparison with phase one, phase two (1993-97) focused more on action, emphasising healthy public policy and comprehensive city health planning. Phase three (1998-2002) brought in cities that had been developing healthy-city projects outside its scope—there was also more of a focus on meeting fixed criteria and on the development of a systematic approach to monitoring and assessment. Phase four (2003-07) promoted partnership working and intersectoral cooperation, and WHO strengthened networking between cities.[87] Phase five (2008-12) makes strong links to the report by the Commission on Social Determinants of Health (2008) and has seen further substantial growth in the number of cities involved.[88] By 2003, 1300 cities in 29 countries in Europe had signed up.[87]

WHO has also initiated Healthy City projects in North America, and, in 1991, selected several cities in low-income countries to help spread the initiative more widely, including Accra in Ghana, Johannesburg in South Africa, and São Paulo in Brazil; this effort was followed by a larger, second phase in 1995 and subsequent growth managed through WHO regional offices.[89] A 2003 WHO report enumerated 16 participating countries in the Americas (including more than 200 communities in the USA and about the same number in Canada, and building on the Healthy Municipalities movement in Latin America), 100 cities in the Western Pacific region, 40 in southeast Asia, and the capital cities of 46 countries in Africa; some penetration has also been recorded in the Eastern Mediterranean.[87] The movement's greatest concentration is in its areas of origin—namely, the European region and North America, although developments such as the Alliance for Healthy Cities, based in southeast Asia and Australia, are rapidly increasing its presence in those regions. This distribution shows the Healthy Cities movement's origins in the concerns of European and North American cities as opposed to the public health concerns of lower-income countries, a challenge that the broader urban health domain has also faced in seeking to begin dialogue with all cities across income divides.

The Healthy Cities movement has taken a grounded and relational view of health, leading to an emphasis on community participation, empowerment, and institution building. As a result it has avoided specifying particular actions that should be taken, in favour of an approach that emphasises continuous improvement, as stated in the WHO's Health Promotion Glossary: "a healthy city is one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and developing to their maximum potential".[90] This approach resonates with the approach to human rights, which comes out of the International Covenant for Economic, Social and Cultural Rights (ICESCR),[91] and stipulates that there is a minimum set of core obligations that should be met and, beyond this, an obligation to progressively realise the right in question—eg, the right to health.

The movement thus has a strong emphasis on process, with three main parts. The first is the building of political commitment and common vision locally, with a view to the movement of health up the urban policy and political agenda. Second, there is involvement of a wide range of stakeholders including local communities, fitting within the ethos of Local Agenda 21 (the community-level movement for sustainable development set out at the Rio Summit 1992) and moving away from an expert-led health agenda towards one that emphasises community empowerment and participation.[85,92,93] Third, strategy development within local government is expected—in the form of a city health plan—based on intersectoral partnerships and the aforementioned stakeholder engagement. Such strategy development goes along with the development of health information systems, the integration of health into a range of other urban policy and planning documents, and the use of procedures to assess effects.

This emphasis on process has extended into the assessment of the Healthy Cities movement and has led to some criticism that the discernment of on-the-ground effects is difficult. Ritsatakis' 2009 assessment of phase three of the Europe region pointed to "an undeniable shift from rhetoric to action in at least half of the cities" but also stated that "few cities had moved to tackle the intermediate determinants of health".[94] The phase four assessment showed that 94% of cities had agreed on partnership between organisations and that 76% of cities were implementing collaborative plans, projects, or programmes with greater cross-sector involvement. City health profiles, city health development plans, and a healthy ageing profile were common; health-effect assessment less so. According to the WHO, two-thirds of healthy city coordinators were "actively involved with urban planners and influential in shaping planning programmes".[95] Three levels of integration were distinguished: focus on essential provisions such as shelter, food, clean water, clean air, and effective sewerage; integration of specific measures into urban environments to encourage, among other things, mobility and social cohesion; and a holistic approach in which health is fully integrated into urban planning. Most cities were struggling with the holistic approach. According to de Leeuw and Skovaard, individual case studies have also shown that "implementing these intersectoral policies has proved more difficult than expected".[96] All these difficulties were compounded in the case of cities in lower-income countries.[97] Overall, assessments of all who signed up to the Healthy Cities movement have repeatedly drawn attention to the limitations in the scale of action compared with original aspirations.[96,98-102]

These aspirations were indeed ambitious (panel 1). Our focus was more restricted, concentrating on how urban planning could shape the physical aspects of an urban environment to promote health. The review of research undertaken by our Commission showed that many people know what a healthy urban environment would look like.[104-106] It would have adequate water and sanitation infrastructure, including in the informal settlements and slums in low-income and middle-income countries. Polluted air and land would be tackled at the city-wide scale but also at the intra-urban scale to avoid the environmental injustice of such pollution being concentrated in lower-income neighbourhoods. All homes would be of adequate construction and design to protect from storm, heat, and cold, while ensuring good indoor air quality and freedom from infestation by pest species. They would be located so as to be resilient to natural hazards, in neighbourhoods that offer social support systems and security from crime. Transport systems for all sectors of the population would not cause air pollution, would reduce traffic accidents, and would promote opportunities for active mobility, supporting individual health. Such mobility would be enhanced by a city-wide infrastructure of public spaces, incorporating urban greenery and water, which would also assist in urban climate control, offer spaces for local food supply, and contribute to mental health. Although the shaping of the urban environment to provide health benefits in these ways is the main focus of this

Commission, we recognise that urban health also needs a system of good health care at the urban scale.

One problem in moving towards such a healthy urban environment that has been repeatedly identified in assessments of the Healthy Cities programme is the absence of a developed conceptual framework to support action, a problem that extends into the urban health field more generally.[107] Several commentators have sought to fill this gap but their contributions have been very general. For example, Barton and colleagues[108] show how people and their health are affected by their lifestyle, their community, the local economy, built en vironment, natural environment, and global ecosystem; Van Kamp and colleagues[109] reviewed a range of high level models, identifying effects on quality of life that include the physical and social environment; and Northridge and colleagues[110] separated out large-scale, medium-scale, and small-scale factors connected to health and wellbeing at the individual or population scale, but do not explore links and relations that cut across the main elements operating at each level.

Healthy cities as complex systems

As Hancock and Duhl[103] make clear, cities are “the example par excellence of complex systems: emergent, far from equilibrium, requiring enormous energies to maintain themselves, displaying patterns of inequality and saturated flow systems that use capacity in what appear to be barely sustainable but paradoxically resilient networks”. Along with several other researchers, the Commission is therefore proposing a complex systems approach to the analysis and promotion of healthy cities;[111-113] as set out by Glouberman and colleagues:[114] “Complex adaptive systems are systems made up of many individual, self-organizing elements capable of responding to others and to their environment. The entire system can be seen as a network of relationships and interactions, in which the whole is very much more than the sum of the parts. A change in any part of the system, even in a single element, can result in reactions and changes in associated elements and the environment. Therefore, the effects of any one intervention in the system cannot be predicted with complete accuracy because the system is always responding and adapting to changes and to the actions of individuals.”

In practice, this idea urges recognition of the multiplicity of the associations that shape urban health outcomes. As Rose has pointed out,[115] the causes of illness in individuals might be very different from the causes of illness in populations; different policies are needed to maintain healthy urban populations than at the individual and household level. A complex systems framework for urban health would encompass the physical, social, economic, and political environments.[116]

Furthermore, these relations are non-linear and causation is multidirectional, so that simple causal relations between dependent and independent factors are difficult to isolate. Causes are also outcomes. For example, people’s travel decisions will be a result of aspects of transport infrastructure provision and local cultural factors, and they will in turn affect air quality outcomes and levels of fitness and obesity. The dynamic complexity of cities means that the time from cause to effect is extended and usually non-linear, making causal relations even harder to identify with conventional analytic methods. Feedback loops are also a common feature of complex systems: as well as travel behaviour being a result of the operation of public transport systems, the levels and patterns of public transport use affect its viability. Negative feedback loops help to maintain equilibrium. For example, fare subsidies can maintain the viability of public transport. Positive feedback loops support irreversible unstable expansions, such as the growth of new suburbs, which tend to evolve with new

motorways.[116] As a result of these aspects, interventions in urban systems are prone to unintended consequences and much uncertainty exists in the prediction of their effects.

Cities can therefore be thought of as networks with emergent properties. For example, the city can be seen from an ecological perspective, providing the context (or habitat) for health and operating as a networked system that is dependent on the functioning of its parts and connections.[117] However, this notion should not lead to an assumption of progress towards any steady state. A city's ability to cope with breakdowns (eg, economic crises, natural disasters, or social unrest) and modify itself and change to meet the always emerging, changing require ments for life is crucial, although some solutions, such as gated communities for the very wealthy, might increase health inequalities. Prigogine and Nicolis[119] drew attention to the fact that new "floats in disorder", so-called dissipative structures, can arise in times of disorder. Such dissipative structures are characterised by flows in and out of the system, which maintains a degree of stability, even though the system is not at equilibrium. Although the Healthy Cities movement was built on an ecological metaphor of the city, which encompasses many of these aspects, that insight has not been fully drawn on in the analysis of specific cases or development of broader recommendations for planning processes.[119,120]

Diversity is another key aspect of this complexity. Intraurban diversity means that cities are a patchwork of communities, both those that are geographically located and those that are not. The social complexity of plural stakeholders with differing and often conflicting interests compounds this aspect.[121] The interests of car owners, who are more likely to have higher incomes than those who do not own cars, often conflict with those who walk or cycle as their main mode of transport. Business interests, whose activities rely on car use, might demand parking provision and sites in out-of-centre locations, making viable and affordable public transport (largely used by low-income residents) more difficult to sustain. Such focus on diversity within a particular city shows how urban systems operate with a high level of specificity so that understanding of the particular patterns in each location and among particular populations is important.

The complexity of urban health systems varies with scale. Most existing models analyse systems very generally and do not consider different levels and the details of interconnectedness. For example, the healthy-cities framework devised by Barton and Grant[108] regards global ecosystems, the natural environment, the built environment, activities, the local economy, community, lifestyles, and people as successive layers, with healthy people at the centre; by contrast with this approach, a complex systems approach emphasises the interconnectedness that exists across layers. Northridge and colleagues[110] built some more interconnections and some feedback loops, but they fundamentally see each level (large-scale, medium-scale, and small-scale factors) affecting the ones below and above, rather than tracing more complex linkages.

We suggest that, at a broad macro-level scale, urban health outcomes result from the mutual interconnection of the following descriptors: society and governance processes; urban planning, policy making, and management; aspects of the built environment and of the ways in which social use is made of that environment; how the built environment affects health; and health outcomes themselves (figure 4). Although comprehensive and a reminder of the need to consider multiple factors, this suggestion provides little guidance for the detailed analysis of specific health issues and interventions in the urban environment—a more focused approach is needed to identify specific aspects of cities and their associated urban health implications. Inevitably, such an approach cannot be fully comprehensive and is in danger of both leaving out specific aspects and failing to capture crucial interconnections. Nevertheless, it is a useful heuristic method of analysis and policy development. The

Commission focused on the way in which interventions in the physical fabric of cities or the built environment affect health outcomes (figure 5). In the case studies we discuss below, we provide a more detailed mapping of such linkages, with other examples available elsewhere.[122] Our argument is that this level of detailed analysis is necessary to understand the problem of urban health. We have identified five case studies below to describe the argument of complexity in greater depth: sanitation and the management of wastewater, building standards and indoor air quality, urban transportation and mobility, measures to deal with the urban heat island, and urban agriculture initiatives. These case studies are not intended as best-practice examples. Rather, they are used to explore some of the complexities of urban systems and to understand some of the factors that shape the tenuous connections between a particular urban planning policy and better health outcomes.

