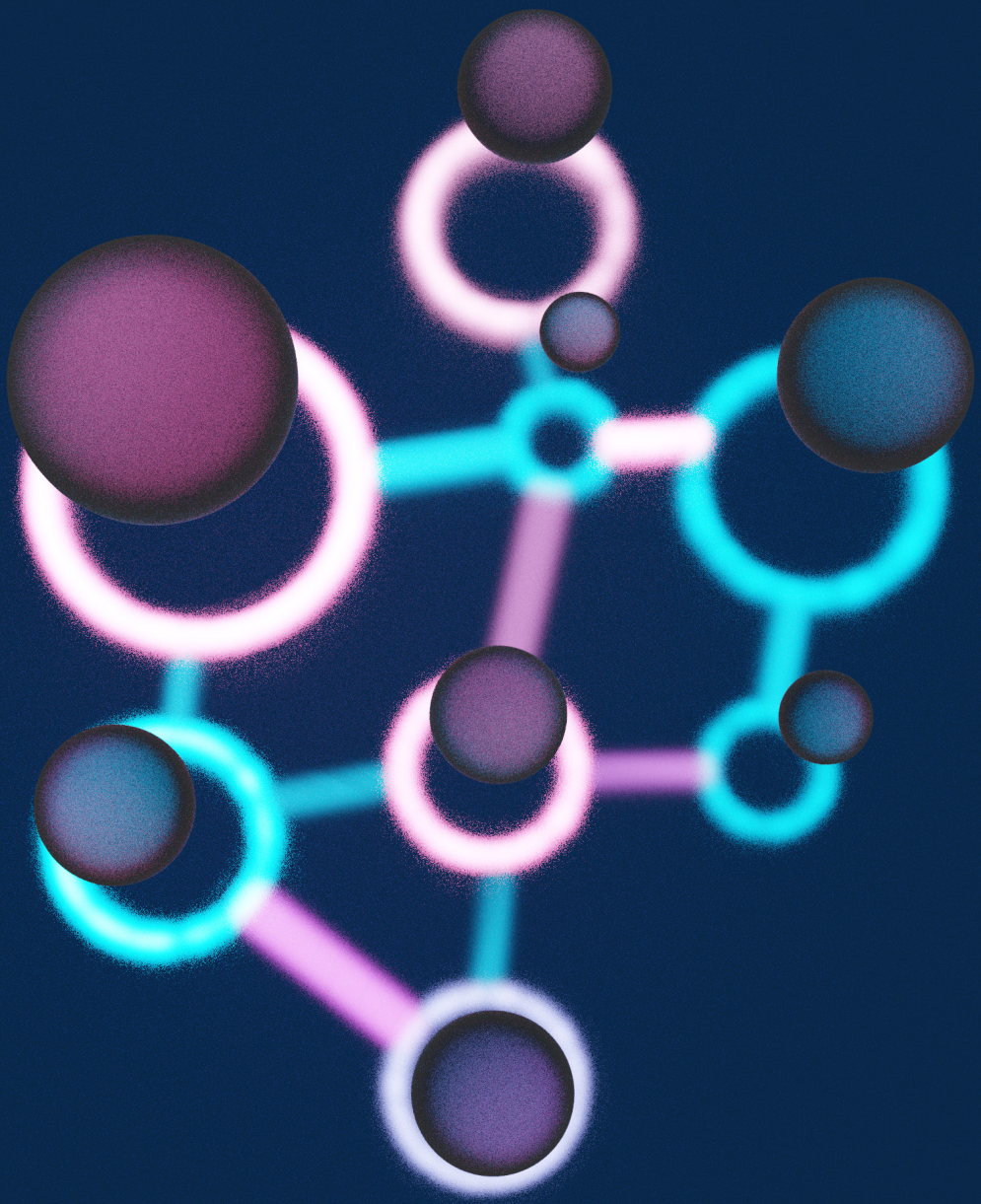
Systems thinking for noncommunicable disease prevention policy

