



The significance of urban systems on sustainability and public health

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SPECIAL COLLECTION:
URBAN SYSTEMS FOR
SUSTAINABILITY AND
HEALTH

EDITORIAL

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HIGHLIGHTS

Urban areas are highly complex systems, with interconnections between their political, economic, social, natural and built environments components, and each with its own unique priorities and contexts. They are also facing key global and local sustainability challenges such as a changing climate, air pollution and waste, all of which also present risks for population health. Improving urban sustainability can provide co-benefits for population health; however, the effectiveness—or unintended consequences—of policies or actions can depend on the behaviours and relationships in the wider urban system. The papers published in this special issue explore issues related to urban sustainability and health, including urban design and environmental justice, scale, and informal settlements. The papers also describe issues at the interface of different system components, demonstrating the systemic challenges that can act to enhance or prevent sustainable change. The complexity of urban environments presents challenges for research and policy, both of which can be reductive, and conducted independent from other disciplines or government departments. However, by moving from this siloed approach towards a broader systemic understanding, there are opportunities to develop and implement evidence-based solutions that have the potential to lead to significant improvements in sustainability and health.

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1. INTRODUCTION

The world is faced with complex interacting environmental, social, health and political challenges, which are increasingly dynamic. Traditionally, these challenges have been seen as discrete problems, to be dealt with by separate organisations with different institutional rules, competing for resources and agency. The call to researchers in this special issue was to urgently identify systemic interventions to these challenges, where the potential for generating co-benefits in health and wellbeing could be realised and replicated.

Human-induced climate change is one of the major challenges facing cities. There has been an increase in global mean temperature of 1°C above the pre-industrial average (Haustein *et al.* 2017), and seven of the hottest years on record have occurred since 2014 (NCEI 2019). At the current rate of greenhouse gas (GHG) emissions, children born today could live in a world 3°C warmer than the pre-industrial average (Watts *et al.* 2019). Additional environmental concerns include accelerating levels of GHGs, pollution, loss of biodiversity, as well increasing use of land and resources. Compounding these environmental challenges are interrelated social sustainability challenges, which include growing inequity in access to safe, secure, affordable housing, adequate income, and secure assets. These inequities have a marked impact on social cohesion, fairness and justice both locally and internationally (Dempsey *et al.* 2011).

These sustainability challenges have significant implications for the environment, as well as human health and wellbeing. The rapidly changing climate poses significant risks for food security, water availability, disease transmission and exposure to extreme events such as flooding and fires (Watts *et al.* 2019). Exposure to high temperatures and extreme heat can lead to increased morbidity and mortality from heat stress and heatstroke, as well as increases in cardiovascular and respiratory diseases (Guo *et al.* 2014; Ebi *et al.* 2021). A recent study has estimated that, between 1991 and 2018, 37% of global heat-related deaths could be attributed to manmade climate change (Vicedo-Cabrera *et al.* 2021). Exposure to air pollution has been associated with cardiovascular and respiratory diseases (Arden Pope *et al.* 2011; Atkinson *et al.* 2013), birth defects (Padula *et al.* 2013), poor mental health (Braithwaite *et al.* 2019; Horsdal *et al.* 2019), and cognitive function (Delgado-Saborit *et al.* 2020). Globally, an estimated 7 million deaths from cardiorespiratory diseases are attributable to indoor and outdoor air pollution annually (WHO 2018a).

Exposure to these environmental hazards is not equally distributed across the global population. Developing countries are facing the greatest risks from the changing climate, and are also the most vulnerable to its impacts (Watts *et al.* 2019). Cumulative socio-economic disadvantages mean low-income populations in urban areas worldwide are more likely to be exposed not only to higher levels of outdoor (Brainard *et al.* 2002; Fecht *et al.* 2015; Brunt *et al.* 2017; Milojevic *et al.* 2017; Tonne *et al.* 2018) and indoor air pollution (Ferguson *et al.* 2020), but also in summertime to both outdoor (Mitchell & Chakraborty 2015; Macintyre *et al.* 2018) and indoor temperatures (Lomas *et al.* 2021). Low income and marginalised communities are disproportionately affected by climate change because they lack the financial resources to choose safe locations, or to adapt to the changing climate (Baker 2012). Higher rates of underlying health issues in low income populations can exacerbate poor health outcomes. The young, old and those suffering from chronic diseases or disabilities are at greater risk.