Sanitation and wastewater management

Background

In high-income countries, any household can expect to have potable water supplied regularly to internal bathrooms and kitchens, a flushing toilet, and storm drainage to prevent flooding. In low-income and middle-income countries, this set of standards is often seen in only the wealthiest neighbourhoods and in well managed and comparatively wealthy municipalities. Water and sanitation services, however, are consistently and notoriously absent in badly managed cities and in the poorest parts of many cities. Research has focused on the scarcity of these resources in informal settlements,[123] but the problem is not confined to such settlements.

Sanitation

Investment into infrastructure to supply water tends to be seen as indisputably desirable by politicians and citizens alike, whereas, in political and cultural terms, the disposal of human excreta is comparatively neglected. Because isolation of individual risk-factors in the faecal-oral infection route is not methodologically possible, research and policy making resorts to a composite risk factor of water, sanitation, and hygiene.[124] Diseases related to poor water, sanitation, and hygiene in urban areas include diarrhoeal diseases, other gastrointestinal infections, trachoma, schistosomiasis, and helminthiasis.[125] The links between sanitation, disease, and dignity have spurred some to argue that access to adequate sanitation—defined here as the disposal of human excreta to prevent disease and safeguard privacy and dignity[126]—should be thought of as a basic human right.[127]

Access to sanitation exists at different levels, ranging from open defecation, to unimproved, shared, and improved facilities. Progress, for example, towards the UN Millennium Development Goals, is often measured in terms of increased access to improved facilities—defined as provision of hygienic separation of human excreta from human contact, as is the case with piped sewer systems, pit latrines, and composting toilets. But many systems that might be classified as improved are, in practice, well below the standard needed to reduce the risk of human contact with faeces. Such is the case in dense urban informal settlements, where the quality of construction and maintenance of individual facilities might be inadequate, waste from pit latrines is sometimes dumped near sources of drinking water, or fees for the use of toilets might be set too high for some users.[126,128] Even with low standards, an estimated 2·6 billion people do not have access to improved sanitation, the largest proportion being in south Asia, followed by eastern Asia and sub-Saharan Africa.[127]

Urban areas generally fare better than rural areas, suggesting a potential for the creation of a greater urban advantage. However, methodological difficulties exist in the accurate assessment of the numbers and proportions of people with access to water and sanitation services in urban areas. Statistics are usually derived from household surveys, population

censuses, or local utilities. Quite apart from the fact that criteria for the definition of urban and rural vary substantially across national boundaries, household surveys can estimate proportions of the population living in urban and rural areas, but are unable to identify precise data for individual towns or regions. In many countries, censuses are done irregularly and some times not for several decades. Small urban centres often do not have sewers, and data tend to underestimate the proportion of households who have invested privately in sanitation. But, nonetheless, the lowest shares of population with access to improved sanitation are seen in rural areas (figure 6). However, many of these rural regions have already started to urbanise rapidly, putting stress on local authorities, many of which are badly prepared to deal with the demands of a rapidly growing population.

Urban water and sanitation are usually seen in policy circles as one sector, partly because the first cities to industrialise in the 19th century chose to install large-scale water-based networked systems to take human excreta away from the concentrated population. For example, in London, UK, until the mid-19th century, water was supplied by private companies, and human waste was stored and manually emptied from pit latrines or septic tanks in individual homes and used as fertiliser in the fields surrounding the city. In the face of frequent epidemics and high mortality rates, sanitary reform initially focused on more equitable forms of public supply of water at affordable costs. But greater availability of water, coupled with the mass adoption of private water-based toilets in homes, led to the unintended consequence of overflowing cesspools (mainly in poor neighbourhoods), pollution of sources of drinking water, and a major sanitary emergency popularly known as the Great Stink of 1858. As a consequence, although the incidence of diseases such as cholera and typhoid fever decreased, deaths from gastrointestinal diseases from polluted water sources remained high, leading to the creation of an extensive publicly funded sewerage network, the first modern large-scale urban sewage treatment system, and a 15-year increase in life expectancy between the 1880s and the 1920s—much of which was attributable to major decreases in child mortality.[128]

The association of high-density concentrated populations with water-based, municipally supplied, underground networks to collect and dispose of human waste became the 20th-century standard to be aspired to and adopted in rapidly growing cities around in the world (figure 7).[54] However, coverage of networked sewerage systems is very low in most cities in low-income and middle-income countries in sub-Saharan Africa and parts of Asia and Latin America. Septic tanks, pit latrines, or even open defecation are the norm for most of the population in most sub-Saharan African cities.[130] In densely populated informal settlements, one facility is often shared by many households, sometimes by hundreds of people, with dire consequences for convenience and hygiene (panel 2).

This low coverage of urban sanitation in urban and periurban informal settlements can be partly explained by the combination of a long legacy of supply-led engineering approaches with high operating costs and underused investments, unrealistically high standards of service, and the low political weight of local populations.[133-135] Additionally, because access to sanitation in these areas is separated from the removal, transportation, and treatment of excreta, breakdowns in the service are likely to affect only a few people at a time,[136] thus lowering its political importance at the aggregate city level. Despite the fact that, independently of individual household hygiene, most disease trans mission occurs at the neighbourhood-scale,[124] so-called on-site toilet facilities, are seen by city authorities as the responsibility of individuals. Such deferral of responsibility is a generally accepted principle in cities with substantial gaps in sanitation coverage, meaning that access to sanitation in informal settlements will probably remain inadequate for two reasons: governments are unwilling or unable to invest at a major scale, and poor households give the problem a lower priority than they do other expenditure needs.

As subsidies for sanitation have been reduced, partly because international aid agencies consider them to distort markets and therefore benefit unintended populations (such as middle-income and high-income groups), a new emphasis on social marketing of sanitation in informal settlements has gradually emerged, aimed at stimulation of the private market in individual solutions such as latrine construction and maintenance.[137] But these efforts assume some homogeneity, both among and within low-income households, when the reality is that differences exist, even within the same settlement in terms of culture and religion, as well as in terms of the needs of women, men, and children in the assessment of sanitation facilities. Advocacy for market solutions also ignores the importance in household investment decisions of factors such as security of land tenure and location within the city.[138,139]

A large proportion of the inhabitants of informal settlements live in rented properties,[140] so they might be prepared to pay to use toilets, but are rarely willing to invest scarce financial capital in such facilities. They have to resort to the use of facilities provided by landlords or neighbours, often sharing them with other households, as is the case in some settlements in Nairobi, Kenya, where users who cannot afford to pay money for the use of such facilities do so in kind by helping with construction or cleaning.[138] But thousands of fee-charging toilet blocks have been successfully promoted in informal settlements all over India by the non-governmental organisation (NGO) Sulabh International[128]—at a smaller scale, poor urban communities have built and managed toilet blocks with the help of The Society for the Promotion of Area Resource Centres (SPARC), another Indian NGO.[141] In view of the scale of need in dense settlements and people's willingness to pay (which is often limited by their ability to do so), private businesses offering basic services such as bucket latrines and piped water for washing can even be seen in squatter settlements such as Old Fadama in central Accra, Ghana.

Finally, although plenty of documentation exists about local government and NGO initiatives on sanitation in informal settlements (panel 2), little is known about the daily reality of street dwellers, who number thousands in cities such as Mumbai, India, or Dhaka, Bangladesh. For entire families of pavement dwellers, hygiene is a huge challenge. In Dhaka, for example, women living in the streets prefer to do domestic work rather than better-paid construction work because it offers privacy for bathing and defecating.[138] Social inequality within cities thus drives differentiated outcomes for access to sanitation, with each group enmeshed in its own complex web of connections.

Wastewater: an unseen problem

Wastewater is conventionally described as any water that has been used and is unfit for further use.[142] Cities produce much wastewater from domestic, commercial, and industrial sources, as well as stormwater and effluents from urban and periurban agriculture.[143] Untreated urban waste water contains high concentrations of organic material, pathogens, and toxic compounds, ranging from heavy metals to newly emerging contaminants such as endocrine disrupting substances and pharmaceutical products,[144] a trend that is especially alarming when discharges occur into sources of drinking water.[145] The volume and level of pollution of wastewater in a city depend on a range of factors, such as a city's economic structure, income levels, and patterns of production and consumption. Middle-income cities with a high presence of manufacturing industries, for instance, are likely to have a broader range of chemicals in their wastewater than would a high-income city with little or no presence of manufacturing industries.

The management, treatment, and disposal of wastewater are thus crucial to avoid human and environmental exposure to potential hazards. Additionally, faced with water scarcity in many regions, water reuse is increasingly being advocated. Yet wastewater treatment, if it

exists, is often scarcely available or functions poorly;[146] an average of 35% of total wastewater in Asia is treated, with the proportion decreasing to 14% in Latin America and the Caribbean, and to zero in sub-Saharan Africa.[147] In middle-income countries, city sewerage systems have been growing faster than have wastewater treatment systems, which draws attention to the fact that even in such countries, budgets for infrastructure can come from different departments so that replacement and maintenance might not be synchronised.

Wastewater treatment is planned, engineered, and managed to remove, treat, and dispose of waste in the liquid medium from human and environmental contact (figure 7). Successful wastewater treatment should provide a point of waste collection, waste conveyance, treatment, and storage, and final discharge and disposal of the treated waste, which means that wider planning, social, and engineering issues need to be considered. In the Slum Sanitation Programme in Mumbai, India,[148] 25% of the new toilet blocks built did not have a water connection to flush the toilets and about 70% of the toilet blocks were not connected to sewerage (panel 2). The consequence is that this project, which was sponsored by the World Bank, will not receive a full return on its investment—in terms of improvement of the living conditions in slums—because of this disconnect in the infrastructure system.

In another project, the Mumbai Sewage Disposal Project, sewerage was successfully connected to the sewage treatment plant, but the huge amount of sludge that was produced shifted the problem of original sanitation and wastewater problem to solid waste disposal. The project might have to stop because the civil administration did not anticipate this consequence and does not know how to deal with the amount of solid waste. An estimated 1500 metric tonnes of sludge would be generated daily from 2300 million L of water. Sludge treatment is a major cost in a sewage treatment plant— up to 50% of the total cost of wastewater treatment.[149] From a public and environmental health point of view, although this sludge can be treated, it cannot be disposed of within the local environment. Sludge concentrates the pollutants from the sewage and if not disposed of properly can pose a new environmental threat—eg, by contaminating land and clean water sources.

