



Canadian Academy of Health Sciences
Académie canadienne des sciences de la santé



Systems-based approaches in public health:

WHERE NEXT?

Preface

In 2020, the UK Academy of Medical Sciences (AMS)¹ and the Canadian Academy of Health Sciences (CAHS)² established a small, international Expert Group (Annex 1) to scope out the current state of systems-based public health research and practice and to identify what steps could be taken to advance the field. The project was funded by Wellcome³ and the Health Foundation⁴, two independent, UK-based charities.

The Expert Group met six times virtually between September and December 2020. These online meetings took the place of a scoping workshop that would have been held in person had the COVID-19 pandemic not prevented in-person meetings. The following is a summary of the Expert Group's discussions and its recommendations for how systems-based public health research could be advanced. It also includes a series of case studies that the Expert Group felt illustrated some of the key elements of systems thinking in public health.

As a next step, the Expert Group's conclusions and recommendations need wider discussion with researchers, practitioners and members of the public (including traditionally under-represented groups) that was not feasible during the project.

The Academies are grateful to members of the Expert Group for their efforts in preparing this scoping paper.

The views expressed are those of the Expert Group (Annex 1) and may not necessarily reflect those of the AMS, the CAHS or the project sponsors.

¹ <https://acmedsci.ac.uk/>

² <https://cahs-acss.ca/>

³ <https://wellcome.org/>

⁴ <http://www.health.org.uk/>

Executive summary

Public health – maintaining the health and wellbeing of populations – addresses some of society’s most challenging problems, spanning prevention of infectious and non-communicable disease, promotion of mental health and wellbeing, and reduction of health inequalities. These challenges share a common feature: **complexity**. They have multiple interconnected determinants, spanning biological and psychological predisposition, social and economic circumstances, and exposure to differing built and natural environments.

Despite an increasingly detailed understanding of the determinants of poor health, complex challenges such as obesity and chronic disease prevention are proving exceptionally difficult to solve. In part, this stems from structural aspects of modern societies that are hard to shift, as well as deep-seated beliefs about the root causes and appropriate remedial actions.

However, a further key factor is that modern societies are **complex systems** – dynamic, constantly evolving and responding to fresh inputs in ways that can be hard to predict. **Systems-based public health** embraces this complexity, being founded on the idea that viewing public health through a complex systems lens has the potential to identify more effective ways to improve the health and wellbeing of populations and reduce health inequalities.

Systems-based public health is an **evolving field**, with no widely agreed definition. However, its starting point is the premise that societies are complex systems, and it aims to map out and understand the networks of interactions that influence health outcomes of interest to inform the development and evaluation of interventions.

Systems-based approaches involve the adoption of a broad perspective that focuses on the collective effects of a wide range of factors – such as people’s beliefs, motivations and capabilities; their social networks; societal structures and environmental exposures – and how interactions between

them affect particular health outcomes, as well as potential impacts on other aspects of health and wellbeing.

Despite the increasing use of systems-based approaches in many fields, including health systems research, their systematic application remains the exception rather than the rule in public health. In 2020, a small, international Expert Group set up by the UK Academy of Medical Sciences (AMS) and the Canadian Academy of Health Sciences (CAHS) discussed the current state of systems-based public health to identify steps that could be taken by various stakeholders to fully explore the potential of this field.

The Expert Group’s core conclusions:

1. There are a **wide range** of systems-based public health approaches, although core principles are generally consistent. Many researchers have adopted systems-based approaches **implicitly**, without making explicit reference to systems ways of thinking. Systems-based approaches in public health **lie along a continuum**, with systems thinking applied to different degrees.
2. **Barriers to the wider adoption** of systems-based approaches include **academic literature and terminology** that can be hard to navigate, creating a perception that systems-based approaches are **too difficult to apply**. Advocates for systems-based approaches may be seen as being **outside the mainstream**, or as part of a distinct school of thought.
3. Systems-based approaches **incorporate methods already in use** in public health research and other fields. Researchers keen to adopt systems-based approaches may lack a sufficient appreciation of **how to apply them in practice**, in part because of the diverse technical expertise required and the **interdisciplinarity** of systems-based public health. **New methodological approaches** are likely needed to deepen our

understanding of complex systems and how they shape the health of populations.

4. Studies to date have tended to focus on system **descriptions and evaluation of multi-component interventions**; relatively few have designed or evaluated interventions that take advantage of complex systems properties.
5. There is **limited evidence of the value** of systems-based approaches in public health. Evidence that does exist is **widely dispersed** in the literature and often not labelled as such. Alongside the academic literature, important contributions are made by groups outside academia, such as the consultancy or NGO sectors, or by policymakers and practitioners, in the form of outputs that may be less accessible than peer-reviewed publications in the mainstream academic literature. At this point, **it is difficult to draw firm conclusions about the extent to which systems-based approaches add value**, and when and how they should be used.

Based on the above conclusions, systems-based approaches are promising and warrant further investigation to determine if they truly deliver better public health outcomes. The Expert Group identified three areas for further action to advance this field of research:

Build the evidence base:

- Synthesise existing evidence on systems-based approaches in public health, as well as generate new evidence of added value. This may require new approaches to collate and organise disparate evidence sources.

Build a community:

- Develop a global community of practice for systems approaches in public health, to connect researchers and other key stakeholders, including policymakers and public health practitioners. Such a community could provide a platform to share evidence, support the development of new methodologies and promote the use of existing approaches, with the overall aim of building research capability and capacity.

Facilitate change:

- Target funding for systems approaches to address public health challenges, and for community- and capacity-building activities. Processes for evaluating applications and monitoring progress need to reflect the specific challenges of applying systems-based approaches in public health.

The Expert Group concluded that systems-based approaches that consider complex societal characteristics have great potential to enhance public health policymaking and practice – and ultimately improve population health and wellbeing, while also reducing health inequalities. The Expert Group has proposed an agenda to further develop the field to realise this potential. We look forward to these next steps being discussed by a wider group of stakeholders than has been possible during the scoping phase so that an action plan can be developed and implemented.

Introduction

Over the past century, progress in medicine and public health has contributed to ever-rising life expectancy. However, *healthy* life expectancy has risen more slowly and major inequalities exist in both life expectancy and healthy life expectancy. Much information has been gathered on the risk factors associated with poor health and on the barriers and facilitators to achieving good health. In some areas, such as tobacco control, good progress has been made in designing interventions to reduce these risks. In many other areas, such as chronic disease and substance misuse, the public health community has been less successful at using the wealth of knowledge on causation to design interventions to protect health, enhance wellbeing and reduce health inequalities.

In part, this reflects the fact that many upstream factors affecting health – such as the nature of the built environment, education and welfare systems; and the activities of food and drink industries – are deeply entrenched and perpetuate inequity. Furthermore, decision-makers and other actors may have deep-seated views on the drivers of ill-health and the most appropriate ways to tackle them. When faced with such systemic obstacles to change, it is not surprising that public health interventions have had variable success in improving health outcomes or reducing inequalities.

In addition, today's key public health challenges are typically complex, with multiple intersecting causes and consequences. Decades of research have clearly indicated that many aspects of health and wellbeing are subject to a myriad of interacting influences, shaped by biological factors; family, household and working circumstances,

social structures and norms; local environments; and wider socioeconomic factors⁵. As a result, many diseases show marked social patterning (particularly in relation to social deprivation)⁶.

The combination of limited progress and complexity challenges has led to a growing interest in **systems-based public health**⁷. It remains an **evolving field**, with multiple conceptions and definitions of a systems-based approach having been proposed⁸. The common starting point is the premise that **societies are complex systems**, with multiple influences, interconnections and feedback loops¹³ (see Box 1). This knowledge underpins the development of multifaceted interventions tailored to local contexts that respond to dynamic system behaviour, increasing the likelihood of achieving improved health outcomes.

Broadly speaking, systems-based approaches may encompass one or more of the following elements:

- Mapping out the relationships between multiple influences on health outcomes of interest.
- Using such maps to identify multiple potential points of intervention.
- Working with communities and other stakeholders to understand context, develop interventions and evaluate their impact, taking into account population diversity and inclusion.
- Designing interventions that take into account the distinctive properties of complex systems (e.g. interconnections and feedback loops; Box 1).

⁵ Bibby J, Lovell, N. What makes us healthy? An introduction to the social determinants of health. 2018. London: Health Foundation. Available at <http://reader.health.org.uk/what-makes-us-healthy>

⁶ Williams E, Buck D, Babalola G. What are health inequalities? 2020. London: King's Fund. Available at: <https://www.kingsfund.org.uk/publications/what-are-health-inequalities>

⁷ Rutter H, Savona N, Glonti K, Bibby J, Cummins S, Finegood DT, Greaves F, Harper L, Hawe P, Moore L, Petticrew M, Rehfuss E, Shiell A, Thomas J, White M. The need for a complex systems model of evidence for public health. *Lancet*. 2017;390(10112):2602-2604. doi: 10.1016/S0140-6736(17)31267-9.

⁸ Arnold RD, Wade JP. A definition of systems thinking: A systems approach. *Proc Comp Sci*. 2015; 44:669-678

- Teasing out how different pathways influence health outcomes of interest.
- Exploring additional outcomes beyond an immediate health outcome of interest – either anticipated benefits or unintended consequences (positive or negative).
- Iteratively piloting and refining interventions in light of experience.

Complexity is not restricted to public health; other disciplines have embraced new ways of thinking. The second half of the 20th century saw the emergence of a new field of study devoted to complex systems⁹. Although initially applied to systems in the physical sciences and computing, systems thinking has permeated much wider, into environmental science and ‘human systems’, including management theory¹⁰ and, more recently, public health¹¹. Although the individual elements that make up a system differ across domains of study, many core principles are consistent.