Guidance to bring systems approaches into practice



World Health Organization
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Abstract

Systems thinking is a comparatively novel but rapidly developing area of knowledge that can offer a number of approaches to address complex public health problems such as the prevention of noncommunicable diseases (NCDs). The use of systems approaches can potentially contribute to the development of effective evidence-informed policies, encourage stakeholder involvement in the decision-making process and improve the coherence of policy implementation. This guidance provides a comprehensive overview of the systems approaches that can be applied to the different stages of the policy cycle: (i) problem identification and policy analysis; (ii) policy development; (iii) policy implementation; and (iv) policy monitoring, enforcement and evaluation. Several systems approaches used throughout the policy process are illustrated with a list of comprehensive case studies that demonstrate practical applications in NCD prevention policy. The guidance also includes a practical decision aid based on the benefits and limitations of each approach. By weighing resource considerations and potential benefits, this decision aid is designed to support the selection of an appropriate approach when considering incorporating systems thinking into the policy cycle.

KEYWORDS

SYSTEMS ANALYSIS, NONCOMMUNICABLE DISEASES, POLICY-MAKING, HEALTH POLICY, STAKEHOLDER PARTICIPATION, CAPACITY-BUILDING

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Contents

Foreword

Noncommunicable diseases (NCDs), particularly cardiovascular diseases, diabetes, cancer, chronic respiratory diseases and mental disorders, are responsible for approximately 90% of deaths and 85% of years lived with disability in the WHO European Region. Equally, behavioural risk factors that have a significant impact on the development of these diseases, such as tobacco and alcohol use, unhealthy diet and insufficient physical activity, can be successfully prevented.

It is well recognized that prevention of NCDs is a multilayered, complex public health issue that cannot be effectively addressed using a one-size-fits-all approach. Systems thinking is a comparatively novel but rapidly developing area of knowledge that can offer a number of approaches to support policy-makers in tackling NCDs. It encourages policy-makers to adopt a broader viewpoint, recognizing how people, populations and organizations act and evolve in response to each other and their varying contexts. Given the interrelated causes of many NCDs and the complex contexts in which policies are designed, the value of systems thinking in NCD prevention policy is becoming increasingly recognized. It can contribute to the development of effective evidence-informed policies, ensure stakeholder involvement in the decision-making process and improve the coherence of policy implementation.

However, it can be difficult to enter into and navigate the nebulous concept of systems thinking without guidance, and even more challenging to choose the right approach. The WHO European Office for the Prevention and Control of NCDs continues to support policy-makers in Member States by developing this guidance to introduce systems thinking in an applied way, underpinned by a theoretical framework and illustrated by a range of practical case studies. The guidance provides a user-friendly decision aid that can guide the decision-making process on selecting an approach to incorporating systems thinking into the policy cycle.

The application of a systems thinking lens will enable policy-makers to consider preventive policies, taking into account other determinants of health. It will help them to recognize the potential impacts of policies implemented in the dynamic contexts, facilitate consensus-building among stakeholders and increase the transparency of the policy cycle.

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Abbreviations

ABM agent-based modelling

CLD causal loop diagram

CVD cardiovascular diseases

FCTC Framework Convention on Tobacco Control

GMB group model building

HiAP Health in All Policies

NAN nutrition actor network

NCD noncommunicable disease

NGO nongovernmental organization

QCA qualitative comparative analysis

SDM system dynamics modelling

1. About this guidance

There is increasing interest in the potential of systems thinking for solving complex population health problems. Previous WHO publications have introduced the key concepts underpinning systems thinking applied to other health-related domains, for example when applied to health systems strengthening *(1)*. Policies aimed at preventing noncommunicable diseases (NCDs), which overlay the complexity of the policy process onto the complex causal drivers of NCDs, are an emergent but rapidly growing area of application for systems approaches.

To support growing practitioner interest, this guidance focuses on how approaches informed by systems thinking can be used to support policy-making for NCD prevention. Applying systems thinking in policy and practice can be challenging: while many policy-makers agree with systems thinking in principle, they may struggle to see the practical utility of it in their work *(2,3)*. The intention behind this guidance is to help interested practitioners to learn about a range of systems approaches that may be relevant for their work and assess their suitability while considering the resource implications and benefits.