The problem of sanitation and wastewater provision is not unique to low-income countries. In a high-income urban area such as London, UK, the sanitation system is mostly water-based and wastewater treatment is crucially important to protect the health of the city. The combined sewer network funnels both sewage and rain water to the sewage treatment plant. At times of heavy rainfall, untreated raw sewage overflows directly into the River Thames and, with a growing population living and working in the city and a potentially increasing frequency of heavy rainfall with climate change, this issue is becoming a major public health and environmental concern. As a result, Thames Water, the Environment Agency, the Port of London Authority, and the Greater London Authority have proposed the construction of the Thames Tunnel, running under the river to capture and store sewage that would otherwise be discharged and return it to sewage works for treatment. Construction of this tunnel is a major investment to deal with the unintended consequences of a historic decision to have a combined sewer network in conditions of unanticipated urban growth and climate change.

Not all societies treat wastewater as waste. With separation of household wastewater into black water (from toilets), grey water (from showers and sinks), brown water (containing faecal matter), and yellow water (containing urine), different waste streams can be treated and reused. Increasingly, urban planning and building design are regarding the recycling of wastewater as an integral part of sustainable buildings and developments. At a city-wide scale, energy can be generated through anaerobic digestion of sludge or wastewater recycled back for reuse in gardening or, after further purification, to produce a potable water supply, as happens in Singapore and is proposed in Australia. Where urban and periurban

agriculture is present, there is the potential for wastewater to complement other sources of irrigation and to potentially help recycle plant nutrients such as nitrogen and phosphorus, thus providing an effective replacement for chemical fertilisers.[143,150] The main challenge here is the short environmental cycle to treat pathogens and hazardous chemicals in the wastewater so that innovative technologies and vigilant practices are essential to secure the safe use of this resource.[151,152] Moreover, as a city's economy and household consumption patterns shift towards more manufacturing-intensive processes and products (eg, as seen in some of China's rapidly industrialising cities) the presence of chemical pollutants in wastewater might increase substantially, thus rendering it unusable for irrigation. The challenge for public health practitioners, engineers, and planners is to balance the health risks and the social, economic, and environmental benefits of wastewater reuse.[153]

Building standards, thermal comfort, and indoor air quality

Background

Building design provides an excellent example of the potential co-benefits of urban health and other social and economic policy goals, such as development goals and climate protection through reduction in greenhouse gas emissions. A WHO report[154] draws attention to the fact that although costs are incurred in the reduction of carbon in buildings and in household use of energy, the potential benefits for health are substantial, particularly for low-income households. However, this issue also draws attention to the complexities and tensions that can arise and how the policy approaches need to vary dependent on context.

Buildings, energy, and health

Buildings account for about 38% of total global primary energy use and 25% of energy-related CO_2 emissions;[155] of which buildings in cities account for two-thirds. A key measure to reduce urban greenhouse-gas emissions is improved efficiency in the use of urban household energy—improved insulation, control of ventilation, and efficiency of heating and other household devices; this has a bearing on several pathways and exposures that affect health (figure 8). The key elements are (1) indoor temperature and protection against cold and heat, depending on the setting, which often have indirect effects on physical health and psychosocial wellbeing, and (2) indoor air quality, which is governed by air exchange, outdoor pollutant levels, and production of indoor pollutants (this last including products of combustion, tobacco smoke, radon, and specific agents derived from materials and products contained within the dwelling).

The quality of the building materials is especially important for thermal control over heat losses or gains through the walls, windows, and roof. Ventilation characteristics affect the indoor air quality both through the overall permeability of the dwelling and via any purpose-built ventilation system (ranging from simple opening windows to more complex mechanical approaches).

Evidence suggests that household energy efficiencies have the potential for immediate, direct, and positive effects on health.[156] Greenhouse-gas mitigation measures offer an opportunity not only to reduce the risks of climate change, but also, if well chosen and implemented, to deliver substantial, short-term improvements in health. Such benefits will potentially be seen in both high-income and low-income urban settings. In general, household energy interventions in low-income settings have greater potential to improve public health overall than do those in high-income countries, but household energy interventions in high-income settings have the larger potential for greenhouse-gas reduction because of higher energy use per person.[157] In settings such as India, for example, there are substantial disease burdens associated with exposure to indoor air pollution from the inefficient and inadequately ventilated combustion of biomass for cooking and heating.

Thus, a strategy to deploy, at low cost, cleaner stove technology could yield very substantial health gains and also contribute to global greenhouse-gas reductions.[156]

There are also important health benefits from access to energy, especially electricity, which underpins so many of the functions taken for granted in high-income settings—eg, facilities for refrigeration, and therefore safer storage of food, and street lighting for more secure mobility. Restricted access to affordable energy is an underlying factor of poor health in low-income settings,[158-161] but is also an issue in higher-income countries. In England and Wales, for example, during the winter of 2007-08, more than 25 000 excess deaths occurred compared with the average for the rest of the year, many due to a combination of inadequate heating and underlying health problems in elderly and immobile populations, which are disproportionately concentrated in urban areas.[162] In the stated desire for improvement of energy efficiency, a need exists in many settings to increase affordable access to energy—a tension that needs to be overcome in urban policy.

Within cities in low-income countries, building quality and indoor environments can vary substantially, but many households live in substandard conditions.[163] In such countries, the internal environment typically has a greater effect on health than it does in high-income settings, resulting from poorly built dwellings that increase exposure to heat and cold and to the highly polluting fuels for heating, cooking, and lighting released into the living space. The direct effects of living in poor quality housing in terms of exposure to cold and mortality are less clear, although studies have drawn attention to seasonal effects in health, especially in children,[164] which might be reduced with better quality housing.

WHO estimates, however, suggest that compared with outdoor air quality, indoor air pollution carries a greater burden of ill health globally as a result of cooking and heating practices, coupled with inadequate ventilation. Estimates suggest that about 1·5 million people die as a result of indoor air pollution from the use of unclean fuels,[159] and switching to a cleaner fuel in low-income and middle-income urban settings could substantially reduce mortality. Furthermore, women will typically spend a greater amount of time indoors than will men, because they are responsible for food preparation and cooking and the care of infants and young children, and therefore have more severe exposure to pollutants.[165] Children exposed to high pollution levels have acute infections of the lower respiratory tract, [166] and women are at high risk of chronic obstructive pulmonary disease and lung cancer. Respiratory disorders are a leading cause of death, especially in children, in urban as well as rural households in the low-income and middle-income countries.

Building standards

The standards by which buildings are constructed offer an opportunity for improved building performance in both environmental and energy terms. However, the extent to which structure and form can be determined by authorities—through such measures as building regulation and codes—varies enormously from setting to setting. In informal settlements in many low-income urban areas, there is almost no appropriate control over even the most basic regulations for building form and quality. But inhabitants of such dwellings are also among those who would benefit most from simple measures to reduce exposures. Methods to engage with and assist inhabitants in such communities will need a process very different from those of formal regulation and standard setting. Despite such challenges, there is much potential for low-income and middle-income countries to build more efficient buildings that would have a substantial effect on public health with direct effects on respiratory and circulatory symptoms and, at the same time, on future energy demand, a conclusion supported in a UN report on the green economy.[167]

In high-income countries, building regulations and development controls are used in an attempt to ensure adequate indoor environmental quality, and large-scale research-based refurbishment programmes have begun, driven largely by the decarbonisation agenda. These programmes could have a large positive effect on health at the population level, provided they take account of the relevant complexities and are carefully implemented to combine improved thermal performance with adequate ventilation (panel 3). Policies have also been developed to target households in the lowest socioeconomic classes, for example, to target fuel poverty—the label applied to individuals who have to spend more than 10% of their income on fuel to heat their home satisfactorily[171]—which has been associated with cold-related health risks, mental illness, and asthma.[171-174] Strategies to tackle fuel poverty and inadequate access to energy use have included subsidy of winter fuel costs, and energy efficiency measures for vulnerable households to improve the quality of the home.[175]

In view of the potential health benefits of energy efficiency, city-level policies for energy efficiency and energy systems can be an important catalyst to improve health. Trillions of US dollars are expected to be invested into the decarbonisation of the built environ ment and to address the energy supply infrastructure worldwide during the next three decades. In high-income cities and in high-income neighbourhoods in many other urban areas, improved building energy efficiency is expected to make a major contribution to the achieve ment of decarbonisation targets; in low-income and middle-income cities, energy efficiency might not be a priority compared with other built environment needs (such as sewerage or water), but its inclusion in policies could aid in the development of healthier indoor environments and can establish a basis for efficient building codes.

Transportation, mobility, and physical activity

Background

Another area in which the complexity involved in the addressing of urban health issues can be seen is in the links between transportation and households' mobility patterns. Much daily human physical activity in cities takes place outside enclosed private spaces, areas influenced by urban planning and management. Such policies can contribute to many policy goals: carbon reduction and economic development, but also health through reduced pollution, greater safety measures, and—the focus here—provision for active mobility.

Built environment and physical activity

Compelling evidence shows that both objective measures and perceived features of the built environment are associated with health outcomes. The idea of walkability, for example, is now commonly used in studies of physical activity and health to refer to neighbourhoods where the environment is more conducive to walking, because of both the objective physical features and residents' positive perceptions of the benefits associated with walking and personal safety (figure 9).[176] Features of the built environment can enable physical activity by offering supportive infrastructure and associated programmes at an affordable (or no) cost.[177]

Although walking and cycling are traditional modes of both transportation and leisure-time physical activity, differentiating between utilitarian (eg, commuting) and leisure-time activity helps to clarify the complex associations between environmental attributes and physical activity levels. High levels of physically active transportation (ie, getting from one place to another) are associated with low socioeconomic status in both adults[178] and school children and adolescents,[179] with the evidence being stronger in low-income and middle-income countries than it is in high-income countries. However, poor people will probably not choose to walk or cycle to work or school because of the health benefits associated with active transportation; this decision is often more a matter of a household's financial

resources rather than the result of personal choice.[180] The choice of location within the city is determined by several factors, household income being paramount (figure 9). For the urban poor, many of whom are located far from centres of employment, the use of public transport, especially if more than one fare is needed, places a heavy burden on household finances. Utilitarian walking tends to be more prevalent in the poorer than in wealthier groups, whereas leisure-time physical activity is more common in higher-income groups. Low incomes can lead to lower levels of mobility, which in turn can restrict a person's ability to become financially better off (figure 9).[181]

Although there is no doubting that walking and cycling are beneficial for health, the fact that poor people are often forced to walk long distances, especially those living in large cities, is not a good situation. For those who choose to walk or cycle, an important consideration is a perception of safety from crime and from the dangers of traffic (and associated emissions).[182] Perceived safety from traffic in children is strongly associated with active transport and leisure-time physical activity,[183] suggesting that—when they have a choice—parents are unlikely to allow children to move around in neighbourhoods in which traffic accidents are a major concern. In terms of crime, the less safe a neighbourhood is, the less likely are its residents to walk to meet their transport needs.