Systems-based approaches have been used in multiple public policy fields^{12 13}. For example, participatory systems modelling has been used to explore the implications of UK energy policy¹⁴. Systems-based approaches have also been adopted in health-related areas, such as health systems research¹⁵, urban sustainability¹⁶ and health systems strengthening¹⁷.

Despite some notable exceptions^{18 19 20}, systems-based approaches have not gained similar traction in public health; studies have mostly focused on describing systems rather than testing interventions. Over a series of online meetings, an international expert group convened by the UK Academy of Medical Sciences and the Canadian Academy of Health Sciences aimed to explore the current state of systems-based public health approaches and to provide suggestions for how to advance the field. It also aimed to identify several case studies that illustrate how systems-based approaches have been adopted, to varying degrees, in a range of public health settings.

⁹ Castellani B. Map of the Complexity Sciences. 2018. Art & Science Factory. Available at https://www.art-sciencefactory.com/complexity-map_feb09.html

¹⁰ Checkland P. From Optimizing to Learning: A Development of Systems Thinking for the 1990s. *J Opl Res Soc.* 1985;36(9): 757-767

¹¹ Chughtai S, Blanchet K. Systems thinking in public health: a bibliographic contribution to a meta-narrative review. *Health Policy Plan.* 2017;32(4):585-594. doi: 10.1093/heapol/czw159.

¹² Gates EF. [Making sense of the emerging conversation in evaluation about systems thinking and complexity science](#). *Eval Program Plann.* 2016;59:62-73. doi: 10.1016/j.evalprogplan.2016.08.004.

¹³ Eppel EA, Rhodes ML. Complexity theory and public management: A ‘becoming’ field. *Public Management Review.* 2018; 20(7):949-959. doi.org/10.1080/14719037.2017.1364414

¹⁴ Barbrook-Johnson P, Penn A. Participatory systems mapping for complex energy policy evaluation. *Evaluation.* 2021; 27(1):57-79. DOI: 10.1177/1356389020976153

¹⁵ Rusoja E, Haynie D, Sievers J, Mustafee N, Nelson F, Reynolds M, Sarriot E, Swanson RC, Williams B. Thinking about complexity in health: A systematic review of the key systems thinking and complexity ideas in health. *J Eval Clin Pract.* 2018 Jun;24(3):600-606. doi: 10.1111/jep.12856.

¹⁶ Crane M, Lloyd S, Haines A, Ding D, Hutchinson E, Belesova K, Davies M, Osrin D, Zimmermann N, Capon A, Wilkinson P, Turcu C. Transforming cities for sustainability: A health perspective. *Environ Int.* 2021 Jan 7;147:106366. doi: 10.1016/j.envint.2020.106366.

¹⁷ WHO. Systems thinking for health systems strengthening. 2009. Geneva: WHO. Available at: <https://www.who.int/alliance-hpsr/resources/9789241563895/en/>

¹⁸ National Cancer Institute. Greater Than the Sum: Systems Thinking in Tobacco Control (NCI Tobacco Control Monograph Series 18). 2007. Bethesda, MD: US Department of Health and Human Services, National Institutes of Health, National Cancer Institute. Available at: <https://cancercontrol.cancer.gov/brp/tcrb/monographs/monograph-18>

¹⁹ Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, Parry V. Foresight: Tackling Obesities: Future Choices – Project Report (2nd Edn). 2007. London: Government Office for Science. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf

²⁰ Royal Academy of Engineering, Academy of Medical Sciences, Royal College of Physicians. Engineering Better Care. 2017. London: Royal Academy of Engineering. Available at: [https://www.raeng.org.uk/policy/publications-\(1\)/interactives/engineering-better-care](https://www.raeng.org.uk/policy/publications-(1)/interactives/engineering-better-care)

Systems-based approaches in public health

The **goals of systems-based approaches** are no different from those of public health more generally – to protect health and wellbeing and to minimise health inequities. In essence, systems-based approaches build on and extend public health research, policy and practice in ways that take into account the nature of complex systems.

Systems-based approaches encourage a **shift in perspective**, with particular attention paid to the context

of target populations, the potential for multifactorial interventions, and impacts on a wide range of measures (Box 2). Interventions can be envisioned as interruptions to a system, to focus attention on the system and how it responds to interruptions²¹.

The **dynamic nature of systems** makes it difficult to predict the full impact of interventions, and emphasises the need to adopt flexible approaches that allow ‘course corrections’ informed by experience and the emergence of new data.

Rather than being categorised in a binary way as either systems-based or not, systems-based approaches can be situated along a continuum, corresponding to the degree that they reflect the principles of systems-based approaches and a ‘complexity perspective’ as illustrated in the figure below.

Box 2: Sowing the seeds

To adopt a horticultural metaphor, **public health interventions** can be considered as ‘**seeds**’. The immediate **context** into which these seeds are placed in is the ‘**soil**’. **Outcomes** can be viewed as the ‘**harvest**’.

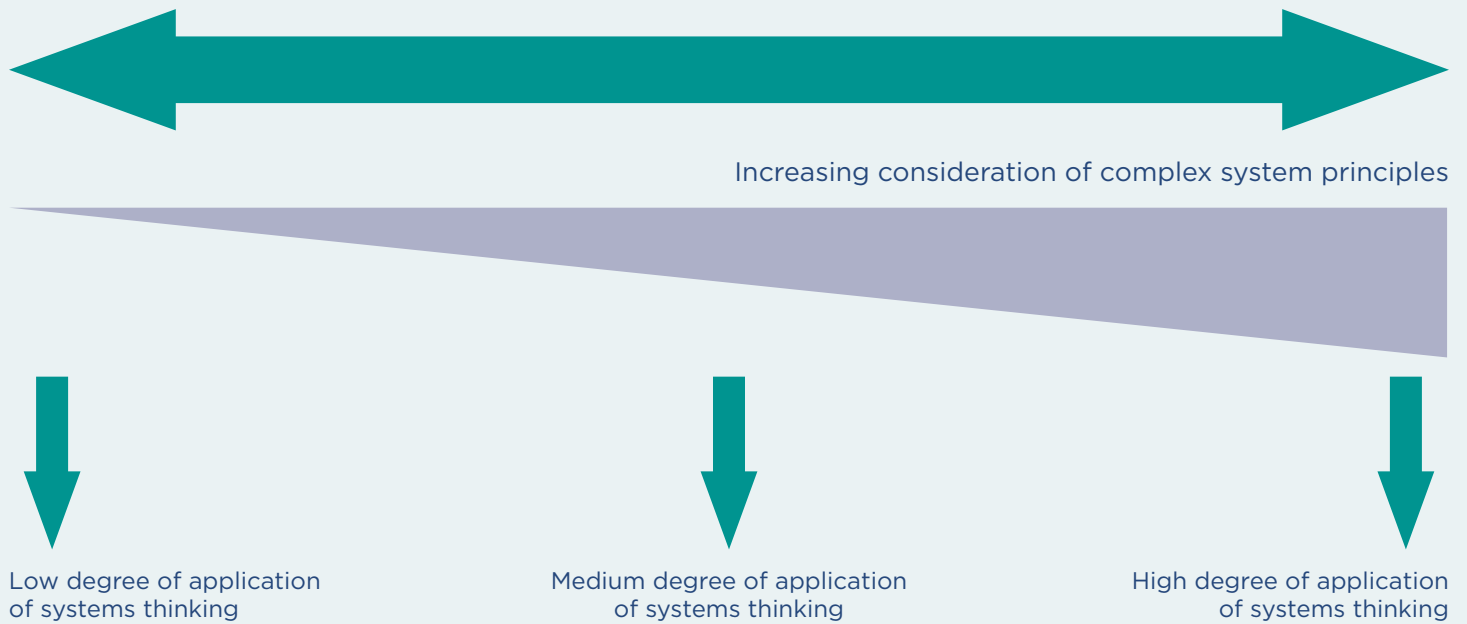
How the seed develops depends not just on the nature of the soil into which it is planted but also on multiple other factors – weather, pests, cultivation techniques, the expertise of gardeners. A successful harvest means choosing the seed most appropriate to the properties of local soil and also taking account of the other factors affecting growth. Moreover, as well as productivity, growers must also consider

wider environmental impacts, such as run-off and effects on biodiversity.

Similarly, systems-based approaches in public health focus not only on identifying effective interventions, but also on determining which are the most appropriate intervention(s) for a given context, and what else needs to be done to ensure that such interventions are as effective as they can be. Like the grower, users of systems-based approaches must consider a wide range of possible consequences of their activities, positive and negative, intended and unintended, and they must monitor progress and make adjustments when necessary.

²¹ Hawe P, Shiell A, Riley T. Theorising interventions as events in systems. *Am J Community Psychol*. 2009;43(3-4):267-76. doi: 10.1007/s10464-009-9229-9.

Systems-based approaches lie along a spectrum



The following examples illustrate systems thinking at different points along the continuum.

Low degree of systems thinking

- Identifying the groups of people, institutions and structures that influence a public health issue of interest.
- Mapping the relationships of these 'agents' with target populations and with each other.
- Carrying out multifaceted evaluations that capture multiple outcomes and process data.

Medium degree of systems thinking

- Collaborating with communities and stakeholders to understand context, develop interventions and evaluate their impact; documenting and harnessing multiple perspectives on problems and solutions.
- Developing computer models or simulations to quantify relationships and to explore the dynamic system behaviour and the potential impact of interventions over time.

- Using maps and models to identify potential points of intervention, trade-offs, unintended consequences and adaptive responses that may mitigate or enhance the impact of interventions.