This guidance, informed by a recent systematic scoping review *(4)*, builds on existing publications by summarizing how systems thinking has been applied to NCD prevention policy in real-world contexts. Given the range of systems approaches that are applied in the NCD prevention policy space, a detailed manual of how to apply all of the included systems approaches is beyond the scope of this guidance. Instead, the focus is to introduce the reader to real-world examples of systems approaches in action, focusing on the practical aspects of how systems approaches are used throughout the policy process.

The guidance is organized into three main sections followed by a concluding section. Section 2, Systems thinking and approaches for NCD prevention policy, provides a brief introduction to systems thinking and describes a range of systems approaches that have been used in the area of NCD prevention policy. Section 3, Bringing systems approaches into practice, presents a series of considerations to inform the choice of approach, and insights on their use drawn from the literature. Section 4, Systems approaches in action, introduces accompanying case studies to illustrate the practical applications of these approaches in NCD prevention policy.

2. Systems thinking and approaches for NCD prevention policy

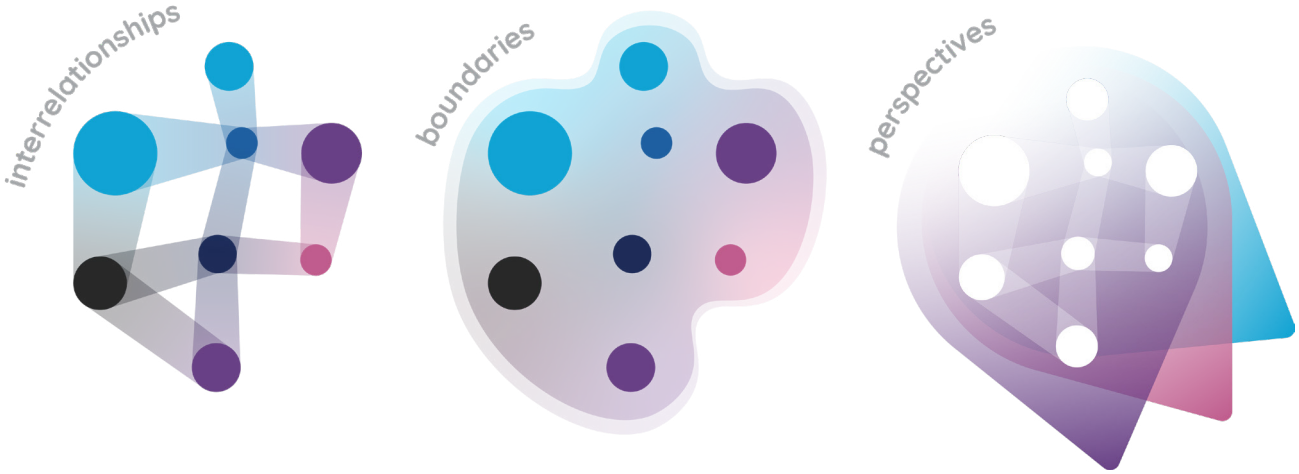
2.1 What is systems thinking?

Systems thinking includes established and emergent ideas and methods that encourage us to look at the bigger picture. Consequently, it is broadly characterized by the idea that real-world phenomena exist within systems composed of dynamic actors including people, populations and organizations, all acting and evolving in response to each other and their contexts *(5,6)*. Health-care systems can be understood in this way, as can other systems with direct health impacts such as transport, education and food systems.

Key elements in systems thinking include *(7)*:

- interrelationships (connections between elements of the system);
- multiple perspectives (the acknowledgement that understanding a system requires approaching the system from different points of view); and
- boundaries (definitions of what lies within and beyond the system of interest).

As well as emphasizing the network of connections between different elements, systems thinking also emphasizes the idea that elements may relate to each other in nonlinear ways. This can make the outcomes of intervening in a complex system, for example by implementing a policy, difficult to predict.