Available evidence suggests that neighbourhood safety is positively related to higher levels of leisure-time physical activity in adults,[184] and that aesthetic factors might also play a part. The role of aesthetic factors in physical activity levels, however, is not straightforward. For example, one study in Brazil[185] recorded somewhat puzzlingly that garbage accumulation near a household can be conducive to physical activity. However, physical activity (eg, walking) is a need and not a choice for poor people, especially in low-income and middle-income countries, and poor people are more likely to live in areas where solid waste is not collected regularly from the streets. Therefore, this association is probably best explained by residual confounding for socioeconomic position. In this particular case, this suggestion is substantiated by the fact that the magnitude of the association was largely reduced after adjustment for socioeconomic position.

Urban density, another factor shown to be positively associated with physical activity, might also help to explain these complex relations. In high-income countries, shorter distance to facilities, such as pharmacies and shops, for example, has been associated with increased active travel, though not with leisure-time walking.[186] Sprawling urban development is associated with increased use of cars or buses,[187-189] and urban development patterns in high-income cities have been linked to obesity, with people in sprawl areas more likely to be overweight.[190,191] In low-income and middle-income countries, however, findings are less consistent, with one study reporting that neither active travel nor leisure-time physical activity were related to distance to facilities and physical activity levels.[192]

Although studies in high-income countries have shown positive cross-sectional associations between residential density and walking for transportation, no association seems to exist between density and recreational walking.[193,194] In Colombia, for example, higher park density is related to active park use, whereas residential density was unrelated to leisure-time physical activity.[195] In San Francisco (CA, USA), factors such as density, land use, and street connectivity had small effects in the promotion of walking and cycling for trips of less than 5 miles, although personal and household attributes were stronger predictors. In Atlanta, (GA, USA), land-use mix, residential density, and street intersection density were positively related to the amount of moderate physical activity done per day. Additional evidence from Bogota[195-199] suggests that street connectivity and mixed land use are less important than in US cities.

The main limitation of available studies of the association between physical activity and the environment is the absence of prospective data. Most studies so far are cross-sectional, and very little is known about the effectiveness of interventions in the urban environment on levels of physical activity.[200] Although the evidence is patchy and cannot be generalised across high-income and middle-income countries, nor even within the same country, urban planners could probably help to promote higher levels of physical activity through plans that seek to increase population density, diversify land uses, and improve street connectivity, paying particular attention to the transport demands associated with heterogeneous populations in cities.

Disability and the built environment

The link between disability and the built environment has received little attention by urban and transport planners, especially in low-income and middle-income countries. Although no reliable data exist, an estimated 15% of the population has some form of physical, sensory (deafness, blindness), intellectual, or mental health disability that will have serious implications for how they interact with the urban environment in which they live.[201] The recognition of disability is an important urban policy and planning issue, and is a matter of social and political priority. The UN Convention on the Rights of Persons with Disabilities, now ratified by 105 countries, specifically addresses the creation and enforcement of laws at the national level that ensure and improve accessibility. Accommodation of the needs of people with disabilities in the design of a city usually needs changes to the urban fabric. Retrofitting housing (ie, making changes to existing structures, rather than complete replacement), transportation systems, and public places to take into account the needs of people with disabilities can be expensive when infrastructure is often decades old and substantial changes such as ramps and widened entry-ways are needed for wheelchair users. However, newly designed or adapted transport systems, housing, roads, pavements, and urban public spaces offer an opportunity to provide more inclusive environments and, when properly planned and designed, additional costs are minimal (<3% of the total costs without these special measures).

The fact that much of the world's urban growth is taking place in low-income and middle-income countries is an opportunity to plan and design urban environments that provide disabled populations with greater opportunities for mobility and leisure. But because much urban growth is informal, and laws and regulations that should guarantee accessibility are poorly enforced, true accessibility for people with disabilities will continue to be an important issue for years to come. The health implications for such people are substantial—good and accessible built or retrofitted environments allow people with disabilities to access the surrounding urban environment for employment, leisure, or access to health facilities, or to buy food and goods, socialise, and participate in activities in the surrounding communities. Inaccessible environments, by contrast, limit or completely restrict people with disabilities from participating in such activities and place additional (and unnecessary) burdens on members of their households and social support systems.

Interventions and physical activity

City governments are especially relevant to people's daily lives in the public realm because they plan and manage infrastructure and services that directly affect people's quality of life and their sense of order and security.[202] As has been widely documented,[203] the lack of an effective planning framework, coupled with poor or non-existent basic infrastructure services (including paved streets and public transport), can have negative consequences for people's health, particularly poor and disabled people in urban areas. In most low-income and in many middle-income countries, local governments do not have the human and financial resources to fulfil these responsibilities, which are done by central government

agencies or not done at all. A consequence is that much new development takes place spontaneously, with individual households or private developers building and extending the city alongside roads, with little or no infrastructure to sustain dense populations of people. Such spontaneous development characterises slum areas and other informal settlements, some of which house a substantial proportion of a city's population, as has happened in Mumbai, India (panel 2). However, the example of Bogota suggests that there are valuable instances of city governments that have been able to break the deadlock of deficient resources and ineffectiveness, to provide infrastructure that not only helps increase the quality of life in urban areas but might actively contribute to the reduction of poverty levels (panel 4; figures 10 and 11).

The urban heat island effect

Background

Changing urban form is implicated in a range of feedback loops with potentially adverse consequences for urban residents. For example, urban forms disturb the local climate, which can affect health through modified temperatures—especially in extreme weather conditions. The latest UN Habitat Global Report[212] on Human Settlements states that "Evidence is mounting that climate change presents unique challenges for urban areas and their growing populations. These impacts are a result of the following climatic changes: Warmer and more frequent hot days and nights over most land areas; Fewer cold days and nights in many parts of the world; Frequency increases in warm spells/heat waves over most land areas..."

Since increasing heat greater than a city-specific threshold affects mortality rates in most settings,[213,214] the combination of climate change with the urban heat island effect is anticipated to have substantial health effects (figure 12).

Health implications

An urban heat island is characterised by the temperature difference between the urban and surrounding rural regions,[215-218] and has been noted as one of the most evident climatic manifestations of urbanisation (figure 13).[220] The health effects of the urban heat island relate not only to the direct effects of temperature but also to the related production of ozone.[221] The increment in temperature above background is determined by various factors: the solar energy captured, stored, and released by urban surfaces; the effect of urban geometry on the release of heat, convection, and advection; evapotranspiration; and anthropogenic heat sources.

Urban expansion will exacerbate the heat island effect, and urban land cover in a global sample of cities was shown to be increasing at more than twice the rate of urban population growth.[222] When expansion takes the form of urban sprawl, it adds more area covered by impermeable surfaces, longer travel distances generating more vehicle trips and air pollution, and more buildings generating heat emissions. The anthropogenic component of the heat balance of urban areas has proved substantial[223] and might increase the urban heat island increment by 1-2°C.[224] Rising urban temperatures in a city might reach a threshold above which the uptake of domestic air conditioning accelerates, further adding to anthropogenic emissions via a positive feedback loop. The difference in average temperatures caused by the urban heat island effect will depend largely on local climate and surrounding geography, the extent of the urban environment, and the type and quantity of anthropogenic emissions.[225] The effect is variable, but, as a general rule, peaks after sunset. A lack of spatial resolution in monitored data means that generalisation about the intensity of the urban heat island effect is difficult. However, differentials of up to 10°C have been noted at times in large cities.

The relation between outdoor temperature and mortality risk for many cities is well established. Evidence from several studies of heat waves in European and US cities shows that heatwaves have been linked to substantial increases in mortality and morbidity.[226,227] However, the actual effect of the urban heat island in terms of indoor temperatures on health is less well understood, especially the contribution of other factors such as building quality. The starting point for the development of strategies for any city to tackle the urban heat island effect should be to establish the net effect and then to plan how to minimise the negative effects while retaining the benefits (eg, reduced cold-related mortality). Otherwise, the danger is that strategies that focus on the reduction of this heat effect might, in isolation, have the unintended consequence of increasing the overall health burden.

A range of urban planning interventions are available that will tend to reduce the urban heat island effect, although their potential will vary from city to city (panel 5). Such interventions include increased greenery and inclusion of water features, increasing the solar reflectance of hard surfaces (eg, painting rooftops white), the reduction of anthropogenic heat emissions, and increased air flow through the city. Appropriate measures, that can identify and quantify the effectiveness of various planning, building, energy, and health policies, are being developed. For example, in a heat island project focusing on London, UK,[228] a series of quantitative measures have been developed to model the urban local climate at a city, neighbourhood, and street level. A range of such measures is likely to be necessary to address the urban form implications of the urban heat island effect at different scales.[231] However, the net result of the summer and winter health effects of any urban-form interventions to reduce the effect should be taken into account in individual cities in the development of relevant strategies.

Urban food production

Background

The future of urban and rural areas is closely linked through food supply. Rapid urbanisation of peri-urban arable land is likely to lead to an overall drop in agricultural production of 20-40%, depending on the assumed severity and length of global natural disasters.[232] Simultaneously, food export restrictions by food-producing nations[233] and constrained access to sustainable energy and water might further inhibit an affordable food supply. In urban areas, malnutrition, undernutrition, and increases in food prices have placed access to nutritious food high on the list of health concerns for poor urban dwellers. The implementation of urban agriculture—the cultivation, processing, and distribution of food within the city—could prove an important response to anticipated food shortages, while also providing several economic and health benefits. This section is more prospective than our other case studies.

Urban agriculture is often sidelined in urban planning policies, especially in high-income countries, despite the fact that access to food in poor neighbourhoods is an important concern. A 100 m^2 plot and a 130-day period with temperatures suitable for growing food can sustain a family for a year with fruit and vegetables and a nutritional intake of vitamin A, vitamin C, and half the vitamin B complex and iron needed.[234,235] Although few studies have been done of the individual health benefits derived from the tilling of soil in addition to the nutritional benefits of the food grown, for young gardeners it has been described as a foundation for efficacy, pride, self-esteem, and personal satisfaction.[236,237] Researchers have identified gardening as a viable form of exercise that can reduce the risk of coronary heart disease in men and women,[238,239] and can reduce obesity[240] and diabetes, as well as improve glycaemia control, in adults and elderly men.[241] WHO's Healthy Cities programme has recognised the benefits of urban agriculture and appealed to cities and their governments to incorporate food policies into urban plans.[242]

Experience with urban agriculture

Urban agriculture is not a new occurrence. Its popularity and adoption has varied during the past thousand years, from the recycling of urban wastes and *qanat* tunnel irrigation networks for agriculture in ancient Persia, to the stepped cities and farming terraces of Machu Picchu, Peru, which can be regarded as a precursor to hydro ponics. So-called Victory Gardens were successfully used in the UK to alleviate food shortages during the two World Wars with rooftops, balconies, pontoons, and public parks appropriated for food production.[243] In the USA, in a remarkably ambitious programme, gardening classes and committees were organised, seeds and fertiliser were provided, and guidance was published, yielding war-garden crops worth more than half a billion US dollars at the end of the first World War. Nowadays, urban agriculture is an important source of nutrition in low-income countries (panel 6 and 7; figure 14).