Transformative changes are necessary to mitigate threats to global sustainability and population and planetary health to protect ‘the health of human civilisation and the state of the natural systems on which it depends’ (Whitmee *et al.* 2015: 1978). Indeed, actions to improve sustainability can provide important co-benefits for human health, wellbeing and equity (Giles-Corti *et al.* 2016). Cities are critical arenas for making these changes because they are home to an increasing majority (54%) of the global population and economic activity (85% of gross domestic product—GDP) (UN 2018). Cities also have a significant impact on global sustainability, with a disproportionate share of global energy (60–80%) and resource consumption (75%) and they emit around 70% of global GHG emissions (UNEP 2013). Therefore, it is essential that urban areas reduce their environmental footprints and increase their resilience to environmental hazards, while protecting and promoting planetary health.

Urban policies and sustainable development have significant—but largely unrealised—potential to improve population health and wellbeing (Kleinert & Horton 2016). While it is increasingly common for urban planners to consider the environment, as well as health and wellbeing, much of the recent global increase in urbanisation in the Global South has occurred with little attention being paid to these issues. Such omissions can have serious long-term consequences, because building and urban design have environmental ‘lock-in’ effects for both embodied and operational carbon (Ürge-Vorsatz *et al.* 2018).

1.1 COMPLEXITY

The key research challenge is the complexity of urban environments. Cities are complex systems (Siri 2016) characterised by multiple, connected elements and interdependencies between various factors, *e.g.* greenspace, urban density, populations, housing, transport, water and sanitation, waste, air quality, health systems, and city governance. The interactions, relationships and dependencies between these various components of the urban system can determine systemwide properties, as well as the progress, resistance and unintended consequences of actions to improve sustainability and health (Gatzweiler *et al.* 2018).

Complex systems are composed of multiple interacting elements. These interactions, which can include dependencies, competitions and various feedback loops, make complex systems difficult to model, meaning that changes to the systems can be unpredictable and lead to unintended consequences; conversely, there may also be the possibility to identify counterintuitive solutions for key challenges. Cities are good examples of complex socio-ecological systems, with interdependencies between political, economic, social, natural and built environments components—each consisting of its own nested subsystems. Successful implementation strategies to improve health and sustainability need to account for these complex interactions between the different elements of urban systems.

Solutions to urban problems are therefore co-dependent and interconnected. As described above, the co-benefits to health from improving sustainability discussed above are relatively clear when examining causal relationships. However, the complexity can lead to unintended consequences. As an example, energy efficient retrofit of housing provides benefits for reducing GHG emissions, improving mental health and lowering exposure to cold; however, if done improperly, it may increase the risks from indoor air pollution, damp or summertime overheating (Shrubsole *et al.* 2014; Lomas 2021). Converting a neighbourhood to a low traffic zone may cause about half of the traffic to divert to other routes, leading to exposure disparities in outdoor air pollution level (Goodwin *et al.* 1998). Consequently, basing models or policies intended to improve urban health and sustainability on evidence from reductive studies may lead to different outcomes than intended.

In this new urban focus, scholars have called attention to the complexity of the factors affecting sustainability and health in cities (Gatzweiler *et al.* 2018) and the potential for policy instruments that support co-benefits for social, economic and environmental outcomes (Dora *et al.* 2015).

1.2 OBJECTIVES FOR THIS SPECIAL ISSUE

This special issue provides evidence on how to achieve the transformation changes in urban areas to address these population and planetary health challenges. There is an intended emphasis on the roles and connections between different elements of the urban system. For example, the special issue call was for research articles that increased understanding of how to use research evidence, in collaboration with the public and decision-makers, to promote sustainable and healthy pathways of development and to track progress towards the Sustainable Developmental Goals (SDGs). The overall objective was to provide evidence on how to achieve the necessary transformative change in urban areas that meet sustainability goals and improve population health, while taking account of the interactions between different components of complex urban systems.

A total of 10 papers were selected from 22 contributions from Bangladesh, China, Finland, France, India, Kenya, New Zealand (Aotearoa) and the UK (**Table 1**). These papers use a range of research methods for understanding the interactions and interfaces between different elements of urban systems, and their impact on health and sustainability, across a range of spatial scales and developmental contexts. Half the papers selected arise from the Wellcome-funded Complex Urban Systems for Sustainability and Health (CUSSH) project, a transdisciplinary programme that developed ‘action’ and ‘change’ models which have been carried out by a consortium of research partners in London (UK), Rennes (France), Nairobi and Kisumu (Kenya), and Beijing and Ningbo (China). Other papers are from researchers independently answering the invitation to submit papers to this special issue.