High degree of systems thinking

- Harnessing the characteristics of complex systems, such as the tendency towards self-organisation and co-evolution, to design, implement and evaluate interventions.
- Building complex dynamic computer models that include adaptive responses and feedback loops, and are grounded in evidence-based models of how people and communities behave.
- Conceptualising interventions as a broad range of activities that are flexibly applied to influence routines, relationships, resources, power structures, symbols, forms of talk and sets of values, rather than only as specific programmes, technologies, or sets of products²².
- Creating 'learning systems' by iteratively piloting, evaluating and revising interventions.

²² Hawe P. Lessons from complex interventions to improve health. *Annu Rev Public Health*. 2015;36:307-23. doi: 10.1146/annurev-publhealth-031912-114421.

These examples are not intended to be definitive or comprehensive groupings, but illustrate the broad principle that systems approaches can be applied to different degrees. It remains to be determined whether adopting a higher degree of systems thinking delivers better public health outcomes (see ‘evidence’ section below) or whether some components have particular impact. In some resource-poor contexts (for example, limited funds, expertise or time), a low degree of systems thinking might be appropriate and still deliver benefits.

Further discussion is required to refine and test this initial structure to provide researchers, public health practitioners, policymakers and other stakeholders with greater clarity on what applying systems-based approaches means and what impact it can have on public health outcomes.

Understanding context

Adoption of a systems-based approach requires those engaged in addressing a complex problem to decide **what constitutes the system of interest** – where the boundaries of the system lie and how the system interacts with its context/environment. Systems can vary in scale, from within a single organisation or community to a global scale. Decisions have to be made on which people and organisations need to be considered in a systems analysis (Case Study 1 [CS1]). These choices are critical, as they have the potential to exclude important perspectives, which all too often are those of the socially disadvantaged²³.

A systems-based approach means taking a step back from a problem and examining the myriad factors that influence people, organisations and structures in ways that contribute to a public health issue within a particular context. Understanding these influences may involve synthesis of existing evidence, as well as **close engagement with the**

affected communities and other stakeholders (CS1, CS2). Engagement with communities and other stakeholders to develop these maps can help build a common vision (CS1, CS3).

These activities also help to tease out issues that are beyond the immediate public health problem of interest, but matter to communities and therefore need to be noted in the system map. Mapping can also suggest potential entry points for intervention (CS4). Building trust with communities affected by the problem or by an intervention is essential to ensure their full involvement in the design and delivery of interventions, which is a key element of successful projects (CS4, CS5).

Systems-based approaches may generate a **visual map of the system of interest** (CS3, CS4), showing pathways of influence, feedback loops and points in the system where the impact of an intervention could be amplified [figure – Foresight Obesity map]. Additional value can be achieved by **developing models or computer simulations** of systems of interest (CS6).

Developing interventions

A good understanding of key variables and system dynamics is needed to reveal **points of maximum impact** – where changes could have the greatest influence on public health (CS3, CS5). Collaborative development of system maps and models may reveal whether interventions are likely to be feasible to implement and acceptable to stakeholders. If models have been developed, these can be used to explore the potential impacts of interventions at different points in the system (CS7).

A systems analysis may identify one intervention point where substantial public health benefits could be delivered. More likely, several potential intervention

²³ Ulrich W. Reflective practice in the civil society: The contribution of critically systemic thinking. *Reflective Practice*. 2000; 1(2):247–268.

points may emerge, each offering a relatively small effect, but collectively contribute to the overall impact through an additive, synergistic, or interdependent relationship. Interventions are therefore likely to be **multifaceted** (CS2, CS8). Working with communities can identify which of several entry points may be best to start with, taking into account factors such as preference, likelihood of change, and equity. Maps may also reveal potential barriers and pathways to unintended consequences, allowing mitigation measures to be planned. More generally, **risk** needs to be considered and understood across a range of stakeholders, with consideration given to potential unintended consequences across the breadth of the system.

Piloting, adaptation and continuous improvement are common features of systems-based approaches. New elements may need to be added to interventions if barriers to implementation or impact become apparent, emphasising the importance of adopting a reflective and adaptive approach, and ensuring that key variables are measured as work progresses to identify lack of progress or barriers.

Evaluating impact (and beyond)

Systems-based approaches have important **implications for evaluation**, both in terms of what is measured and how it is measured. Evaluations tend to focus on outcome measures relevant to the public health issue of interest. In addition, **process evaluations**²⁴ provide information on how well an intervention was implemented in practice, providing insights into its feasibility and acceptability²⁵.

Systems-based approaches often have an interest in identifying the most significant **routes of influence**. Monitoring changes within system pathways can help to reveal which changes had the biggest impact on anticipated outcome measures. This work may have benefits beyond the immediate project, for example by identifying influential voices that can be engaged in other public health initiatives.

A systems-based approach recognises that **interventions within a system will have multiple consequences**, some intended and some not. Hence, a wider range of health and wellbeing outcomes may need to be assessed, to monitor collateral benefits as well as unintended consequences²⁶ (CS8), including potential exacerbation of inequalities (CS2). Taking a systems approach has the potential to enable the identification of possible unintended negative consequences through risk assessment exercises, allowing for mitigation measures to be planned.

Most systems-based approaches include engagement with communities and other stakeholders. This is important as dialogue with communities (including underrepresented groups) may highlight other variables to be monitored, beyond those of initial interest to researchers.

Although understanding, intervention, and evaluation are discussed separately above, systems-based approaches are **more integrated**. They strive to build shared measurement systems and common goals that support all stakeholders in continuous learning, so interventions are embedded and continually adapted over time. This is easier to envision when systems-based approaches are embedded within public health practice. It is less easy to apply in academic-led projects that are typically of a fixed duration, with a definite beginning and end, and expectations of certain outputs or impact within that timeframe.

²⁴ Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, Moore L, O'Cathain A, Tinati T, Wight D, Baird J. Process evaluation of complex interventions: Medical Research Council guidance. *BMJ*. 2015 Mar 19;350:h1258. doi: 10.1136/bmj.h1258.

²⁵ Bowen DJ, Kreuter M, Spring B, Cofta-Woerpel L, Linnan L, Weiner D, Bakken S, Kaplan CP, Squiers L, Fabrizio C, Fernandez M. How we design feasibility studies. *Am J Prev Med*. 2009;36(5):452-7. doi: 10.1016/j.amepre.2009.02.002.

²⁶ Lorenc T, Oliver K. Adverse effects of public health interventions: a conceptual framework. *J Epidemiol Community Health*. 2014;68(3):288-90. doi: 10.1136/jech-2013-203118.

What methodologies are used in system-based approaches?

Systems-based approaches to public health can **incorporate existing research methods and tools**²⁷. They are not totally distinct from current public health approaches – rather, they offer opportunities to use a wider range of research methodologies according to need/objectives at different stages of research.

Some methods are particularly applicable to systems-based approaches. **Participatory approaches to concept mapping**²⁸ and **group model building**²⁹ are a good basis for developing systems maps collaboratively with communities and other stakeholders. **Agent-based modelling**³⁰ can be used to generate quantitative system simulations to model the impact of interventions as perturbations of the system. **System dynamics modelling** can provide insight into ‘stocks and flows’ – the things that propagate through and accumulate within a network, such as knowledge, money, infectious organisms, or more abstract concepts such as trust – and their impact on behaviours, risks and outcomes³¹ (CS7).

Considerable thought needs to be put into the design of **evaluations**, given the need to focus on outcomes, processes, interactions, and the key contextual factors

that underpin the success of interventions. Such activities can help to tease out the core principles that could be transferable to other contexts. Depending on the intervention design, evaluations are likely to incorporate both quantitative and qualitative methods. With the fundamental importance of context, **process evaluations** can be important for exploring the mechanisms through which an intervention affects outcomes³² (CS9).

Systems-based approaches can draw on a wide range of methods, depending on the research goal and the degree of engagement with system thinking³³. This emphasises the **interdisciplinarity** of systems-based approaches, and the need to involve people from a range of backgrounds (CS6, CS8, CS10). A wide range of methods are now available to public health researchers, but the Expert Group recognizes that some researchers and public health practitioners who are keen to apply systems-based approaches may lack experience or confidence in applying them. There is also scope for additional systems-based methodologies, such as analytical tools for quantitative evaluations based on systems models.

There are opportunities, and a need, for **innovations** in systems approaches. Priority areas could include improved methods for incorporating feedback and adaptation into system dynamic models. Use of ‘big data’ and machine learning to enhance the development of models and to monitor impacts is in its infancy in public health, but represents an opportunity to explore common areas of interest, for example, in relation to ‘smart cities’ and ‘healthy cities’ initiatives^{34 35}.

²⁷ Shiell A, Riley T. Methods and Methodology of Systems Analysis. In APA Handbook of Community Psychology: Vol. 2. Methods for Community Research and Action for Diverse Groups and Issues, M. A. Bond, I. Serrano-García, and C. B. Keys (Editors-in-Chief) 2017 by the American Psychological Association

²⁸ Burke JG, O’Campo P, Peak GL, Gielen AC, McDonnell KA, Trochim WM. An introduction to concept mapping as a participatory public health research method. Qual Health Res. 2005 Dec;15(10):1392-410. doi: 10.1177/1049732305278876.

²⁹ Siokou C, Morgan R, Shiell A. [Group model building: a participatory approach to understanding and acting on systems](#). Public Health Res Pract. 2014;25(1):e2511404. doi: 10.17061/phrp2511404.

³⁰ Tracy M, Cerdá M, Keyes KM. Agent-Based Modeling in Public Health: Current Applications and Future Directions. Annu Rev Public Health. 2018 Apr 1;39:77-94. doi: 10.1146/annurev-publhealth-040617-014317.

³¹ Homer JB, Hirsch GB. [System dynamics modeling for public health: background and opportunities](#). Am J Public Health. 2006;96(3):452-8. doi: 10.2105/AJPH.2005.062059.