Although an established feature of low-income countries, urban agriculture is also a feature characteristic of developed countries, popular in the USA (where they are called community gardens), Russia (dachas), France (jardins familials), the Netherlands (Volkstuinen), and Denmark (Kolonihave). In the UK, allotments in large urban centres such as London and Manchester now have waiting lists of thousands of people.[250] The Intercultural Garden project, a project of the German Association of International Gardens, aims to improve racial integration and promote intercultural interaction, in addition to the production of healthy fruits and vegetables suitable for the participants' customary diets. There are a growing worldwide number of urban agriculture support partnerships, including multisite micro-farming enterprises and the Community Supported Agriculture (CSA) programme[251] in which consumers and farmers share the seasonal risks and rewards of their agriculture partnership. CSA farming is common practice in Canada, Japan, and the USA.[252]

Detroit (MI, USA) offers an instructive example. Subject to social and economic decline, some of Detroit's landscape of vacant land is being transformed into a productive green patchwork of community allotments that yield the co-benefits of health, nutrition, income, employment opportunities, and new skills. According to projected figures, urban agriculture in Detroit in the future could generate US$200 million in sales and about 5000 jobs, with a $1 investment returning about $6 in fruit and vegetables.[253] Thus urban agriculture could present an opportunity to reduce urban poverty, aid government initiatives to get people back to work, increase civic involvement, and coincidently raise the value of local housing stock in a series of positive feedback loops.

Urban agricultural efforts can extend beyond individuals simply producing food for themselves and their families. Skid Row in Los Angeles (CA, USA), home to one of the largest homeless populations in the USA, is one of the beneficiaries of the Urban Farming Food Chain Project. In 2008-09, the project installed a series of 9-m-long walls, each containing 4000 plants to supply the area's dispossessed people with tomatoes, green vegetables, and herbs. Equally as importantly, the programme has drawn together diverse disadvantaged members of the community of all ages and ethnic origins, and has given them an opportunity to learn new skills. For the city of Kitchener in Ontario, Canada, community urban agriculture is estimated to have helped reduce local crime, through greater civic involvement and having more people outside in yards and gardens.[254] Perhaps an even more innovative use of space can be seen in the Brick City urban farms of Newark, New Jersey (USA) based on the Small Plot Intensive (SPIN) relayfarming model devised by the Canadian farmers Wally Satzewich and Gail Vandersteen. Using the simple device of a plastic crate or earthbox, Brick City farmers can colonise disused sites even though the sites have contaminated soil. The small size of the units also allows operations to decamp and plants to re-root in other transient spaces as these become available. Urban agriculture in the future From innovative surfacing materials and interstitial spaces to buildings, we turn to the

vertical farms, championed by Despommier at Columbia University (NY, USA), which take the compact city argument and apply it to agriculture. Despommier's solution lies in three-dimensional hermetic farms that ensure year-round high-yield crop production with minimal risk of infection from agents without the use of pesticides. The tower model also reduces the use of fossil fuels and takes advantage of energy-waste trades with other urban activities. He estimates that a 30-storey-high vertical farm (which would take up one square city block) would provide enough nutrition (2000 kcal per person per day) to accommodate the needs of 10 000 people, using presently available technologies.[255]

For new cities, housing developments can be planned to integrate agriculture at the scale of landscape. In Studio 8 Architects' Guangming Smartcity in China, the city is arranged into optimally sized clusters of housing and farming suburb-terraces (figure 15). The stepped arrangement improves the solar angle for natural lighting within the apartment buildings; natural cross ventilation is possible and the distances between buildings can be reduced to increase housing density without adverse overshadowing. Most importantly, the terracing creates level rooftop surfaces that can be used for farming without fear of erosion and slippage, resulting in a symbiotic spatial connection between mass housing and arable land. Beneath the growing membrane, a gravel substrate is used to clean household water. The city consequently integrates the three functions of shelter, water purification, and food cultivation into the same space, in addition to the improvement of thermal insulation and retention of surface water.[256]

Urban agriculture could contribute to a movement towards the circular economy, an example of the complexity approach being used to develop a virtuous cycle to guide policy (figure 16).Here, the solid organic waste of city dwellers can be chemically transformed via anaerobic digestion into gaseous energy and digestate, which can be used for fertilisation; grey and black water from showers, sinks, and gutters can be treated and used to irrigate crops, provided they are collected in close enough proximity to the urban farm. With enough sunlight, food can be grown in the urban environment. Although this strategy is a model for the future of cities, urban agriculture can expand the contribution that it makes at present, meeting some basic nutrition needs of urban residents and potentially providing some economic, social, and other health benefits.

The promotion of urban health in conditions of complexity

The scope for unintended consequences arising from the interconnected and emergent properties of urban systems is substantial. Academic policy and planning is only slowly coming to terms with the implications of complexity—such thinking calls into question many widely held assumptions about research and policy processes. It challenges the ideas of stability, linearity, and regularity that drive evidence-based policy, emphasising the limitations on the ability to predict, plan, and control the behaviour of social systems.[257] It puts the emphasis on change that is unintended, unexpected, and often even unseen.[258] Failures of policy processes are no longer the result of a scarcity of information, inadequate research, or inappropriate interventions (although these might all play a part); rather, the crucial component of potential failure should be regarded as attributable to the internal dynamics of societal subsystems.[259] In his review of the implications of complexity thinking for policy making,[258] Sanderson proposes an alternative approach that emphasises three key elements.

First, post-complexity policy (policy made on the basis of cities being complex systems) needs to focus on experimentation and trial-and-error as the way to produce desired outcomes. As Glouberman and colleagues[115] point out: "improving health in cities is a matter of making numerous small-scale interventions, selecting those that prove to be

effective, encouraging self-organization among city dwellers, and constantly modifying approaches as the system continually changes and adapts". This idea suggests the promotion of localised projects that are sensitive to specific circumstances, as opposed to heavy investment into broader strategy development. The community-based latrines in Mumbai, India, are a pertinent example of such a project. Kauffman[260] has used what he calls patching to suggest that breaking an overall problem down into smaller issues that can be resolved (patched) through localised projects might yield improved results. The policy practitioner is thus acting as a policy entrepreneur who searches for policy windows to effect change.[261] Some of these opportunities might be community-based and representative of the self-organising potential of complex urban systems, an approach supported by international consensus. Examples of such an approach are local food schemes from city gardens in Detroit, and walking-for-health schemes organised locally by groups of elderly people. However, others will be led by the public sector or partnership bodies that invest in infrastructure. They might include research projects into the unexpected effects of new building standards, for example, or policies to guide the planting of greenery in city neighbourhoods. In line with the logic of a complexity approach, the greater the diversity of the promoted projects, the greater the potential for the complex system to be steered towards urban health benefits. However, the rapidity of climate change and urbanisation means that issues of scale need to be addressed. How the methods by which successful local initiatives can be turned into appropriate experimentation in other contexts should be decided on quickly.

Second, the assessment of these various experiments therefore needs to be strengthened. Such assessment is different from that usually practised in relation to public health interventions, one that fits with ideas of reflexive social learning rather than a modernist idea of reason.[262] Such assessment would be based on dialogue, deliberation, and discussion rather than on a technical exercise done by external experts.[263] As Costongs and Springett[264] argue when discussing assessment, "the particular nature of health-related urban policy demands an open, negotiated and process-orientated approach"; this would also call on a wider range of sources of knowledge, combining statistical data with the insights of tacit and experiential knowledge held by practitioners and the lay knowledge and experience of local communities.[265,266] The aim is to create a community of practice of all stakeholders around the incorporation of health concerns into urban development and regeneration to generate situated learning.[267] The MARI (Monitoring, Accountability, Reporting, Impact assessment) framework could provide such an opportunity, although it tends to be programme-oriented rather than project-oriented.[268] Again, urban health indicator sets, such as the WHO Urban Health Equity Assessment and Response Tool (Urban HEART) scheme, might prove a valuable learning device if used to foster communication and learning.

Third, under such conditions, consideration of the value-laden nature of policy interventions is essential.[269] Policy making needs to have a clear space for debate about the moral and ethical aspects of different approaches to urban health and city environments. In-depth consultation, mediation, and deliberation are all processes that can be used to engage stakeholders in detailed and problem-orientated argumentation to deliver potential solutions; Innes and Booher[270] provide case studies of the successful implementation of such techniques. This process could include justification of why specific local sites and communities should be targeted within individual projects. The justification of selection mechanisms within policy processes is an important aspect of an approach that recognises comprehensiveness as unobtainable.[258] But it is also about the prioritisation of the urban health issue, which, among other things, the Healthy Cities movement has been so effective in promoting. However, the realities of the promotion of health interests in the face of often powerful vested interests needs to be acknowledged.[270] Especially if health equity concerns are to be addressed, the inclusion of the full range of community representatives within such

deliberation and debate will be necessary, as the 2010 Kobe report from the WHO Urban Forum argued.[271-273]

This form of planning under conditions of complexity implies a very different view of the process as a whole. It can no longer be seen as a well structured sequential process or policy cycle (as presented, for example, in the WHO Urban HEART scheme).[274] Rather, it is a series of events pursued over time, in which the public decision maker is not in control but is a participant—one who has to be able to respond to the outcomes and effects of their interventions as they occur.[258] This issue raises important questions about the nature of strategy development. Many commentators on planning for urban health emphasise the need for comprehensive strategy devel opment based on extensive intersectoral and cross-organisational working. For example, the WHO Urban Forum[14] emphasised working across sectors and the integration of health in all urban policies in its Kobe report. Although such building of an alliance for action on urban health should be welcomed, these actions can be misguided if strategy development becomes a substitute for—or repeatedly delays—experimental implementation efforts. Complexity thinking underscores that the development of a plan that anticipates all future change will not be possible; instead, incremental attempts to reach a goal need to be tried and tested. Work with environmental effect assessments, strategic environmental assessments, and health effect assessments can have a useful role if they support project-based implementation of strategies, rather than strategy development alone (panel 8).[284,285]

The lessons of a complexity approach to planning urban environments for health are, therefore, that planners need to engage in widespread policy debate to instil healthy city values in the policy process, but that thereafter the focus needs to be on the identification and promotion of a wide range of urban health interventions, assessing them and learning about their potential for success and failure.

Recommendations

The Commission recommends that improved urban health outcomes will need a concerted effort to create and maintain the so-called urban advantage through reshaping city environments. Furthermore, such urban planning needs to take account of the inequalities between cities across the world and within individual cities when devising policy. Urban planning efforts should be based on a complexity approach that recognises multidirectional causality, feedback loops, and unintended consequences. Such an approach is more capable of producing effective action than are more conventional linear approaches. An integral part of such a complexity approach is an emphasis on project-based experimentation and social learning through discursive and inclusive assessment.

We summarise our recommendations for policy practitioners as follows. First, city governments should work with a wide range of stake holders to build a political alliance for urban health. Such stakeholders should include all those able to deliver urban change for health in active dialogue. In particular, health officials and practitioners need to be in dialogue with urban planners and managers at all levels. Second, attention to health inequalities within urban areas should be a key focus of planning the urban environment. Such efforts will necessitate community representation in forums of policy making and planning for urban health and might need local government to support under-resourced and less well organised sections of the urban population.