In this editorial, these papers are placed in a wider discussion of the complexity in the built environment, which highlights the importance of research-based decision-making in urban systems. As expected, the special issue reveals gaps in our knowledge and practices, and uncovers different practices in urban governance and public health internationally. In addition, we describe how sustainable and healthy development relies on transdisciplinary collaboration between experts and actors within the urban systems, and how this presents key challenges for the academic community, governments, communities and real estate sectors.

Table 1: Articles in this special issue ‘Urban Systems for Sustainability and Health’, *Buildings & Cities* (2021), 2(1); guest editors Jonathon Taylor & Philippa Howden-Chapman.

Note: ^aPapers in the Complex Urban Systems for Sustainability and Health (CUSSH) transdisciplinary programme.

AUTHORS	TITLE	DOI
J. Taylor & P. Howden-Chapman	The significance of urban systems on sustainability and public health	https://doi.org/10.5334/bc.181
N. Mohajeri, A. Walch, A. Gudmundsson, C. Heaviside, S. Askari, P. Wilkinson & M. Davies	COVID-19 mobility restrictions: impacts on urban air quality and health ^a	https://doi.org/10.5334/bc.124
L. Ferguson, J. Taylor, K. Zhou, C. Shrubsole, P. Symonds, M. Davies & S. Dimitroulopoulou	Systemic inequalities in indoor air pollution exposure in London, UK ^a	http://doi.org/10.5334/bc.100
R. Chapman & P. Howden-Chapman	Does reframing urban policy around wellbeing support carbon mitigation?	http://doi.org/10.5334/bc.115
C. Deloly, A. Roué-Le Gall, G. Moore, L. Bretelle, J. Milner, N. Mohajeri, D. Osrin, G. Salvia, P. Symonds, I. Tsoulou, N. Zimmermann, P. Wilkinson & M. Davies	Relationship-building around a policy decision-support tool for urban health ^a	https://doi.org/10.5334/bc.110
H. Pineo, K. Zhou, Y. Niu, J. Hale, C. Willan, M. Crane, N. Zimmermann, S. Michie & Q. Liu	Evidence-informed urban health and sustainability governance in two Chinese cities ^a	http://doi.org/10.5334/bc.90
C. Turcu, M. Crane, E. Hutchinson, S. Lloyd, K. Belesova, P. Wilkinson & M. Davies	A multi-scalar perspective on health and urban housing: an umbrella review ^a	https://doi.org/10.5334/bc.119
C. Goodess, S. Berk, S. B. Ratna, O. Brousse, M. Davies, C. Heaviside, G. Moore & H. Pineo	Climate change projections for sustainable and healthy cities ^a	https://doi.org/10.5334/bc.111
A. Joutsiniemi, M. Vaattovaara & J. Airaksinen	Empowered by planning law: unintended outcomes in the Helsinki region	https://doi.org/10.5334/bc.116
J. Fernandez Gonzalez & A. Gongal	Unidirectional pedestrian circulation: physical distancing in informal settlements	http://doi.org/10.5334/bc.113
S. A. Urme, M. A. Radia, R. Alam, M. U. Chowdhury, S. Hasan, S. Ahmed, H. H. Sara, M.S. Islam, D. T. Jerin, P. S. Hema, M. Rahman, A. K. M. M. Islam, M. T. Hasan & Z. Quayyam	Dhaka landfill waste practices: addressing urban pollution & health hazards	http://doi.org/10.5334/bc.108

2. DIMENSIONS OF URBAN COMPLEXITY

2.1 URBAN DESIGN AND ENVIRONMENTAL ISSUES

There has been considerable attention in recent years to unequal environmental burdens using evidence from various cities around the world, including air and noise pollution, and levels and placement of waste disposal sites. Much of the existing work has been framed in terms of environmental justice, or the presence of unequal environmental burdens between socio-economic groups. It is only relatively recently that environmental burdens have been framed as a systematic inequality, where the embedded systems—such as the design of urban environments—act to

burden certain groups disproportionately (Klinsky & Mavrogianni 2020; Tessum *et al.* 2021). As more deprived communities typically have less economic and political power, they often receive less attention and fewer resources from government institutions compared with more affluent neighbourhoods (Corburn 2017).