³² Salter KL, Kothari A. Using realist evaluation to open the black box of knowledge translation: a state-of-the-art review. Implement Sci 2014;9:115. doi:10.1186/s13012-014-0115-y

³³ Williams B, Hummelbrunner R. Systems Concepts in Action: A Practitioner’s Toolkit. 2010. Stanford: Stanford University Press. Available at: <https://www.sup.org/books/title/?id=18331>

³⁴ Rydin Y, Bleahu A, Davies M, Dávila JD, Friel S, De Grandis G, Groce N, Hallal PC, Hamilton I, Howden-Chapman P, Lai KM, Lim CJ, Martins J, Osrin D, Ridley I, Scott I, Taylor M, Wilkinson P, Wilson J. Shaping cities for health: complexity and the planning of urban environments in the 21st century. Lancet. 2012;379(9831):2079-108. doi: 10.1016/S0140-6736(12)60435-8.

³⁵ UCL. Complex Urban Systems for Sustainability and Health (CUSSH). Available at: <https://www.ucl.ac.uk/complex-urban-systems/>

How strong is the evidence in favour of a systems perspective in public health?

Systems-based approaches have emerged from multiple directions. One approach draws on methods and frameworks developed in other fields such as dynamical system theory, computational modelling and network science. This work tends to require significant expertise and uses unfamiliar terminology, and as such has not become widespread or embedded in public health policy or practice³⁶.

Advocates of a systems approach in public health have written many commentaries and opinion pieces³⁷. While these have helped to create an intellectual foundation for the field and to argue the case for the application of systems-based approaches in public health, they do not constitute the kind of evidence that researchers, policymakers and practitioners need to support evidence-based decision-making.

The value of taking a systems-based approach has been arrived at both theoretically and empirically, through the recognition that addressing one issue in a complex system does not necessarily achieve the desired outcome and may have unintended consequences. As a result, researchers, practitioners and policymakers may apply systems principles or thinking without explicitly stating that this is the case, making it hard to assimilate the learning and evidence from their studies into the systems-based approach literature.

Non-academic bodies such as non-governmental organisations (NGOs) and consultancies can also make significant contributions to both public health and to systems-based approaches. Reports and other outputs from these projects may include valuable evidence of systems-based thinking or practice, but the 'grey literature' is less structured and accessible using current search practices than the formal academic literature.

As a result, evidence of relevance to systems-based approaches in public health is widely dispersed and hard to synthesise. **It is therefore difficult to provide compelling evidence of the effectiveness of systems-based approaches, to identify when they are most appropriate, or to determine which aspects of them have greatest added value**³⁸. It is likely that such evidence exists, but it will require considerable collaborative effort and new approaches for it to be extracted and synthesised. We were unable to do this during the development of this scoping paper, but it is clearly a priority for future work.

These issues are not specific to public health research. In the arguably more well-established field of health systems research, a recent systematic review found it challenging to identify and extract relevant papers to analyse. However, its final analysis of 35 studies suggested that adoption of systems-based approaches was associated with enhanced patient and service outcomes³⁹.

Other evidence syntheses in health services research have shown that interventions whose design incorporates characteristics of complex adaptive systems can deliver better health outcomes, even when interventions were not designed explicitly as a 'systems approach'. For example, in an analysis of type 2 diabetes care interventions, patient outcomes were positively correlated with the number of complex systems principles adopted in the studied

³⁶ Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ. Practical challenges of systems thinking and modeling in public health. *Am J Public Health*. 2006 Mar;96(3):538-46. doi: 10.2105/AJPH.2005.066001.

³⁷ Carey G, Malbon E, Carey N, Joyce A, Crammond B, Carey A. [Systems science and systems thinking for public health: a systematic review of the field](#). *BMJ Open*. 2015;5(12):e009002. doi: 10.1136/bmjopen-2015-009002.

³⁸ Finegood DT. Can We Build an Evidence Base on the Impact of Systems Thinking for Wicked Problems? Comment on "What Can Policy-Makers Get Out of Systems Thinking? Policy Partners' Experiences of a Systems-Focused Research Collaboration in Preventive Health". *Int J Health Policy Manag*. 2020. doi: 10.34172/ijhpm.2020.194.

³⁹ Komashie A et al. A systems approach to health service design, delivery and improvement: A systematic review and meta-analysis. 2020. *BMJ Open*.

interventions⁴⁰. These examples strengthen the case for experimenting with systems-based approaches in public health.

More generally, there is a need to consider **the kind of evidence required to demonstrate the value of a systems approach**. Decision-makers are likely to want evidence of what works (and at what cost), in order to justify decisions to invest in change. An emphasis on evidence-based medicine has led to the development of hierarchies of evidence⁴¹, which favour randomised controlled trials as the most reliable source of evidence because they seek to control for multiple confounders⁴². Efficacy is seen as a core attribute of an intervention, but a systems perspective highlights the fundamental influence of context on efficacy – the ‘confounders’ may actually be critical to the effectiveness of an intervention.

Rather than trying to identify the ‘best’ intervention, it may be more helpful for policymakers and practitioners to focus on identifying the intervention(s) most likely to be effective in their specific context, how they can be adapted to local settings, and how collaborative activities across stakeholders (including representatives of local populations) can support their successful implementation¹⁵.

In some situations, randomised controlled trials may be feasible and appropriate, including trials of ‘**complex interventions**’ (those involving multiple elements and/or significant dependence on context)⁴³. Context can be incorporated into intervention and trial design. For example, rather than standardising components of interventions in terms of the form they take, the function that components play in an intervention can be preserved

while allowing their form to adjust to context. In other words, an intervention with the same mechanism or theory-of-action can look different in different sites⁴⁴. **Cluster randomised trials** can be used to compare intervention and matched control areas, and to explore contextual factors affecting effect sizes. **Pragmatic trials** and **realist evaluations** can also draw out important information on ‘real world’ factors affecting impact. In other settings, alternative approaches might be needed to generate evidence of effectiveness, such as analysing the impact of ‘natural experiments’ and interrupted time series analyses⁴⁵.

These issues highlight the challenge of **generalising evidence** across settings – contexts, particularly cultural ones that influence health-related behaviours, may be so locally specific that evidence on the effectiveness of interventions cannot easily be generalised. However, systems-based approaches can help to identify contextual factors, mechanisms of action, and pathways of influence that shape the effectiveness of interventions, positively or negatively. This will provide policymakers with information on the likelihood that an intervention is effective, or how it could be tailored to local settings to increase the chances of success.

Synthesis of existing evidence from studies applying systems-based approaches could shed light on the core elements or ‘essence’ of systems-based interventions, which could inform the design of interventions and how they are introduced in other settings¹⁵. In health systems, work on quality improvement has explored how to address the generalisability challenge, which may hold lessons for public health⁴⁶.

⁴⁰ Leykum LK, Pugh J, Lawrence V, Parchman M, Noël PH, Cornell J, McDaniel RR Jr. Organizational interventions employing principles of complexity science have improved outcomes for patients with Type II diabetes. *Implement Sci*. 2007 Aug 28;2:28. doi: 10.1186/1748-5908-2-28.

⁴¹ Balshem H, Helfand M, Schünemann HJ, Oxman AD, Kunz R, Brozek J, Vist GE, Falck-Ytter Y, Meerpohl J, Norris S, Guyatt GH. GRADE guidelines: 3. Rating the quality of evidence. *J Clin Epidemiol*. 2011 Apr;64(4):401-6. doi: 10.1016/j.jclinepi.2010.07.015.

⁴² Academy of Medical Sciences. Sources of evidence for assessing the safety, efficacy and effectiveness of medicines. 2017. London: Academy of Medical Sciences. Available at: <https://acmedsci.ac.uk/file-download/43777204>

⁴³ O’Cathain A, Croot L, Duncan E et al. Guidance on how to develop complex interventions to improve health and healthcare. *BMJ Open* 2019;9:e029954. doi: 10.1136/bmjopen-2019-029954

⁴⁴ Hawe P, Shiell A, Riley T. [Complex interventions: how “out of control” can a randomised controlled trial be?](#) *BMJ*. 2004;328(7455):1561-3. doi: 10.1136/bmj.328.7455.1561.

⁴⁵ Ogilvie D, Adams J, Bauman A, Gregg EW, Panter J, Siegel KR, Wareham NJ, White M. Using natural experimental studies to guide public health action: turning the evidence-based medicine paradigm on its head. *J Epidemiol Community Health*. 2020 Feb;74(2):203-208. doi: 10.1136/jech-2019-213085. Epub 2019 Nov 19.

⁴⁶ Øvreteit J, Leviton L, Parry G. [Increasing the generalisability of improvement research with an improvement replication programme](#). *BMJ Qual Saf*. 2011;20 Suppl 1(Suppl_1):i87-91. doi: 10.1136/bmjqs.2010.046342.

Decision-makers are likely to want to understand the **economic consequences** of an intervention. Systems science modelling can support exploration of potential benefits and drawbacks, and their respective costs. While the impact of interventions in complex systems are inherently hard to predict, systems science models enable a deeper understanding of possible outcomes and uncertainties.

Many challenges to identifying the impacts of interventions – time lags between interventions and outcomes, cross-sectoral impacts, unintended consequences – are not unique to systems-based approaches⁴⁷. However, a systems perspective requires attention to impacts beyond health outcomes, such as the additional capabilities of communities or other stakeholders⁴⁸. In addition, the concept of cost-effectiveness as an innate property of an intervention, core to health technology assessments, is difficult to apply if effectiveness varies with context. Further dialogue with policymakers and decision-makers is required to develop appropriate frameworks for systems-based economic evaluations to inform evidence-based decision-making in public health.

Barriers to the uptake of systems-based approaches

The expert group identified a range of barriers that limit the wider adoption of systems-based approaches:

1. **‘I don’t know what it is’**: Researchers, policymakers and other stakeholders may struggle to understand what systems-based approaches actually are, with unfamiliar terminology being a specific challenge, and may not recognize their relevance to real-world problems.