Third, action needs to be taken at the urban scale to create and maintain the so-called urban advantage in health outcomes through changes to the urban environment. Frameworks for planning in cities should explicitly incorporate urban health goals and policies aimed at the improvement of urban health, as a signal to key decision makers of the importance of action

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for urban health. Fourth, policy makers at national and urban scales would benefit from undertaking a complexity analysis to understand the relations between interventions that affect the urban environment and urban health outcomes, identifying bidirectional relations of causality, feedback loops, and tensions between objectives, and being alert for the unintended consequences of their policies. And finally, progress towards effective action on urban health will be best achieved through local experimentation in a range of projects, supported by assessment of their practices and decision-making processes by practitioners. Such efforts should include practitioners and communities in active dialogue and mutual learning. Interventions such as impact evaluation and indicator sets should be used judiciously to strengthen such assessment.

Acknowledgments

We thank the very insightful and constructive comments made by Anne Johnson, Hugh Montgomery, David Satterthwaite, and four anonymous reviewers. We are also grateful for financial support from UCL Alumni and the Engineering and Physical Sciences Research Council Crucible Programme.

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Key messages

- Cities are complex systems, so urban health outcomes are dependent on many interactions
- The so-called urban advantage—whereby urban populations are, on average, at an advantage compared with rural populations in terms of health outcomes—has to be actively promoted and maintained
- Inequalities in health outcomes should be recognised at the urban scale
- A linear or cyclical planning approach is insufficient in conditions of complexity
- Urban planning for health needs should focus on experimentation through projects
- Dialogue between stakeholders is needed, enabling them to assess and critically analyse their working practices and learn how to change their patterns of decision making

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Panel 1: Key features of a healthy city[103]

- A clean, safe, high quality environment (including adequate and affordable housing)
- A stable ecosystem
- A strong, mutually supportive, and non-exploitative community
- Much public participation in and control over the decisions affecting life, health, and wellbeing
- The provision of basic needs (food, water, shelter, income, safety, work) for all people
- Access to a wide range of experiences and resources, with the possibility of multiple contacts, interaction, and communication
- A diverse, vital, and innovative economy
- Encouragement of connections with the past, with the varied cultural and biological heritage, and with other groups and individuals
- A city form (design) that is compatible with and enhances the preceding features of behaviour
- An optimum level of appropriate public health and care services accessible to all
- A high health status (both a high positive health status and a low disease status)

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Panel 2: The Slum Sanitation Programme in Mumbai, India

Mumbai's first sanitary sewer system was built in the 1860s. In 1979, a 25-year sewerage system masterplan was launched, establishing an infrastructure development strategy that consisted of a system of seven zones, each operating independently of one another. This plan was completed in 2004 and now encompasses more than 1500 km of sewers, with a total capacity of 2530 million L per day. The World-Bank-funded Mumbai Sewage Disposal Project is one of several projects launched under the plan.

Half of Mumbai's population of 11·2 million live in areas classified as slums (covering only 8% of the land area), most of which has poor access or no access at all to wastewater systems so that their residents have to use public toilets or defecate in the open. In these slums, the use of conventional water-based sewer-system infrastructure is ruled out by tenure insecurity, restricted space, and affordability considerations. Thus, an important component of the Sewage Disposal Project is the Slum Sanitation Programme (SSP). The largest programme of its kind in India, it seeks to provide access to adequate sanitation (one toilet per 50 people), by 2025, to one million people who were living in slums on municipal land in 1995.[131] The scheme is demand-driven and premised on participation, partnership, and cost recovery, the first of which was a prerequisite for World Bank funding (matched by the State Government). It builds on the idea that a sense of ownership encourages communities to maintain the toilet blocks more effectively than would the state.[132]

Construction of the toilet blocks was allocated to two private construction firms and one large local non-governmental organisation through competitive bidding. By mid-2005, the SSP had built 328 two-storey and three-storey toilet blocks with more than 5000 toilets, reaching an estimated 400 000 slum dwellers. Blocks are administered by local community organisations charging either monthly family fees or single-use fees. Fees cover regular maintenance, including water and electricity costs, with minor repairs done by the community, and the local authority undertaking major repairs. Some toilet blocks have also become community centres, providing space for teaching and meetings. Fees have allowed high standards of care to be maintained, but evidence exists that in some of the poorer settlements, only the wealthier families are able to pay the fees, with the remaining population still having to resort to open defecation.[132]

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Panel 3: Refurbishment for energy efficiency and indoor air quality in London, UK

There are 3·2 million dwellings in London,[168] almost all of which will need some modification to meet decarbonisation targets. The UK Government has a national CO_2 commitment of a 34% reduction by 2020 and 80% reduction by 2050 from 1990 levels. London has set itself an even more challenging target by requiring that existing emissions are reduced by 60% by 2025 from the 1990 level. A large proportion of these emission reductions is proposed to come from London's buildings.[169]

This huge scale of refurbishment presents enormous and complex challenges—in part because of the nature of London's buildings. This stock is not only diverse in its construction methods, which span several centuries, but also in ownership. The level of energy efficiency of the stock is also highly variable. Many properties have already undergone some energy efficiency refurbishments that are not, however, adequate for the 2050 commitment. Indeed, these moderately refurbished properties might provide the greatest retrofit challenge.

One of the key problems for retrofit policy is to ensure that greater energy efficiency does not compromise health. If energy efficiency is in part achieved though greater ventilation control (reductions in air exchange), ventilation might become insufficient to remove pollutants from indoor sources. Conversely, uncontrolled ventilation impairs protection against outdoor pollution. The optimum ventilation rate for buildings has not been adequately researched, but decarbonisation strategies are prescribing ever tighter ventilation controls. For example, in a mechanical ventilation with heat recovery (MVHR) system, warm, moist air is extracted from kitchens and bathrooms via a duct system and is passed through a heat exchanger before being released into the environment. Fresh incoming air is preheated by the exchanger and transferred to habitable rooms. Although offering substantial potential benefits, the very large scale installation of MVHR coupled with the very high degree of dwelling air-tightness that are needed for the effective use of such systems might be cause for concern if the systems are poorly installed, maintained, or operated. MVHR could also increase energy demand compared with passive ventilation systems. Consideration of the health effects arising from improved control over ventilation and associated changes in the ingress of pollution from outdoors will be essential—such pollution depends on other sectors such as transport and industry in the city.

Mitigation measures might affect health through a range of pathways, several of which are likely to be as important as the usual exposures, if not more important. Thus a wider array of pathways than has been attempted previously should be considered. Encouragingly, there is at least a growing recognition of the associated complexities, and, for example, relevant guidance for the Building Regulations for England and Wales is continually updating its treatment of building-material permeability and ventilation control.[170]

Panel 4: Governance and the built environment in Bogota, Colombia

Bogota, the capital city of Colombia, offers an interesting case of a city where the built environment has been actively transformed in an attempt to reduce car dependency and promote more physical activity among its residents. Throughout the 1990s and early 2000s, the city underwent substantial institutional and urban transformations that have caught the imagination of urban planners and managers in many low-income and middle-income countries.[204,205] A succession of city administrations led by charismatic mayors helped to strengthen city finances and introduced a series of measures to, among other things, reduce the use of private vehicles and promote use of public transport, cycling, and walking. Such measures—in a city with more than 7 million people and a high density of construction, few open spaces, substantial socioeconomic inequalities, high rates of both violence and fatal traffic accidents, and woefully inadequate finances—have been regarded as successful. However, these measures have fallen short of the needs of a population that has continued to grow, especially in view of the fact that the increase in the number of private vehicles (including motorcycles) far exceeds population growth, which is a good example of a positive feedback loop whereby growth of private vehicles has led to instability in the public transport system. And despite improvements, most of the adult population remains inactive, with only 44·7% meeting guidelines for physical activity, suggesting that more needs to be done.[206] An initiative launched in 1974, predating these administrations, is the Ciclovía Recreativa (traffic-free streets; figure 10), whereby street closures to motorised traffic for fixed periods on Sundays and public holidays are put in place.[207] This initiative has been associated with increased physical activity (eg, walking, cycling), although this activity tends to be more common in young middle-income and high-income men than it is in other social groups. Bogota's Ciclovía normally shuts 97 km of its streets, more than any other city in the Americas, at an annual cost of US$1·7 million to the city's finances. Between 600 000 people and 1·4 million people regularly use it to exercise, with 41% of adults participating for more than 3 h at a time. Every $1 invested (both by the city and by individuals) leads to an estimated net annual saving in health costs of between $3·23 and $4·26 per person.[205] Although associated with reduced emissions, these reductions have not been quantified, nor have their economic implications, which are likely to be positive.

Other measures have included urban and transport improvements associated with Transmilenio (figure 11), a mass-transit system that uses Bus Rapid Transit technology introduced in 2000, with dedicated lanes and fixed bus stations.[208] Covering 25% of daily public transport trips in 2010,[209] this system has not only reduced car use and average commuting times of its users, but has also prompted users to walk longer distances to stations than the system previously used whereby buses stopped wherever users asked them to do so. The physical improvements in pavements and public spaces introduced as part of the construction of the system have also encouraged greater use of these places by pedestrians.[210] Implementation of the system has also been associated with improvements in air quality by helping to reduce congestion, thus increasing average speeds, as well as by transporting more passengers in shorter times—an example of further feedback loops.[211]

Since 1998, the local government has created a 334-km cycle-path network (Ciclo-Rutas) that covers the city. But despite the existence of this network, only 2% of daily journeys are made by bicycle.[207] The reasons for such low use of the network has not been adequately researched, although anecdotal evidence points to perceptions of a high number of traffic deaths in cyclists, fear of crime, and lack of secure parking facilities for bicycles as deterrents. Walking is the main mode of daily transport for 12% of the

population, particularly those in lower socioeconomic groups (61·5% of those who walk for non-recreational purposes have only primary education).

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Panel 5: The urban heat island in London, UK

In August, 2003, a heatwave in the UK provided a striking example of how vulnerable large cities can be to heat. This heatwave was associated with at least 600 excess deaths (the number of recorded deaths minus the number of expected deaths) in London alone. This was part of a much larger European effect; the urban heat island effect seems likely to have contributed to this burden in many major cities. However, London also has a substantial burden of cold-related morbidity and mortality, and the urban heat island effect might in part help to reduce it during the winter.

Modelling work undertaken in the LUCID project[225] suggests a temperature differential of 5°C between the centre of London and outlying rural areas. Such concentration of heat in urban areas, or urban heat island intensity, is not uncommon. In monitored data, heat intensities for London of up to 10°C have been recorded. What effect this heat has on health is not accurately known. However, for May-June, 2006, when the maximum daily temperature in London was about 0·45°C warmer than in surrounding areas, an estimated 40% of London's heat deaths could be attributed to the effect of the urban heat island.[228] This finding should be interpreted as only a very approximate estimate that will also vary substantially from period to period and between settings.