Systems thinking offers a broader perspective on how phenomena relate to one another within the overall context and provides insights to inform effective ways of intervening in a complex system to achieve desired outcomes, identifying leverage points that have the potential to maximize impact. It takes into account the fact that interactions between system components can lead to unexpected outcomes, and that interventions within systems can have unintended consequences. For example, a tax on tobacco may lead consumers to switch to a brand of cigarettes that is cheaper, but higher in tar and nicotine *(8)*. Less-affluent consumers may be more likely to make this switch, potentially making inequities in health outcomes worse.

Table 1 defines some of the key concepts in systems thinking. A range of resources and guidance covering systems thinking in various health-related fields are also available (Annex 1).

Table 1. Key concepts in systems thinking

Concept	Definition
Systems thinking	A set of ideas and methods which encourage us to look at the bigger picture
Systems approaches	Specific methods or methodologies (a set of procedures for gathering or interpreting data and/or evidence) informed by systems thinking principles
Leverage point	A point in a system where a small intervention can lead to substantial, system-wide changes
Unintended consequence	Response provoked when intervening in a system that is unintended or difficult to predict (can be harmful or beneficial)
Nonlinear relationship	A relationship between two elements in a system where the cause does not produce a proportional effect
Feedback loop	A closed chain of causal connections resulting in the output of a system or system element feeding back into itself
Delay	An interval of time between cause and effect, which can create instability and fluctuations in system behaviour

Sources: WHO, 2009 *(1)*; Meadows,2008 *(6)*; Sterman, 2006 *(9)*.

2.2 What might systems thinking contribute to policy for NCD prevention?

Many of the theories and methods in use in systems thinking were primarily developed in business and management studies *(10)*. The resulting emphasis on dynamics within organizations makes systems approaches well adapted to health-related applications such as health-care delivery and health system strengthening *(1)*.

However, systems thinking can also be helpful in developing effective policies to prevent NCDs at the population level. Population strategies for preventing disease focus on shifting the distribution of a risk factor for the population as a whole *(11)*. This emphasis highlights that, along with the health-care system, many other systems or areas have significant impacts on health. Some of these may already be considered as systems; government departments, such as planning, transport or agriculture, may carry out work that impacts NCDs and may have overlapping responsibilities for factors that support or undermine NCD prevention. In addition, many other nongovernmental actors, including private companies or non-profit-making organizations, also have a role in shaping the environments that impact NCDs. In applying systems thinking to NCD prevention policy, all of these actors and organizations are considered as belonging to the same system. Depending on the specific NCD or risk factor, and the context of interest, boundaries of these systems can be drawn in different ways with a focus on different elements and relationships within the system in question.

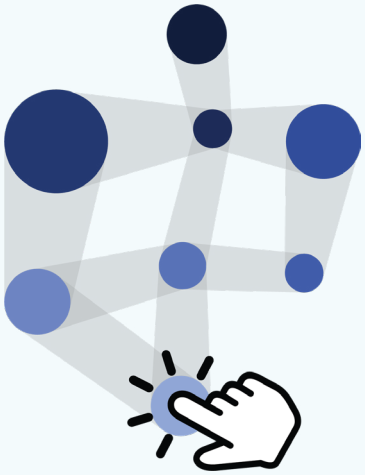
NCD prevention is characterized by several layers of complexity:

- a wide array of causal factors;
- a spread of responsibility for policies with direct and indirect effects on NCDs across multiple government departments; and
- a variety in the roles of nongovernment actors in shaping the environments that support or undermine NCD prevention.

Systems thinking can make a substantial contribution to NCD prevention by encompassing this complexity, facilitating consensus-building and stakeholder engagement, ensuring rigour and transparency in policy-making and supporting the development of policies that are coherent rather than counterproductive.