2. **‘It’s too hard’**: There is a perception that systems-based approaches are too difficult to apply, requiring new approaches and complex skills.
3. **‘It’s not worth it’**: There are doubts that systems-based approaches add value, and therefore merit the additional effort and resources required.
4. **‘I don’t know how to do it’**: Even among those who can see the potential of systems-based approaches, uncertainty about methods and how they are applied in practice can inhibit researchers.
5. **‘It’s not what I do’**: Proponents of systems-based approaches may be mistakenly seen as a distinct ‘school’, promoting alternative methods, rather than as part of the mainstream applying a different, but complementary set of tools.
6. **‘It’s not valued’**: Current funding mechanisms and academic advancement processes may be disincentives to researchers considering more systems-oriented research.

Advancing the field

The expert group identified a range of options to address these challenges, so that systems-based approaches could become more embedded in public health.

• Build the evidence base

Establishing a stronger evidence base for systems-based approaches is essential. One important task is to **synthesise existing evidence** to identify the **added value** of systems-based approaches, the specific aspects of systems-based approaches that add most value, and where they can best be applied. Given that evidence is widely dispersed and in different forms, better literature search and synthesis

⁴⁷ Waters E, Doyle J, Jackson N, Howes F, Brunton G, Oakley A; Cochrane Collaboration. [Evaluating the effectiveness of public health interventions: the role and activities of the Cochrane Collaboration](#). J Epidemiol Community Health. 2006;60(4):285-9. doi: 10.1136/jech.2003.015354.

⁴⁸ Shiell A, Hawe P, Gold L. [Complex interventions or complex systems? Implications for health economic evaluation](#). BMJ. 2008;336(7656):1281-3. doi: 10.1136/bmj.39569.510521.AD.

approaches may be required to include the grey literature and to synthesize across different methods.

The lack of a consistent definition, conceptual framework and taxonomy for systems-based public health is a barrier to the aggregation and analysis of information. Further development of the idea that systems-based approaches **lie along a continuum** could help to generate a set of overarching principles, and provide an opportunity to test the hypothesis that greater adoption of a systems perspective leads to better outcomes.

Such a set of overarching principles could also be used to assess the extent to which projects or activities incorporate systems thinking, analogous to those developed for clinical trial reporting. Such an assessment would not be a rating system, but would encourage more structured consideration of systems-related issues, application of the full range of systems-based approaches, and aid subsequent evidence synthesis.

The second key need is to **generate more evidence** of the added value of systems-based approaches. To date, most systems-based work in public health has been descriptive, elucidating the systems affecting key public health outcomes; fewer studies have attempted to design and evaluate interventions on the basis of these systems-based analyses.

• Build a community

There is a need to develop a **connected global community** with an interest in systems-based approaches in public health. While many communities exist to support students, researchers, practitioners and policymakers interested in complexity (e.g. <https://necsi.edu/> and <https://www.santafe.edu/>), these communities have generally not attracted or created a home for the broad range of actors interested in healthcare and public health.

Building a public health community of practice interested in different types of systems-based approaches is, like the topic itself, complex. Initially, people come to networks because there is something in it for them, such as an **online**

hub that supports dialogue and exchange of information. An initial workshop or conference could be held to kick-off this effort to foster exchange and collaboration between academics, practitioners, policymakers and other stakeholders, such as NGOs.

An early goal for this community could be to develop a set of overarching principles for assembling the evidence base on systems approaches. Such an effort could help to build a glossary-type resource to aid navigation of the literature, enable cross-disciplinary communication, and become the basis for evidence syntheses. The community could also support discussion of areas where methodological or analytical innovation is required.

Systems-based public health should be founded on strong **partnerships**. Processes and structures are needed that support and incentivise the building of relationships between researchers, practitioners, policymakers, and affected communities. Connections could be established with researchers working in other areas of public policy evaluation, for example, to share insights into methodologies and working practices.

Embedding systems-based approaches in public health will require integration into **educational curricula** (such as for master's of public health and related courses). Although there are accreditation requirements for systems thinking as part of curricula, more capacity is needed to deliver this kind of curriculum. This should form part of a wider drive towards **capacity building**, to ensure that researchers, practitioners and policymakers in public health and related domains (such as urban planning) develop the skills to make better use of systems-based approaches.

To ensure the applicability of research, **practitioners and policymakers** need to be involved in discussions about the use of systems-based approaches. There is a need to grow awareness, knowledge, and skills among practitioners and policymakers regarding systems-based approaches, their key features, how they can be applied, and the value they add⁴⁹. Early engagement with policymakers and

⁴⁹ Wutzke S, Morrice E, Benton M, Wilson A. [Systems approaches for chronic disease prevention: sound logic and empirical evidence, but is this view shared outside of academia?](#) Public Health Res Pract. 2016;26(3):2631632. doi: 10.17061/phrp2631632.

public health will ensure that further development of systems-based public health is rooted in practical realities. Embedding academics in public health practice (and vice versa) may also help to strengthen links between academic and practitioner/policymaker communities, including exchange of information and experience⁵⁰.

- **Facilitate change**

Funding agencies have a critical role to play in nurturing the nascent field of systems-based public health. As well as creating new **funding schemes**, funding agencies can also support the development of systems approaches in multiple other ways, such as through promoting **training and exchange**, by organising workshops and planning ‘matchmaking’ activities to build relationships across different disciplines. A systems-based approach to facilitating change is to build a community of practice; funders are well positioned to enable this type of work.

There is also the question regarding the most appropriate **processes to be used to request and assess proposals**. For example, it is well recognised that proposals for interdisciplinary approaches are often disadvantaged in peer review⁵¹. It will therefore be important to ensure that key groups of people, such as panel members and chairs, have relevant expertise and experience related to systems-based approaches in public health spanning academic disciplines.

Funders also need to consider whether funding processes based on projects of a fixed length with detailed plans articulated at the beginning of the granting process are compatible with systems thinking. Projects incorporating systems-based approaches would benefit from adopting more flexible and adaptive frameworks to take into account the unpredictable nature of complexity, and developing learning systems that can adapt and co-evolve, rather than following rigid *a priori* designs.

Conclusions

For more than a century, progress in medicine and public health has helped people to live longer, healthier lives. With health systems facing the challenge of increasing costs and demands, particularly with ageing populations, the added pressures created by the COVID-19 pandemic, and persistent health inequities, there has never been a more important time to focus on and advance public health to protect people’s health and wellbeing.

Human societies have evolved into complex highly interconnected structures. The nature of these structures has profound consequences for our health and wellbeing. Recognising and working with this complexity offers the prospect of more effective interventions that accelerate improvements in public health. This will require a focus on creating the conditions for continual incremental change, learning from what works (and what doesn’t) in specific settings, and recognition that complexity is not just a challenge to be overcome, but can be exploited to build stronger and more resilient systems that better protect the health and wellbeing of all.

We hope that this report makes a valuable contribution to this process, providing a stimulus for wider discussion of how the value of systems-based approaches in public health might be further explored and developed.

⁵⁰ McAteer J, Frank JW, Di Ruggiero E, Fraser A. Bridging the gap between public health research and policy/practice: Lessons from Canada, Scotland and rUK. *Journal of Public Health* 2018 doi:10/1093/pubmed/fdy127

⁵¹ Bromham L, Dinnage R, Hua X. Interdisciplinary research has consistently lower funding success. *Nature*. 2016;534(7609):684-7. doi: 10.1038/nature18315.

Box 1: Complex systems

Systems can be characterised as simple, complicated or complex. Complicated systems have many constituent parts and interactions, but can be understood by deconstruction and are essentially predictable. Complex systems, by contrast, are characterised by a wide range of different relationships between elements and dynamic change. A car engine could be seen as a complicated system – removal of one component has predictable consequences for its operation; a hospital is a complex system – removal of one component leads to adaptation, and the consequences are harder to predict.

Complex systems tend to be defined on the basis of their properties. The term ‘complex adaptive system’ is often used to emphasise the point that systems do not simply adjust in response to an external input, but also adapt and self-organise. In human-based systems, this may reduce or enhance the impact of an intervention over time. Recognition of complexity includes acceptance that there are no final answers and inquiry is never-ending.

Key properties of complex adaptive systems in public health:

- **Self-organisation and emergence:** Order is created in a system through the interactions of its parts, rather than being imposed from above. The properties of a system as a whole are not necessarily predictable from an understanding of its basic components.

Example: Social norms around vaccination, arise spontaneously as a result of multiple social influences affecting individual decision-making.

- **Feedback and adaptation:** Elements of systems respond to, compensate for, or exaggerate the effects of an intervention

Example: Changes in food or drink policy on advertising may lead companies to identify alternative routes to increase exposure of their products to consumers.

- **Non-linearity:** The effects of an intervention cascade through a system with multiplying effects, so outcomes are not necessarily proportional to inputs; lags and phase transitions contribute to the non-linear, time-dependent and unpredictable nature of complex system responses

Example: One paper linking MMR vaccination to autism triggered media coverage and campaigns that led to a significant decline in vaccination coverage in many countries.

- **Interdependence and interconnectedness:** Actions taken in one part of a system have effects that propagate through multiple system pathways; interactions between and among agents and subsystems are important drivers of system behaviour.

Example: Quarantining for COVID-19 protects health, but has economic consequences for those whose work is disrupted.

- **Sensitivity to initial conditions:** The response of a system depends on its past history and initial state

Example: Reluctance to adopt mask wearing to combat COVID-19 in the USA has been influenced by strongly held views on personal liberty.

Case studies

Case Study 1: Shape up Somerville

The Shape up Somerville project, a partnership between Tufts University and the city of Somerville, Massachusetts, adopted a systems-based approach to address the growing problem of youth obesity.