Mohajeri *et al.*'s article 'COVID-19 mobility restrictions: impacts on urban air quality and health' uses a natural experiment promoted by the COVID-19 restrictions on travel to measure the impact on outdoor air pollution in four UK cities (Greater London, Cardiff, Edinburgh and Belfast). They found that the COVID-19-related mobility restrictions resulted in the most extensive changes to outdoor air pollution (concentrations of PM_{2.5} and NO₂) related to human behaviour ever recorded. A weather-corrected machine-learning technique identified that, relative to the previous year, all these cities had lower concentrations of pollution compared with those expected. The authors attributed these lower levels of air pollution to the mobility restrictions imposed by the pandemic lockdown. They also showed a significant correlation between the lowering of ambient NO₂ and reduction in public transport and driving, which provided empirical evidence of ways to reduce air pollution. The results show that the unintended consequences of lockdown were reducing motor traffic air pollution, and if these reductions can be produced by other interventions, such as the promotion of well-designed urban design and the promotion of walking and cycling and local availability of amenities, these policies can substantially reduce long-term air pollution and thus have positive health impacts. In London, air pollution reductions were greatest in low income areas (Kazakos *et al.* 2021), which indicates that such interventions may disproportionately benefit the most deprived communities.

The paper by Ferguson *et al.*, 'Systemic inequalities in indoor air pollution exposure in London, UK', synthesises evidence to show the factors that lead to unequal burdens of indoor air pollution exposure in London. Exposure to indoor air pollution is dictated by various factors such as housing location and outdoor air pollution, maintenance by landlords, overcrowding, and the behaviour of neighbours. This paper provides evidence for how many of these factors are biased towards increasing exposure to indoor air pollution in low income households. By using a systems thinking framework, the paper then shows how environment, housing, behavioural and health factors all contribute to elevated indoor exposures to air pollution in low income communities, and many of these drivers are outside the direct control of the residents. These results are consistent with previous studies that indicate that individual interventions are unlikely to reduce overall exposures, and efforts to reduce exposure disparities need to address a number of these issues within the wider system (Jennings *et al.* 2021).

While Ferguson *et al.* explored issues of air pollution exposures, they note that many of the same factors that drive these exposure inequalities may also be relevant to other environmental burdens, such as noise and inadequate housing in general. For example, Grenfell Tower, which was comprised of predominantly social housing and situated in a London borough where one-fifth of children live in income-deprived households (Shildrick 2018), was rapidly consumed by fire in 2017. The initial findings of the inquiry into the causes of the fire were released in October 2019 and stated that inappropriate cladding on the building's outer facade was primarily responsible for enabling the fire to spread (Moore-Bick 2019). However, poor housing standards, poor enforcement and neglect of local infrastructure such as fire engines with extension ladders which could reach the top of apartment buildings were also part of the systemic failure, as well as the inability of local councils to learn from such failures elsewhere (Werna *et al.* 2020). The effects of inadequate housing can be measured as potentially avoidable hospitalisations and mortality in the most vulnerable subgroups of the population. With appropriate governance structures to ensure that good standards are promulgated, evaluated and maintained, social or public housing can potentially overcome many of these risks and demonstrably improve the health status of tenants.

In New Zealand, the government has established wellbeing as a policy framing, which, aligned with the critical issue of climate change mitigation, is influencing many aspects of public policy. Highlighting elements of wellbeing, such as co-benefits rather than trade-offs, aligns with the SDGs and is moving the policy debate away from economic growth alone towards a broader agenda

where managing environmental, social and health crises (such as COVID-19), decarbonisation, and housing affordability have more prominence. Chapman and Howden-Chapman's paper 'Does reframing urban policy around wellbeing support carbon mitigation?' describes a comparative study of seven public housing providers whose tenants can all access income-related rents capped at 25% of the households' incomes. The relative impacts of different governance structures, finance, tenant support strategies, scale and quality of housing, embodied carbon and surrounding community regeneration are compared within a broad wellbeing framework adopted by the central government. Public housing is studied in the context of neighbourhood amenities, such as the availability of public transport and opportunities for active journeys. Evidence is being gathered by direct monitoring of the indoor environment, surveys and use of the integrated data infrastructure, which under strict rules enables access to citizens' contact with all government services, as well as modelling to calculate carbon emissions. The interdisciplinary research team is co-designing the study with the public housing providers and results will be available to both parties during the course of the study.