During the past decade, efforts in London to analyse the importance of building characteristics on indoor temperatures suggests that the combined effect of built form, geometry, and thermal quality of a building might be of greater importance for overheating than is the location of the building in the urban heat island effect.[228,229] The proper adaptation of buildings will therefore also provide enhanced protection to heat via direct modification of the indoor environment. Thus attempts to offset projected increases in temperature should integrate external and internal strategies. Evidence suggests that if cities have more intense heatwaves in future, strategies to help to reduce the urban heat island effect might be an important focus for urban development policies. However, such strategies have to be done in conjunction with policies for building design for the greatest health benefits.

In London's climate-change adaptation strategy, specific reference to heat islands as a cause for concern is made, especially their ability to exacerbate heatwaves and their associated health effects.[230] The strategy identifies a series of measures to manage the urban heat island effect at various urban scales (ie, city-wide, neighbourhoods, and individual buildings), including a possible Urban Heat Island Action Area, where green space and vegetation will be increased and major new developments would need to meet specific requirements to reduce their effect on the urban heat island.

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Panel 6: Food production in Havana, Cuba

After the 1989 collapse of the Soviet Bloc, from which Cuba imported most of its food, Cuba developed a state-supported sustainable urban agriculture infrastructure. The sudden loss of petroleum, machinery, and fertilisers severely affected local food production, distribution, and even refrigeration, compounding the immediate food shortage. In response, the Cuban government adapted city laws, granted basic units of cooperation production (ie, rights over previously state-owned land),[244] and declared indefinite free right to public land to cultivate food production for a starving population. In Havana, the inhabitants converted patios, rooftops, and unused parking lots into productive vegetable allotments, and reared livestock in a collective effort. The land was cultivated with manual labour and organic waste. The Cuban Ministry of Agriculture also initiated networks of so-called extension agents,[245] mainly local women, to educate urban cultivators in methods of permaculture, composting, and the use of biological pest control. Such control methods included the use of repellent plants such as marigolds to keep pests away because chemical pesticides were outlawed within the city. Permaculture enabled a sustainable high-yielding ecosystem and increased biodiversity. Co-operatives were established, owned, and managed by city dwellers, encouraging the trade of other scarce items such as seeds and tools. Local kiosks were set up as farmers' markets in every community, trading local provisions and eliminating the need to travel and reducing the carbon footprint. Cuba now grows 90% of its fruits and vegetables, with 4 million tonnes of vegetables every year from urban allotments in Havana alone.[246]

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Panel 7: Urban agriculture in Accra, Ghana

In 1972, Ghana's food movement, called the Feed Yourself Operation (FYO), initiated city dwellers in Accra to farm in enclosed gardens around their homes and on the edges of cities. In Accra, poor people in urban areas and rural migrants to urban areas often engage in open-space food cultivation without official access on undeveloped community land belonging to central and municipal governments, including irrigation, railways, and aviation authorities, as well as parks and university campuses. At no cost to the city, the benefits of urban agriculture extend beyond the planting of greenery and management of public spaces; it reduces refuse dumping and illegal drug-related activities. Furthermore, there have been calls to recycle the mounting daily municipal organic waste for urban agriculture and discourage the use of artificial fertilisers by the uninformed cultivators.[247] In Accra, most urban cultivators are men, although urban agriculture in Africa is a successful form of self-employment for women[248] because it allows women to cultivate while undertaking other household and parental responsibilities. For Ghanaian families, urban agriculture is an important income-diversification strategy that supplies months of staple food for the family. Despite the socioeconomic and environmental benefits, Ghanaian policy makers and municipal government have yet to reassess their urban land-use planning regulations to address issues of land tenure and security to support urban agriculture.[249] This oversight is typical of most cities in low-income countries and draws attention to the need for urban agriculture to be at the heart of urban planning and urban health efforts, as well as the importance of the integration of policies for formal and informal institutions.

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Panel 8: Strategies to support urban initiatives—green infrastructure in Toronto, Canada

A substantial body of research shows that the planned provision of green infrastructure supports good physical and mental health through the reduction of air pollution and heat stress, and the provision of opportunities for physical activity, social encounters, and engagement with nature.[275-278] Toronto provides a good example of how urban planning can deliver such infrastructure. Toronto is known as "a city within a park",[279] with 12% of its surface devoted to green space and about 1500 parks. Furthermore, there are 187 km of bike paths, 7·8 km of pedestrian paths, and 3 million publicly owned trees, providing 17% canopy cover.[280] Diabetes in Toronto has been reduced in areas with parks and other spaces conducive to physical activity.[281]

Although Toronto's physical geography readily supports vegetation, its green infrastructure is also a result of a proactive and opportunity-alert local government policy. First, flooding during Hurricane Hazel in 1954 led the City to acquire substantial floodlands, increasing their extent from 0·67 km^2 in 1953 to more than 80 km^2 in 1999; this increase provided an opportunity for health and flood protection to go hand-in-hand, with the green space providing space for exercise as well as an urban drainage feature, soaking up excess rainfall. Second, deindustrialisation produced another opportunity through substantial brownfield land (sites of abandoned or underused industrial and commercial facilities), which the City was proactive in converting to parkland as part of its regeneration policy during the 1990s; 14 separate brown-to-green projects generated 6·14 km^2 in this period.[282] Additionally, the Water Regeneration Trust was charged with improving access to and use of the Lake Ontario waterfront with the benefit of CAD $10·5 million investment.

This approach aims to plan for full coverage of green infrastructure across the city and across different social groups; green spaces have also been planned for usability by less physically able people, children, women, and ethnic groups. Additions to green infrastructure are set within an overarching and enabling policy that identifies different green spaces as meeting needs at different scales: local parkland consisting of parkettes (a locally coined term to describe small parks) and local parks; and city-wide parkland, which is consists of district parks and city parks. However, assessments have shown that provision of green infrastructure is still lowest in low-income areas and for elderly people in Toronto.[283]

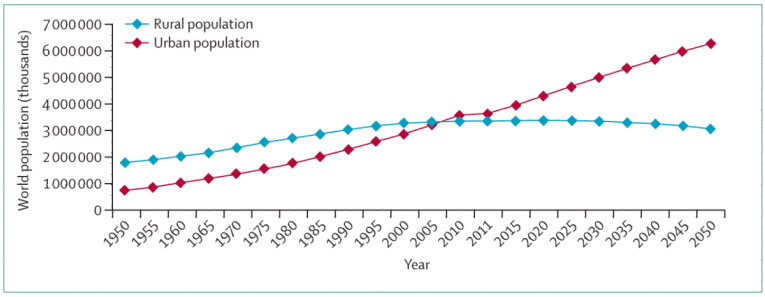

Figure 1. World population growth, 1950-2050
Data are from reference 3.

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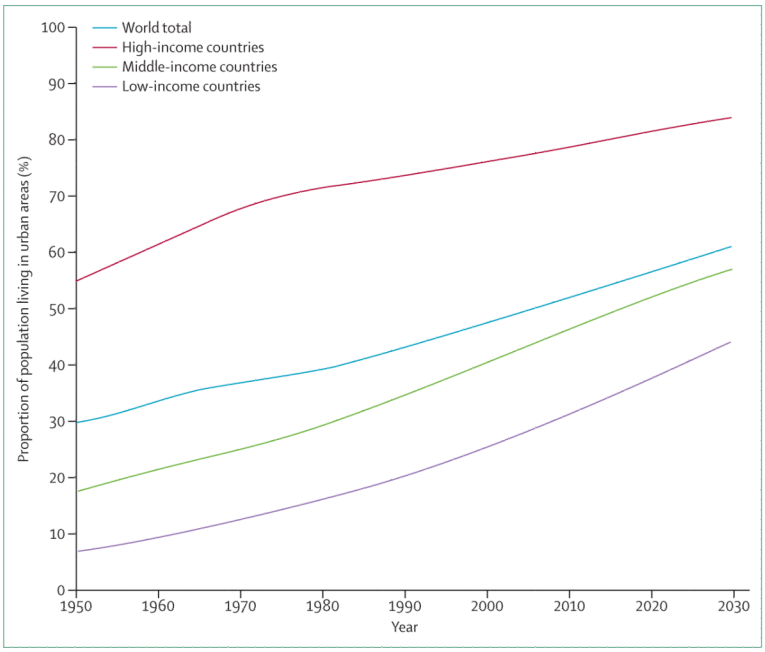

Figure 2. Proportion of the world population living in urban areas
Data are from reference 4.

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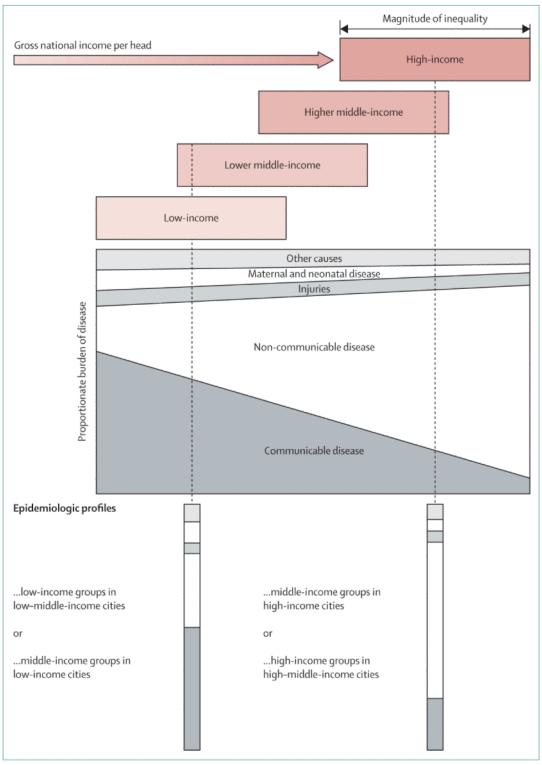

Figure 3. Burden of disease in cities and in groups within cities

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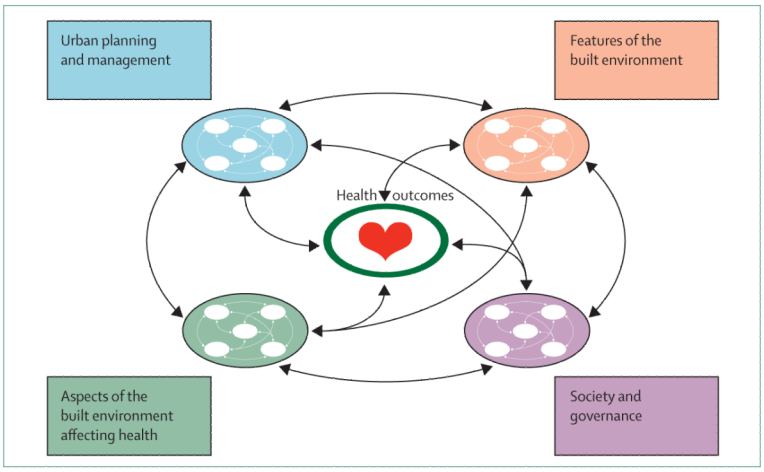