Somerville is a small, but densely populated city in New England. It has an ethnically diverse student body and a high proportion of school students from a low-income household. Shape up Somerville was launched in the early 2000s as both health professionals and community representatives grew increasingly concerned about rising levels of obesity among young people.

The project took an integrated cross-sectoral approach, identifying multiple stakeholder groups involved in activities that shape physical activity levels and healthy eating behaviours among young people locally. Its steering committee included representatives from more than 25 stakeholder groups.

Extensive community consultation through focus groups, one-on-one interviews, and community meetings were held to share data, gather input on which solutions were likely to be the most effective, and design a pilot interventional programme.

Strategies introduced included ensuring healthier options were available in restaurants, changing school meals, and improvements to local parks. Initial analyses showed that the initiative led to a statistically significant drop in average weight within a school year, while children in control communities gained weight.

Over subsequent years, the initiative has been maintained, drawing on the robust partnerships between academics, community groups and public authorities. Activities have continued to focus on creating and maintaining an environment conducive to weight control, through the adoption of evidence-based initiatives targeting both physical activity and healthy eating.

Key factors associated with the success of the Shape up Somerville approach have included the development of a common agenda across stakeholders, including the community, as well as residents, visitors, and people who work in Somerville. This has been backed up by continuous communication focused on addressing health inequalities, as well as deep, early, and inclusive engagement with the community, for example through forums for parents in English, Spanish, Portuguese and Haitian Creole.

The initiative has also been found to be highly cost-effective, with costs averted estimated at US\$500,000 over a decade with a net benefit of nearly US\$200,000.

FSG. Shape up Somerville: A Collective Impact Case Study. 2013. Available at: <https://www.fsg.org/publications/shape-somerville#download-area>

Economos CD, Hyatt RR, Goldberg JP, Must A, Naumova EN, Collins JJ, Nelson ME. A community intervention reduces BMI z-score in children: Shape Up Somerville first year results. *Obesity (Silver Spring)*. 2007;15(5):1325-36. doi: 10.1038/oby.2007.155.

Chomitz VR, Garnett BR, Arsenault L, Hudson D. Shape up Somerville: Building and sustaining a healthy community. Reflections over 15 years. Available at: <https://www.somervillema.gov/sites/default/files/shape-up-somerville-story.pdf>

Coffield E, Nihiser A, Carlson S, Collins J, Cawley J, Lee S, Economos C. Shape Up Somerville's return on investment: Multi-group exposure generates net-benefits in a child obesity intervention. *Prev Med Rep*. 2019;16:100954. doi: 10.1016/j.pmedr.2019.100954.

Hennessy E, Economos CD, Hammond RA; SUS Systems Map Team and the COMPACT Team. Integrating Complex Systems Methods to Advance Obesity Prevention Intervention Research. *Health Educ Behav*. 2020 Apr;47(2):213-223. doi: 10.1177/1090198119898649.

Case study 2: ActEarly

The ActEarly programme is taking a complex systems approach to improve the health and wellbeing of young people in deprived urban communities in the UK. It is based on the understanding that chronic health conditions in later life are strongly dependent on early-life experiences, with exposure to adverse environmental circumstances leading to increased risk of non-communicable diseases through a complex network of influences and interactions.

ActEarly is a multicentre, multisector programme aiming to tackle the upstream determinants of health and wellbeing, focusing on socially disadvantaged populations in Bradford, an ethnically diverse post-industrial city in the north of England, and Tower Hamlets, a similarly diverse and disadvantaged area of Central London.

Focusing on three themes – Healthy Places, Healthy Learning and Healthy Livelihoods – the programme is bringing together multiple stakeholder groups from a wide range of academic disciplines, policymakers, practitioners, and the public in a ‘prevention research consortium’. Placing communities at the heart of activities, it will undertake multiple types of community engagement to explore issues, map relationships, and co-design and evaluate interventions, focusing on upstream prevention.

Monitoring and evaluation will take advantage of a multitude of data sources, drawing on existing cohort studies, local administrative data across multiple social sectors, data collection directly from individuals, and

consumer data from food outlets and supermarkets. Quantitative and qualitative data will be collected, and evaluations will explore health outcomes, processes and economic impacts. As well developing and testing new interventions, the programme will also aim to collect data on the impacts of ‘natural experiments’ (such as planned policy changes).

A system mapping exercise will inform the development of agent-based and/or system dynamic models, which will be used to explore the impact of policy change or other interventions, including potential long-term impacts on non-communicable disease.

The ‘City Collaboratories’ in areas of high child poverty are therefore providing test-beds in which people-centred, data-rich whole-system approaches can be applied in urban settings. As well as generating data on interventions, the programme also plans to extract important learning about the challenges and facilitators of systems-based approaches.

Wright J, Hayward A, West J et al. ActEarly: a City Collaboratory approach to early promotion of good health and wellbeing [version 1; peer review: 2 approved] Wellcome Open Research 2019, 4:156

• ActEarly is supported by the UK Prevention Research Partnership (<https://ukprp.org>), a collaboration between multiple UK governmental and non-governmental agencies.

Case study 3: Tackling Obesities: Future Choices

The UK's Foresight Obesity report was a landmark publication in its application of systems thinking to a major public health challenge.

The 'Tackling Obesities: Future Choices' report, published in 2007, aimed to identify a long-term sustainable response to rising levels of obesity. It was part of the UK Government's Foresight programme, focusing on possible future developments in a range of complex and important fields, to guide policymaking.

The Foresight Obesity project was notable for its multidisciplinary inputs, multidisciplinary evidence synthesis and engagement with multiple stakeholders from the academic, policymaker, industry and civil society sectors.

In doing so, it identified a broad range of factors that influence obesity, and helped to establish a degree of consensus on the most important influences on obesity and their relative importance. It collated evidence on effective interventions, and generated a long-term vision of how the UK could respond to rising trends in obesity.

One of its most influential outputs was a comprehensive system map outlining the complex web of interactions that influence obesity. Equally significant, it provided an influential demonstration that obesity was not simply the consequence of poor individual decision-making, but reflected the cumulative effects of multiple social and environmental influences, over which individuals generally had very little control.

The Foresight Obesity report informed two of the UK's subsequent strategies to tackle obesity and the activities of national research funding agencies, among others. It also had much wider international influence and did much to set the agenda for systems thinking in obesity.

Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, Parry V. Tackling Obesities: Future Choices – Project Report (2nd edition). 2007. London: Government Office for Science. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf

Case study 4: Tackling child obesity

The Healthy Kids, Healthy Communities programme sought to create environments more conducive to healthy eating and active living among disadvantaged US communities at high risk of child obesity.

Socioeconomic status, ethnicity, and geographic location have well-documented impacts on the risk of obesity. To address an alarming rise in child obesity, in 2007 the US Robert Wood Johnson Foundation launched a major programme focus, including the Healthy Kids, Healthy Communities initiative. Rather than focusing on individual behaviours, emphasis was placed on modifying the policies, systems and environments that influence healthy eating and active living.

From 2008 to 2014, the initiative provided support for 49 multidisciplinary and cross-sectoral partnerships in disadvantaged areas of the USA. Rather than specify particular activities, funder requirements included a series of principles for grant holder partnerships, which identified priority actions according to their local contexts.

As well as focusing on policies and environments, the local partnerships had to incorporate a wide range of stakeholders including community groups, public authorities, and the private sector; collaborations had an average of 29 partners. Engaging communities and building stronger links between stakeholders were core to the project, with technical assistance and peer support provided to help partnerships progress.

The initiative also included an extensive independent evaluation to document impact, local implementation, and the community system response to the intervention.

One action of this evaluation was to engage communities in group model building to develop systems maps of influences on healthy eating and active living. These activities helped to build community capacity to apply systems thinking to social challenges.

The community partnerships helped identify 715 policy and practice changes to improve access to healthy affordable food, 576 policy and practice changes to enhance safe physical activity, and 828 changes in the built environment. Beyond this, the initiative helped to build community capacity to organise and advocate for change, and in some cases led to the adoption of more active community engagement by public authorities. In many cases, partnerships continued after the end of Healthy Kids, Healthy Communities funding, while the initiative has provided a template for other similar programmes globally.

Active Living by Design. Growing a Movement: Healthy Kids, Healthy Communities final report. 2014. Healthy Places by Design. Available at: <https://healthyplacesbydesign.org/project/robert-wood-johnson-foundation/>

The Strunk SL, Bussell JB. [Healthy Kids, Healthy Communities national program](#). J Public Health Manag Pract. 2015;21 Suppl 3:S1-3. doi: 10.1097/PHH.0000000000000188.

Brennan LK, Sabouchi NS, Kemner AL, Hovmand P. [Systems thinking in 49 communities related to healthy eating, active living, and childhood obesity](#). J Public Health Manag Pract. 2015;21 Suppl 3:S55-69. doi: 10.1097/PHH.0000000000000248.

Brennan LK, Brownson RC, Kauh TJ. [Evaluation of Healthy Kids, Healthy Communities](#). J Public Health Manag Pract. 2015;21 Suppl 3:S4-7. doi: 10.1097/PHH.0000000000000186.

Brownson RC, Kemner AL, Brennan LK. [Applying a mixed-methods evaluation to Healthy Kids, Healthy Communities](#). J Public Health Manag Pract. 2015;21 Suppl 3(Suppl 3):S16-26. doi: 10.1097/PHH.0000000000000233.

Sallis JF. [Advancing systems thinking through the Healthy Kids, Healthy Communities evaluation](#). J Public Health Manag Pract. 2015;21 Suppl 3(Suppl 3):S88-9. doi: 10.1097/PHH.0000000000000246.

Case study 5: Healthy eating

Low-income communities typically have limited access to healthy foods, contributing to poorer diets and increased risk of obesity and its detrimental health consequences. However, the mechanisms through which socioeconomic disadvantage affect food choices remain poorly understood.