A descriptive paper by Deloly *et al.*, 'Relationship-building around a policy decision-support tool for urban health', also examines framing and collaborative research as a way of increasing the effectiveness of urban policy by increasing trust between researchers and policymakers to address climate change urgently. The aim of this research in Rennes, France, was to focus research on engaging with policymakers to provide evidence on the health and GHG impacts of policies related to buildings, transport, energy and waste. A quantitative policy decision-support tool, the Cities Rapid Assessment Framework for Transformation (CRAFT), was designed to communicate evidence on the relative effectiveness of public policies towards achieving health and sustainability goals. Using an ethnographic approach, the authors describe the development of the relationship between stakeholders over a period of four years, centred around the CRAFT tool as a boundary object. While the tool itself was met with scepticism, the authors they felt that it still laid the foundations for relationship-building across siloed activities, so-called 'boundary scanning', which has the potential to link science to action.

Pineo *et al.* undertook in-depth qualitative interviews, through translators, with Chinese officials in their paper 'Evidence-informed urban health and sustainability governance in two Chinese cities'. Their research also takes a comparative approach by looking at the local 'cultures of evidence use' of health and sustainability policies in Beijing and Ningbo. The officials interviewed described formal rules and processes, where central state planning determines the overall scope of development, which explicitly balances economic and environmental factors. For example, the Healthy China 2030 strategy links a healthy population with a healthy environment, but this direction is interpreted differently by tiers of government. Economic growth, such as large housing developments, whether or not required, are often tied to promotion at city levels. While the researchers found academic evidence was influential, particularly when commissioned by government departments, public opinion arising from the media, e.g. identification of contamination that could affect children, as well as government economic priorities also influenced the use or weight of evidence in policymaking. They concluded that the majority of scientific evidence produced or commissioned by government was related to risk factor and disease monitoring to inform urban health and sustainability policy. Environmental governance could be strengthened in these settings through increased cross-sector data-sharing and integration of diverse knowledge types. However, while environmental and health data were transparently used for monitoring policy implementation, the method of setting policy targets was not clear. Nonetheless, a strength of China's approach is routine data collection that feeds a monitoring and policy cycle rarely achieved elsewhere. This cycle provides feedback to government departments, allows policy adjustment over time and can inform decisions during crises.

2.2 QUESTIONS OF SCALE

How the urban built environment impacts human health at different geographical scales—buildings, neighbourhoods, the city, regional and planetary levels—is crucial for framing research on policy-relevant issues. Turcu *et al.* focus on this important issue in their paper 'A multi-scalar

perspective on health and urban housing: an umbrella review' and highlight that taking this perspective of the built environment enables a comprehensive view of how housing and health interventions can be implemented more efficiently and effectively by adopting the World Health Organization's (WHO) housing and health guidelines (WHO 2018b). Most of the articles in this review of reviews included research from high income countries, the UK, Europe and North America; few were from low income countries. Most of the research is focused not on buildings, but on the determinants of health at the neighbourhood level, such as greenspace, physical and socio-economic conditions, transport infrastructure and access to local services. Moreover, the main emphasis in the reviews is on physical health and individual behavioural outcomes, although they note an emerging interest in mental health outcomes. This review confirms that, as with most of the papers included in this special issue, there is surprisingly little evidence emerging on interventions that take account of planetary health outcomes beyond a growing awareness of GHG emissions and climate change. The authors note that these significant gaps pose difficulties for conceptualising the relationship between health and the urban built environment, particularly when seeking to design and implement actions to protect and improve health.

Goodess *et al.*'s paper 'Climate change projections for sustainable and healthy cities' explores how cities can use detailed models of projected climate change to develop environmental and health policies. The authors reviewed a 'cascade' of climate models of increasing complexity and resolution as a way of constructing climate projections for global climate models of a few hundred kilometres, regional climate models of 12–50 km and convection-permitting models at 1 km resolution. The focus in this paper is on the hazard, *i.e.* climate variability and change including extreme events, and the urban heat island effect. The city-region projections developed for the CUSSH cities provide the basis for a qualitative description of potential changes in climate under two different emissions scenarios and enable comparisons and assessment of potentially suitable city interventions. The high-resolution model of urban climates can be used to study urban heat islands and adjust, for example, the effects of urban canyons and green infrastructure, such as tree canopies and green roofs, which can help to identify ways to improve comfort by reducing heat stress and the mortality associated with increasing heat. The authors acknowledge that generalising from one city to another can be problematic, but conclude that tailored climate projections for specified cities, combined with similarly tailored health impact models, can contribute to an evidence base to ensure designs for buildings and urban areas can adapt to future climates. They highlight that future models need to engage with the complex social, political, cultural and environmental factors that affect climate adaptation policies in cities, including historical policies that may have contributed to inequitable exposures to heat, flooding and other environmental risks.