Figure 4. Health problems in different urban contexts

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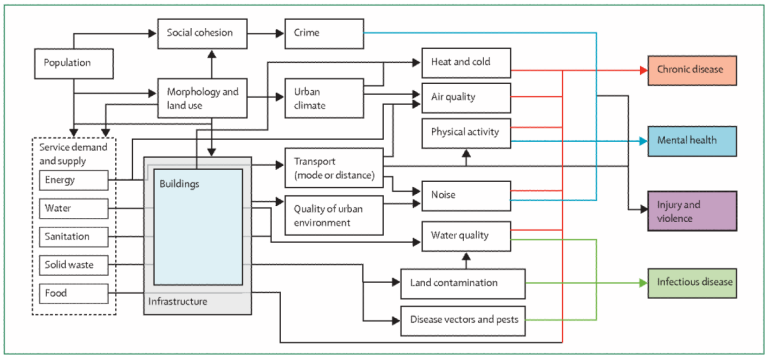

Figure 5. Health outcomes and the urban environment: connections

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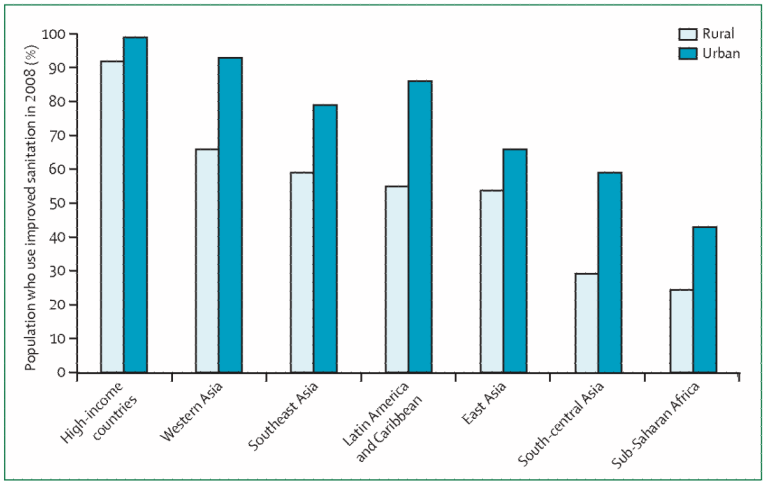

Figure 6. The urban-rural divide in access to improved sanitation, 2008
Data are from reference 129.

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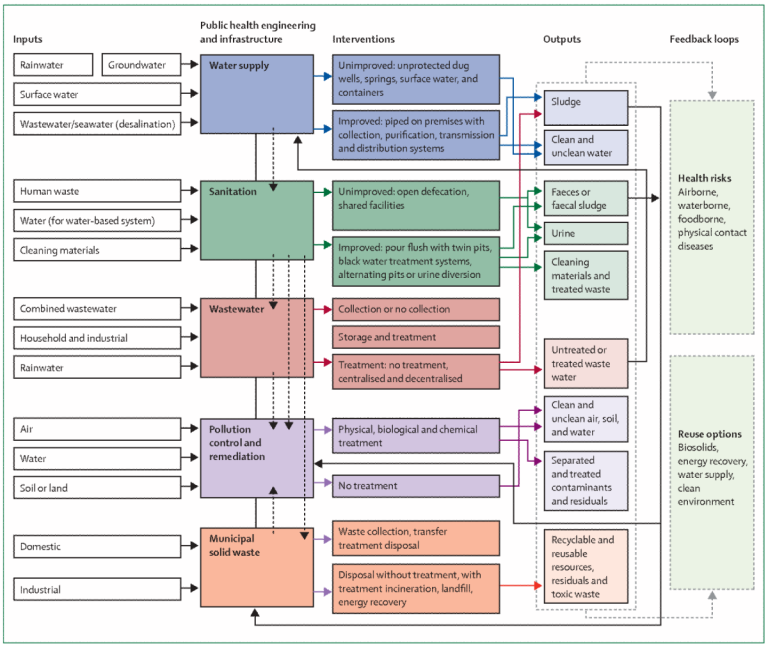

Figure 7. Connections between urban sanitation and wastewater treatment

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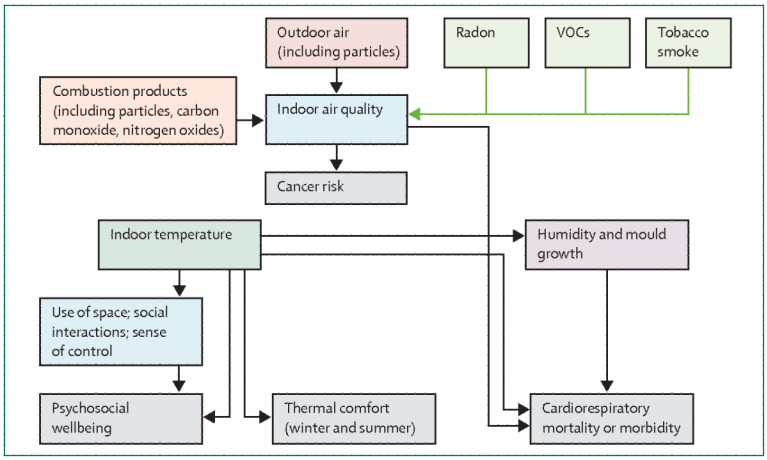

Figure 8. Connections between the built indoor environment and health

VOC=volatile organic compounds. Reproduced with the consent of Wilkinson and colleagues.[33]

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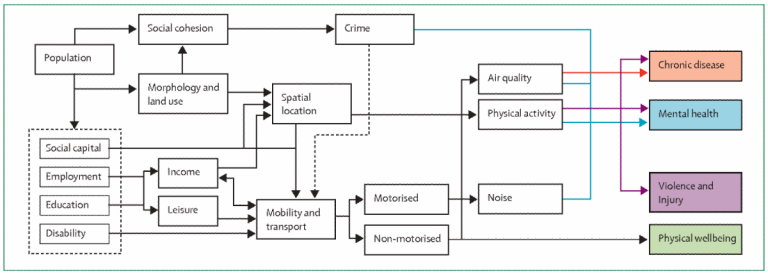

Figure 9. Urban connections between transportation and health

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Figure 10. Bogota's bicycle path (C*iclorutas*) network

Figure 11. Bogota's *Transmilenio* Bus Rapid Transit system

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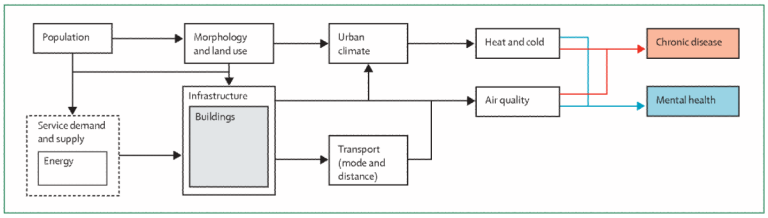

Figure 12.
Connections of the urban heat island and health

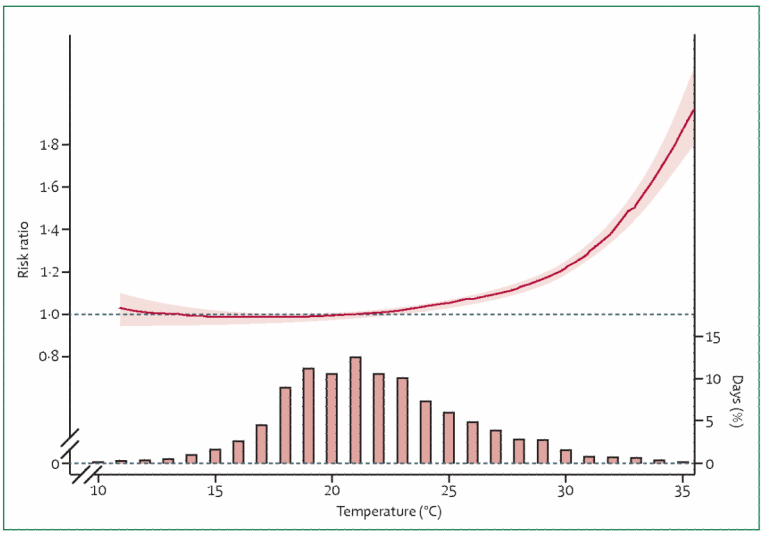

Figure 13. The association between temperature and mortality in London

Temperatures are 2-day maximum temperatures after adjustment for potential confounders. The shaded area shows the 95% CIs. Data are from reference 219.

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Figure 14. City centre farming

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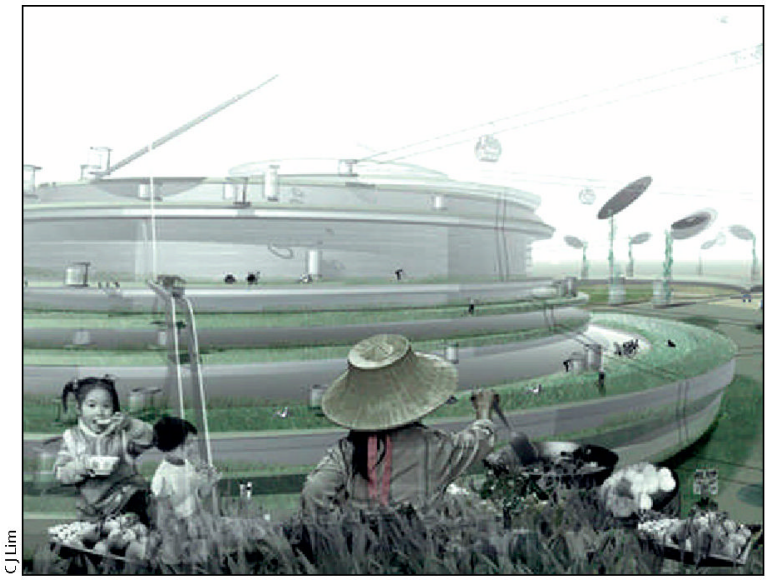

Figure 15.
A visionary plan for Guangming Smartcity, China

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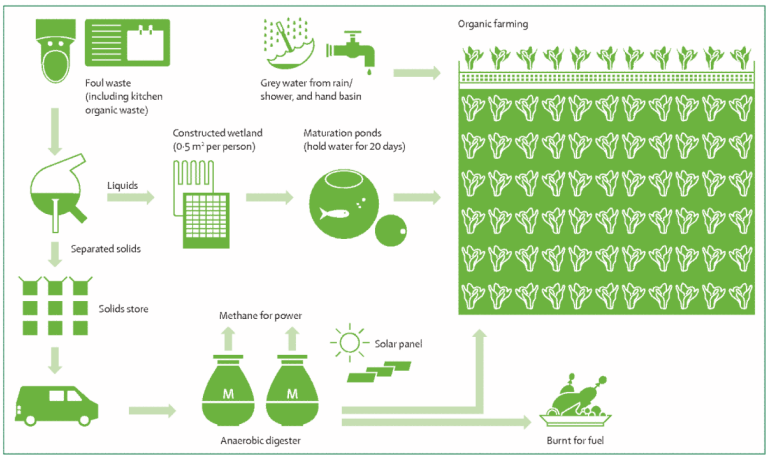

Figure 16.
The creation of a virtuous cycle of connections with urban agriculture

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