In order to gain a clearer picture in a low-income area of Baltimore, Mui et al. undertook a participatory community-based workshop involving residents, owners of food outlets, neighbourhood organisations, and city agencies. The two-day workshop included interactive and iterative group model-building exercises in order to develop a systems-based map of the dynamic factors affecting the local food ecosystem.

The workshop identified 21 factors, with feedback loops, influencing healthy food availability and consumption. Notably, concerns about crime emerged as particularly significant, with healthy food being seen as ‘risky food’. Fear of crime also disrupted social ties that might promote healthier eating.

By taking a participative and systems-based approach, the study identified important factors that might not otherwise have been considered as affecting food choices. It has also highlighted points at which interventions might address both crime and access to healthy food.

Mui Y, Ballard E, Lopatin E, Thornton RLJ, Pollack Porter KM, Gittelsohn J. A community-based system dynamics approach suggests solutions for improving healthy food access in a low-income urban environment. PLoS One. 2019;14(5):e0216985. doi: 10.1371/journal.pone.0216985.

Case study 6: Modelling physical activity

An agent-based model captures some of the complex web of factors that influence leisure-time physical activity.

The health and wellbeing benefits of physical exercise are well established, and multiple public health initiatives have attempted to increase leisure-time physical activity. However, very few have delivered meaningful and sustained increases in physical activity levels.

In part, this may reflect the fact that public health initiatives have typically targeted individual decision-making without taking into account the multiple other factors that influence physical activity behaviours. In reality, leisure-time physical activity is a complex, multidimensional behaviour influenced by a network of dynamically interacting factors spanning the nature of the local built environment, a person's social environment, and psychological traits.

Agent-based models provide a methodology for capturing some of this complexity and exploring how intervening at different points might influence physical activity levels. This area has a distinct advantage from a modelling perspective as much is already known about the factors that influence physical activity at different levels, and agent-based modelling provides an opportunity to compile these insights into an integrated systems-based model that incorporates systems dynamics, such as feedback loops.

Florindo and colleagues drew upon existing theories and models, plus empirical data and expert review, to develop a dynamic framework for explaining population patterns of leisure-time physical activity. This framework was then used to develop an agent-based model of a stylised community incorporating interactions between human agents and physical agents (site of physical activity). The model was able to reproduce temporal trends of intention to exercise and leisure-time physical activity reported in the literature.

The model provides insights into factors having the greatest impact on activity levels, as well as a starting point for exploring the impact at interventions at particular points in the system being mapped. There is scope to adapt the model for alternative settings and, over time, it could be further developed to include a wider range of influences on physical activity and updated as more empirical data are gathered.

Garcia LMT, Diez Roux AV, Martins ACR, Yang Y, Florindo AA. [Development of a dynamic framework to explain population patterns of leisure-time physical activity through agent-based modeling](#). Int J Behav Nutr Phys Act. 2017;14(1):111. doi: 10.1186/s12966-017-0553-4.

Garcia LMT, Diez Roux AV, Martins ACR, Yang Y, Florindo AA. [Exploring the emergence and evolution of population patterns of leisure-time physical activity through agent-based modelling](#). Int J Behav Nutr Phys Act. 2018;15(1):112. doi: 10.1186/s12966-018-0750-9.

Case study 7: Healthier cities in Latin America

The SALURBAL programme is taking a systems-based approach to explore the determinants of health in Latin American cities.

More than 80% of Latin America's population lives in cities. In general, urban living is associated with improved health outcomes, but this masks substantial heterogeneity within cities and trends that are driving an increased risk of non-communicable diseases. Conversely, several Latin American cities have taken innovative steps to improve city living, such as mass transport systems and legislation to reduce air pollution, with the potential to improve health outcomes.

Cities are complex adaptive systems in which health outcomes are affected by multiple interacting influences. To gain a clearer picture of these systems in Latin America, the SALURBAL programme has brought together an interdisciplinary research team spanning 14 institutions from eight countries in Latin America and the USA. It is analysing data from 371 cities and nearly 1500 sub-city units in 11 Latin America countries. The programme has a particular focus on diet and urban transport systems, which are critical influences on lifestyle choices affecting health and represent important targets of Latin American policy initiatives.

The programme has invested great efforts into aggregating standardised data on health outcomes and social determinants of health across different urban centres. This has helped to reveal marked heterogeneity in health outcomes, including life expectancy, both within and between cities – up to 15 years within a single city. Its analyses have also identified associations between variation in life expectancy and modifiable risk factors, pointing to possible opportunities for intervention.

The programme has also undertaken participatory stakeholder engagement activities in three cities to map out the complex web of interactions that influence food

consumption behaviours and transport, emphasising the inter-relatedness of the two areas. It also plans to go further, to develop agent-based modelling that will enable the potential impact of interventions to be assessed.

A further aim of the programme is to investigate 'natural experiments' – policy interventions in transport or food policy – to determine their full impact, including unanticipated effects. For example, the interdisciplinary TrUST study is examining the impact of a new mass transit cable car system in Bogota, Colombia, on environmental and social determinants of health, and is also engaging with communities to gain their perspectives on its advantages and disadvantages.

Bilal U, Alazraqui M, Caiaffa WT, Lopez-Olmedo N, Martinez-Folgar K, Miranda JJ, Rodriguez DA, Vives A, Diez-Roux AV. Inequalities in life expectancy in six large Latin American cities from the SALURBAL study: an ecological analysis. *Lancet Planet Health*. 2019;3(12):e503-e510. doi: 10.1016/S2542-5196(19)30235-9.

Bilal U, Hessel P, Perez-Ferrer C, Michael YL, Alfaro T, Tenorio-Mucha J, Friche AAL, Pina MF, Vives A, Quick H, Alazraqui M, Rodriguez DA, Miranda JJ, Diez-Roux AV; SALURBAL group. Life expectancy and mortality in 363 cities of Latin America. *Nat Med*. 2021. doi: 10.1038/s41591-020-01214-4.

Sarmiento OL, Higuera-Mendieta D, Wilches-Mogollon MA, Guzman LA, Rodríguez DA, Morales R, Méndez D, Bedoya C, Linares-Vásquez M, Arévalo MI, Martínez-Herrera E, Montes F, Meisel JD, Useche AF, García E, Triana CA, Medaglia AL, Hessel P, Arellana J, Moncada C, King AC, Diez Roux AV. Urban Transformations and Health: Methods for TrUST-a Natural Experiment Evaluating the Impacts of a Mass Transit Cable Car in Bogotá, Colombia. *Front Public Health*. 2020;8:64. doi: 10.3389/fpubh.2020.00064.

Langellier BA, Kuhlberg JA, Ballard EA, Slesinski SC, Stankov I, Gouveia N, Meisel JD, Kroker-Lobos MF, Sarmiento OL, Caiaffa WT, Diez Roux AV; SALURBAL Group. Using community-based system dynamics modeling to understand the complex systems that influence health in cities: The SALURBAL study. *Health Place*. 2019;60:102215. doi: 10.1016/j.healthplace.2019.102215.

Quistberg DA, Diez Roux AV, Bilal U, Moore K, Ortigoza A, Rodriguez DA, Sarmiento OL, Frenz P, Friche AA, Caiaffa WT, Vives A, Miranda JJ; SALURBAL Group. Building a Data Platform for Cross-Country Urban Health Studies: the SALURBAL Study. *J Urban Health*. 2019;96(2):311-337. doi: 10.1007/s11524-018-00326-0.

Diez Roux AV, Slesinski SC, Alazraqui M, Caiaffa WT, Frenz P, Jordán Fuchs R, Miranda JJ, Rodriguez DA, Dueñas OLS, Siri J, Vergara AV. A Novel International Partnership for Actionable Evidence on Urban Health in Latin America: LAC-Urban Health and SALURBAL. *Glob Chall*. 2018;3(4):1800013. doi: 10.1002/gch2.201800013.

• SALURBAL is supported by the Wellcome Trust.

Case study 8: Enhancing water security

The Revitalising Informal Settlements and their Environments (RISE) project is taking a systems-based approach to address water and sanitation challenges in informal settlements in Fiji and Indonesia.

More than a billion people live in informal settlements, mostly in low- and middle-income countries (LMICs), and their numbers are projected to increase. Informal settlements typically provide poor living conditions, with harmful impacts on health and wellbeing.

One of the biggest threats to health is high exposure to water-borne and other pathogens, reflecting widespread environmental contamination linked to inadequate clean water supplies and sanitation services. In addition, many settlements are at risk of flooding and tidal inundation because of inadequate water management; risks that will be magnified by climate change.

Typical water, sanitation and hygiene (WASH) initiatives attempt to disrupt transmission of pathogens, often focusing on individual behaviours, but have had limited success. The RISE project is taking a more systems-based approach, focusing on multiple aspects of water management in communities in an attempt to improve local environments, reduce exposure to environmental pathogens, and deliver additional benefits that enhance health and wellbeing, including greater community resilience.

The project has assembled a wide range of potential water management solutions, at household and community levels, and is engaging with communities to identify those most appropriate to local contexts. It is working with 12 settlements in Fiji and 12 in Indonesia, to provide a variety of contexts.

RISE is being organised as a cluster randomised trial, with half the settlements in each country acting as intervention sites and half as controls. The trial is focusing on the health of children under five, who are at particular risk of infection, but many other health, wellbeing and environmental factors will also be assessed.

The RISE project recognises the complex interplay between multiple factors that affect communicable disease, health more generally and wellbeing, including environmental conditions, urbanisation, water and sanitation, gender and socioeconomic equity, and climate change. Although its primary focus is on health, it also aims to build longer-term community cohesion and resilience to environmental and climate change. By organising the initiative as a randomised controlled trial, including evaluations of feasibility, impact and economics, it also aims to generate evidence that would support the use of similar approaches in different settings.