The paper by Joutsiniemi *et al.*, 'Empowered by planning law: unintended outcomes in the Helsinki region', analyses planning in Finland and highlights how positive aims and promised designs and plans can be diluted by the planning process. The authors show how changes in the legislation governing planning, rather than enabling the implementation of important urban policies, instead empower and prioritise the role of institutional needs, so that the previously specified outcomes are not achieved. Three scalar levels are analysed: the development and crucial boundary conditions of planning-related legislation; the structure of urban development within the region; and a case study of the 30-year development of an orbital light-rail project. In contrast to traditional accepted planning practices in the literature, such as the benefits of involving stakeholders, this has not led to clear positive changes in the process and implementation. Indeed, this research shows how institutional stakeholders are indeed empowered in current planning practice, but the attempt to make planning more inclusive and participatory has paradoxically led to the empowerment of institutional players at the cost of focused implementation of the desired policies. The actual outcomes of the planning process are side-tracked, and the evaluation is outsourced in the process, which subsequently calls into question the legitimacy of planning actions. The authors highlight the need for planning-related studies to address the legislative boundaries, the concrete outputs of the planning process and predetermined responsibility for evaluating the policies, if progress is to be made on the defined urban planning goals.

Rapid urbanisation led to a realisation that urban infrastructure, both below and above ground, was critical for population health. By contrast with the previous articles cited in Organisation for Economic Co-operation and Development (OECD) countries, Gonzalez and Gogol's paper 'Unidirectional pedestrian circulation: physical distancing in informal settlements' proposes a theoretical solution to how people living in crowded informal settlements, estimated to be 1 billion (UN 2021), can rapidly protect themselves during epidemics and pandemics such as COVID 19, where the regular advice on social distancing is completely impractical in environments with few permanent buildings and little infrastructure (Corburn *et al.* 2020). Informed by the historical urban origins of graph theory, where orientations (or directions) are assigned to edges, the authors propose using a flexible method for mathematical modelling, the so-called Cluster Lane Method, which acknowledges that people want to be part of neighbourhood spatial clusters, where having contact between other people is a vital function. This technique draws on new notions and theorems in graph theory for oriented graphs, which entails turning a planar circulation network—here, the public circulation lanes—of any size or complexity into a network of unidirectional lanes. Conceptually, the authors make the case that this would make physical distancing possible in narrow circulation spaces by limiting face-to-face interactions. They explore the opportunities and challenges of implementing this cost-efficient, low-tech potential solution and propose that by involving the people living in the informal settlement throughout the process, this would help to improve the orientations of the lanes around, within and between clusters of dwellings. Furthermore, distinctively patterned unidirectional tactile paving could be designed and laid, which could clearly signal the assigned direction of a lane to the visually impaired.

The paper by Urme *et al.*, 'Dhaka landfill waste practices: addressing urban pollution and health hazards', considered the comparative size, placement and health effects of two waste disposal sites in north and south Dhaka, Bangladesh. The placement of landfills, which carry serious health risks, are highly contested in most urban areas, but particularly so in highly populated countries with already high levels of socio-economic and spatial inequities. The research team used multi-methods, which included both quantitative measures of pollution and contamination of residential areas, rivers and agricultural land, as well as purposive sampling for qualitative interviews of both officials and nearby residents. The researchers found that both the siting, design and management of the landfills caused severe adverse environmental effects through the percolation of the leachate into the soil and water, air pollution and pungent odours from the incineration of waste and breeding of disease vectors on the site. Nearby residents suffered a wide range of serious self-reported health problems. Recyclable waste continues to be manually segregated by informal workers and sold by these 'pickers', who have no protective clothing, and include women and children. The research team outlined possible low-tech partial solutions, but due to the complex nature of the problem, and an under-resourced government, it is unclear who, if anyone, is going to act on this report.

3. CURRENT CHALLENGES FOR RESEARCH AND POLICY

Contributors to this special issue were encouraged to publish research and ideas that could help improve the built environment, not just describe it. To achieve this aim, many of the articles highlight the need to consider the uses and users of research, and the implications for researchers and the research process. Issues related to planetary health included a growing awareness of the need to mitigate and adapt to climate change, waste production and pollution, and population health. As this special issue shows, there is a growing body of research evidence that shows the relationships between the built environment and urban characteristics, as well as interlinked issues of population health and sustainability. However, despite the identification of health co-benefits for carbon mitigation and sustainability, few cities have embedded long-term environmental goals in their policies that meet both local needs and those for planetary health and wellbeing.

One reason for this lack of progress is the siloed nature of much of the research on these issues, which often focuses on analysing relationships between inputs, or using descriptive modelling to evaluate the impacts of adaptation scenarios (Siri 2016). This reductive approach often overlooks the real-world complexity of urban systems, where different elements, at different levels of governance, are connected, but their relationships are not always clear. Health outcomes and sustainable development are dependent on multiple interactions and feedback loops, and traditional narrowly focused research approaches can underperform if they do not account for this complexity (Newell 2012). However, broader collaborative projects across sectors need to be closely managed to ensure that the preferred outcomes are not forgotten.

Another implication of siloed research is that research outcomes are less likely to inform policy due to a lack of engagement with stakeholders. The challenge for researchers is therefore threefold: (1) to increase the depth of understanding of key health and sustainability issues in cities; (2) to increase the breadth of their research and understand how these issues relate with other within the wider urban systems; and (3) to ensure that research outcomes are communicated to those making the decisions in cities. Knowledge transfer needs to be incorporated in research design, e.g. through participatory engagement with key stakeholders to ‘co-create’ research evidence.

Policy action, too, can be reductive, acting on relatively narrow understandings of the challenges, which excludes awareness of the inequalities in the social, economic and environmental determinants of different populations’ health and wellbeing within and between cities, which is the critical first step to addressing the cumulative disadvantage many urban dwellers face. Rich and poor people can live in very different epidemiological worlds, even within the same city. Within city administrations, key groups such as planners, community services, engineering, public health officials and transport designers often operate somewhat independently.

Therefore, urban policymakers should also incorporate complexity analysis into their decision-making in order to understand overlapping relations that may affect the intended outcomes. There is now increasing recognition of the complex and contested nature of policy processes and the use of evidence within these processes (Pineo *et al.*), as well as the fact that policies can also have unintended consequences. More use should be made of evaluations of natural policy experiments, to judge whether policies can be upscaled or potentially adapted to other jurisdictions. Understanding what works will contribute to more accessible and usable evidence for urban decision-makers. Different approaches to knowledge production and the relationships between ‘producers’ and ‘users’ are required at the science–policy interface, such as participating in new communities of practice such as Future Earth’s Urban Knowledge Action Network.¹

The challenges faced in urban areas in the Global South are particularly significant, as the rapid speed of urbanisation and a lack of resources has led to unregulated growth, and undeveloped infrastructure and social welfare systems. In addition to the need to adapt to climate risks to which they are likely to be more exposed and vulnerable (Watts *et al.* 2019), there is the need to improve access to basic services, safe drinking water, physical security, and to significantly reduce household and community exposures to air pollution. A systems approach can enable the development of new perspectives to problems and help develop context-specific interventions that improve population health and sustainability.

COVID-19 has led to a significant disruption to urban systems, and it offers a number of examples of direct and indirect consequences of the pandemic in cities (**Box 1**). Many of the articles in this special issue relate to the pandemic and its consequences. For example, Mohajeri *et al.* showed how lockdown-related changes to travel behaviour led to reductions in ambient air pollution, correcting for weather effects. Gonzalez and Gongal also looked directly at COVID-19-related issues by examining how organised changes to the routes populations travel upon can be used to reduce crowding. The umbrella review by Turcu *et al.* indicates the need for further research relating housing at different scales to communicable disease outcomes. Finally, Chapman and Howden-Chapman relate the COVID-19 eliminations policy of the New Zealand government to their wider policy of wellbeing.