<https://www.rise-program.org>

Leder K, Openshaw JJ, Allotey P, Ansariadi A, Barker SF, Burge K, Clasen TF, Chown SL, Duffy GA, Faber PA, Fleming G, Forbes AB, French M, Greening C, Henry R, Higginson E, Johnston DW, Lappan R, Lin A, Luby SP, McCarthy D, O'Toole JE, Ramirez-Lovering D, Reidpath DD, Simpson JA, Sinharoy SS, Sweeney R, Taruc RR, Tela A, Turagabeci AR, Wardani J, Wong T, Brown R; RISE Consortium. Study design, rationale and methods of the Revitalising Informal Settlements and their Environments (RISE) study: a cluster randomised controlled trial to evaluate environmental and human health impacts of a water-sensitive intervention in informal settlements in Indonesia and Fiji. *BMJ Open*. 2021;11(1):e042850. doi: 10.1136/bmjopen-2020-042850.

• RISE is supported by the Wellcome Trust.

Case study 9: Schools as complex systems

The 'Learning Together' intervention, designed to address bullying, treats schools as a complex system.

Bullying is a major cause of mental health problems in children, with both short- and long-term consequences for health and wellbeing. To address bullying, a complex, multi-component intervention was developed, 'Learning Together', that targets the overall culture within a school, engaging with both students and teaching staff.

The first strand of the intervention targets schools' policies and processes; the second focuses on 'restorative practice' (activities to prevent or resolve conflicts between students or between students and staff); and the third strand encompasses social and emotional education, to provide students with the skills needed to manage their emotions and relationships.

Some evidence exists that these approaches can be beneficial, but they have not been rigorously evaluated in combination. After successfully piloting Learning Together, it was evaluated in the INCLUSIVE cluster randomised trial, in which 20 schools in the South-East of England introduced the programme, while 20 schools continued with their normal anti-bullying activities.

After three years, the trial found that Learning Together had a small but significant impact on bullying, likely to have population-wide benefit. It also identified positive 'spill over' effects on other health and wellbeing outcomes, including improved psychological function, wellbeing and quality of life, as well as reduced police contact and smoking. Given these impacts, the INCLUSIVE team also

looked for and found further benefits in terms of reduced e-cigarette use, cyberbullying, and truancy.

The study illustrates how a complex intervention can be evaluated in a cluster randomised controlled trial assessing multiple outcomes. An embedded process evaluation explored some of the factors associated with implementation and impacts. Comparatively low fidelity for the curriculum-related aspects of the intervention, for example, suggests that they made relatively small contributions to the beneficial outcomes.

More generally, the study illustrates that beneficial outcomes for individuals can be achieved through a systems-based approach, and not just through targeting of the individuals themselves.

Bonell C, Allen E, Warren E, McGowan J, Bevilacqua L, Jamal F, Legood R, Wiggins M, Opondo C, Mathiot A, Sturgess J, Fletcher A, Sadique Z, Elbourne D, Christie D, Bond L, Scott S, Viner RM. [Effects of the Learning Together intervention on bullying and aggression in English secondary schools \(INCLUSIVE\): a cluster randomised controlled trial](#). *Lancet*. 2018;392(10163):2452-2464. doi: 10.1016/S0140-6736(18)31782-3.

Bonell C, Allen E, Warren E, McGowan J, Bevilacqua L, Jamal F, Sadique Z, Legood R, Wiggins M, Opondo C, Mathiot A, Sturgess J, Paparini S, Fletcher A, Perry M, West G, Tancred T, Scott S, Elbourne D, Christie D, Bond L, Viner RM. [Modifying the secondary school environment to reduce bullying and aggression: the INCLUSIVE cluster RCT](#). 2019. Southampton (UK): NIHR Journals Library

Bonell C, Dodd M, Allen E, Bevilacqua L, McGowan J, Opondo C, Sturgess J, Elbourne D, Warren E, Viner RM. [Broader impacts of an intervention to transform school environments on student behaviour and school functioning: post hoc analyses from the INCLUSIVE cluster randomised controlled trial](#). *BMJ Open*. 2020;10(5):e031589. doi: 10.1136/bmjopen-2019-031589.

Warren E, Melendez-Torres GJ, Viner R, Bonell C. [Using qualitative research to explore intervention mechanisms: findings from the trial of the Learning Together whole-school health intervention](#). *Trials*. 2020;21(1):774. doi: 10.1186/s13063-020-04688-2.

• The INCLUSIVE trial was supported by the UK National Institute for Health Research and the Education Endowment Foundation.

Case study 10: Sustainable and healthy

The Complex Urban Systems for Sustainability and Health (CUSSH) initiative is taking a systems-based approach to the challenge of creating sustainable and healthy cities.

A growing proportion of the world's population are living in cities. Urban areas face the twin challenges of climate change and other environmental issues, as well as city-related health problems and health inequalities. Addressing these challenges calls for system-wide approaches that recognise the multiplicity and complexity of interactions and the potential for unintended consequences in complex city systems.

The CUSSH initiative is exploring how systems-based approaches can be applied at the city level to address both sustainability and population health and inequalities. It is using six cities on four continents, of contrasting income levels and sociocultural context, as test-beds to explore the use of systems-based approaches to inform city-level policy development and implementation.

Two cornerstones of the CUSSH approach are participatory activities to capture inputs from multiple stakeholders, including policymakers, practitioners, and communities; and modelling to simulate the complex network of interactions that affect health and environmental outcomes and to evaluate the impact of interventions. Areas of interest span energy generation, transport, green spaces, health systems, housing, and water and sanitation.

For example, participatory approaches have been used to develop system maps of factors affecting access to green space in London. As well as highlighting possible points of intervention, this exercise also revealed how creating new green space could impact the desirability of neighbourhoods and house prices, potentially leading to gentrification and worsening of health inequalities.

Other studies have addressed indoor air pollution in Nairobi, which highlighted the limited impact that clean

cooking initiatives could have, given the major contribution made by external sources to indoor pollution. Highly granular microsimulation – modelling of individuals – has been used to explore the potential health impacts of changes in air pollution levels in London. More refined microsimulation models are being developed that incorporate additional influences, including behavioural factors affecting exposure to pollution.

CUSSH is therefore applying a cross-disciplinary approach combining participatory approaches and other forms of evidence gathering to explore the complex system dynamics of cities, to assess potential interventions, and to provide the tools for monitoring and evaluating policy changes. Sustainability and health are both critical challenges, yet neither can be considered in isolation – while more sustainable cities are likely to be healthier, that cannot be taken for granted, and the potential to worsen health inequalities must also be considered.

Pineo H, Moore G, Braithwaite I. Incorporating practitioner knowledge to test and improve a new conceptual framework for healthy urban design and planning. *Cities Health*. 2020;1-16. <https://www.tandfonline.com/doi/full/10.1080/23748834.2020.1773035>

Dianati K, Zimmermann N, Milner J, Muindi K, Ezech A, Chege M, Mberu B, Kyobutungi C, Fletcher H, Wilkinson P, Davies M. [Household air pollution in Nairobi's slums: A long-term policy evaluation using participatory system dynamics](#). *Sci Total Environ*. 2019;660:1108-1134. doi: 10.1016/j.scitotenv.2018.12.430.

Symonds P, Hutchinson E, Ibbetson A, Taylor J, Milner J, Chalabi Z, Davies M, Wilkinson P. [MicroEnv: A microsimulation model for quantifying the impacts of environmental policies on population health and health inequalities](#). *Sci Total Environ*. 2019;697:134105. doi: 10.1016/j.scitotenv.2019.134105.

Zimmermann N, Symonds P, Davies M, Wilkinson P, Dianati K, Taylor J, Milner J. (J). Urban systems complexity in sustainability and health: an interdisciplinary modelling study. *Lancet Planetary Health*. 2018; 2:S21. [https://doi.org/10.1016/S2542-5196\(18\)30106-2](https://doi.org/10.1016/S2542-5196(18)30106-2)

Pineo H, Turnbull ER, Davies M, Rowson M, Hayward AC, Hart G, Johnson AM, Aldridge RW. [A new transdisciplinary research model to investigate and improve the health of the public](#). *Health Promot Int*. 2020 Jan 15;daaa125. doi: 10.1093/heapro/daaa125.

Zimmermann N, Symonds P, Dianati K, Baghaei Lakeh A, Robertson L, Wilkinson P, Davies M. A participatory process for modelling green infrastructure implementation in London. *SALUS*. 2020; 11 February 2020. <https://www.salus.global/article-show/a-participatory-process-for-modelling-green-infrastructure-implementation-in-london>

• CUSSH is supported by the Wellcome Trust.

Annex 1 List of Expert Group members

- Professor Susan Jebb FMedSci (Co-Chair), Professor of Diet and Population Health, University of Oxford
- Professor Diane Finegood FCAHS (Co-Chair), Professor, Centre for Dialogue, Simon Fraser University
- Professor Ana Diez Roux, Dean and Distinguished University Professor of Epidemiology, Drexel University
- Professor Harry Rutter, Professor, Department of Social & Policy Sciences, University of Bath
- Professor John Clarkson FEng, Professor of Engineering Design, University of Cambridge
- Professor John Frank FCAHS, Chair in Public Health Research and Policy, University of Edinburgh
- Professor Noralou Roos FRSC, Professor of Health Policy, University of Manitoba
- Professor Chris Bonell, Professor of Public Health Sociology, London School of Hygiene and Tropical Medicine
- Professor Susan Michie FMedSci, Professor of Health Psychology and Director of the Centre for Behaviour Change, University College London
- Professor Penny Hawe, Senior Lecturer in the School of Public Health, University of Sydney