Other papers in the special issue contain indirect insights for the pandemic. For example, Pineo *et al.* and Deloly *et al.* provide valuable insights into how governments engage with scientific data to develop policy in different locales. Ferguson *et al.* describe the structural determinants of indoor air pollution exposure and health, showing how low income individuals are more likely to live in overcrowded, poorly ventilated and dense homes, all of which have been cited as probable risk factors for COVID-19 transmission within the home (SAGE 2020a).

The ongoing global COVID-19 pandemic has brought to the forefront the complex interactions between urban systems, sustainability and population health. Urban and national systems around the world have responded differently to the pandemic, highlighting the key role of structural determinants such as government, economy, welfare systems, housing, education and working environments on population health. Characteristics of urban areas that influence the spread of COVID-19 include, for example, household overcrowding, social inequalities, baseline health, ambient air pollution and the quality of housing (Frumkin 2021). These structural determinants have exasperated inequalities, contributing to higher rates of COVID-19 in low socioeconomic status (SES) groups internationally (Baena-Diez *et al.* 2020). For example, between March and May 2020, there were 23 more COVID-19 deaths per 100,000 people in the most deprived 20% of neighbourhoods in London than in the least deprived areas (Trust for London 2020).

The complexity of urban systems means COVID-19 has also had knock-on effects on urban environments, and how they are used. Impacts of the pandemic in cities have included: increased remote working; decreased road traffic and increased the use of streets as outdoor spaces; an increased appreciation for greenspace and nature; and in some locations, population movement from urban centres to ex-urban areas (Frumkin 2021). It has also raised questions about how we design and construct our cities. For example, various studies have sought to link urban density with the spread of COVID-19; however, the association has not always been clear, and connectivity and overcrowding—or the proximity of individuals in the population to each other—has been suggested to be a more reliable indicator of risk (Teller 2021).

The pandemic has also demonstrated the relationships between housing quality, suitability and occupant health. High rates of within-household transmission have been observed during the COVID-19 outbreak in the UK (SAGE 2020a), and a report on COVID-19 and ethnicity found a high correlation between larger household sizes and multigenerational living and the elevated risk of within-household infection and mortality (SAGE 2020b). COVID-19 is commonly accepted to be transmitted through direct contact with contaminated surfaces; via large respiratory droplets; and by small airborne microdroplets (Morawska & Cao 2020). Evidence from the 2003 severe acute respiratory syndrome (SARS) outbreak suggested that transmission of the virus was mediated via the high-rise structures characterising Hong Kong's housing stock (Swaffield & Jack 2007; Gao *et al.* 2008) and similar concern regarding COVID-19 has been attributed to London's high proportion of multi-unit accommodation and dense housing developments (Bray *et al.* 2020; Kenway *et al.* 2020). This has led to calls for buildings to be developed with engineering controls to ensure adequate ventilation as well as filtration and disinfection (Morawska *et al.* 2020).

Box 1: Complex urban systems and COVID-19

4. CONCLUSIONS

The papers in this special issue provide a broad discussion about key issues of sustainability and health in urban environments, with each paper exploring the links between different components of urban systems. A wide variety of research methods have been used: qualitative methods such as surveys, interviews, ethnographic observations and minutes of joint meetings to carry out quantitative health impact assessment; natural experiments; comparative case studies; modelling; and systematic reviews. However, the emphasis by and large has been on descriptive and observational studies, rather than on implementation studies.

The papers address a range of different health challenges, developmental contexts, scales and relationships between components of the urban systems and they present some key conclusions for sustainable urban development. Key sustainability challenges such as climate change, or health challenges such as COVID-19, present opportunities for a shift in focus from economic development to broad wellbeing frameworks which map Sustainable Development Goals (SDGs).

Some of the key contributors to urban health problems are environmental burdens and these, like other determinants of health, can be unequally distributed. Reducing environmental burdens is complex and requires a set of policies that address the wider systemic causes of exposures. Implementing these policies raises important questions about who oversees them, how the responsibility is distributed, how unintended consequences are avoided and how progress is measured.

Academic research can help evaluate the optimal policy solutions for health and sustainability, but for this information to be put into practice requires engagement with decision-makers in cities. Such engagement is not straightforward and needs to be incorporated in planning from the beginning of the research process. Similarly, policy assessment by researchers or governments would benefit from systems analyses to identify high-leverage actions, which will lead to significant changes in the systems, as well as potential unforeseen consequences.

NOTE

1 See <https://futureearth.org/networks/knowledge-action-networks/urban/>.

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The authors have no competing interests to declare.

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