2.2.1 ENCOMPASSING COMPLEXITY

Frameworks for understanding and shaping the contexts that generate health outcomes have historically relied on linear models *(12)*. While these models have yielded substantial benefits, it is increasingly recognized that this reductionist thinking and practice has its limitations, and that a systems perspective on health practice, education, research and policy is required *(13)*.



This is particularly true in the context of policy for NCD prevention, where the causes of disease are complex and preventive policy is implemented by different government actors in a number of dynamic contexts. Systems thinking can be useful in assessing the impacts of policies that are removed from their potential outcomes in terms of time or causality, and in assessing what conditions might be necessary for a policy to be successful *(14)*. It can also help with identifying leverage points, the most effective places to intervene to create system-level change *(6)*. For example, after considering how urbanization, industry action and public policy interacted in an urban system, a community-based system dynamics workshop focused on urban health identified policy leverage points such as taxation on ultra-processed food and changes to urban planning policies *(15)*.

2.2.2 POLICY COHERENCE

By inviting us to adopt a broader viewpoint, systems thinking highlights how components fit together and interact. This is particularly important for NCD prevention policy, where the determinants of health may be under the control of many different government departments and responsibility may be shared across local, national and supranational levels. In light of this, a Health in All Policies (HiAP) approach is increasingly advocated for tackling NCDs. A systems perspective provides opportunities to identify ways of creating more coherent and synergistic policies and to consider how different policy activities may support each other or be counterproductive. It also provides a perspective allowing actors not traditionally aligned with health (for example in transport or taxation) to understand where they can or do contribute to health outcomes.

2.2.3 CONSENSUS-BUILDING, STAKEHOLDER ENGAGEMENT AND ENHANCING DEMOCRATIC PROCESSES

Systems thinking, and the approaches it informs, lends itself well to stakeholder engagement, as well as to communicating the processes and rationales underpinning policy decisions *(16)*. One of the key strengths of participatory systems approaches lies in facilitating consensus-building among stakeholders *(17,18)*. This can be achieved by inviting stakeholders to participate in the development of systems models and maps, facilitating agreement on an optimal policy strategy when tackling a given health problem *(17)*.

Just as systems approaches may be useful in building consensus between different actors involved in making and implementing policy, they may also be used to give a voice to members of th communities who may benefit from (or be harmed by) different policies. The policy process does not always give adequate weight to these perspectives, and the numerous participatory approaches informed by systems thinking can contribute to remedying this. Such an approach can be particularly important in the context of NCD prevention, where powerful actors, such as the tobacco, alcohol and food and beverage industries, as well as less-powerful actors, such as marginalized communities, all have interests at stake. While these approaches require time and investment in building relationships, they can support a more democratic and inclusive approach to policy-making.

2.2.4 RIGOUR AND TRANSPARENCY IN POLICY-MAKING

Policy practitioners already deal with complexity in their day-to-day work, balancing complex issues of aims and resources, and networks of individuals and organizations with their own interests and priorities. Systems approaches provide a framework for making these considerations explicit and transparent. Compared with unstructured methods, participatory approaches informed by systems thinking provide opportunities for in-depth and systematic use of the input from different stakeholders for many kinds of robust, quality evidence to inform decision-making.

2.3 What systems approaches have been used in making NCD prevention policy?

Systems thinking has informed the development of a range of specific approaches or methods (hereafter referred to as systems approaches) that can be usefully applied in NCD prevention policy. These range from more qualitative approaches such as concept mapping to quantitative computational modelling approaches such as system dynamics modelling (SDM) and agent-based modelling (ABM). This section introduces key systems approaches that have been used in NCD prevention policy.

2.3.1 RESEARCH WITH A SYSTEMS LENS: DOCUMENT ANALYSIS, QUALITATIVE RESEARCH AND CASE STUDY RESEARCH

A systems lens can be incorporated into more conventional approaches to research, guiding practitioners in understanding a system and deciding how to intervene within it. This can be a useful way of applying systems thinking to a problem without requiring additional modelling expertise or specialized software.

This approach can involve reflecting on how different parts of a system affect one another. Such a perspective may offer new insights when analysing policies that have been implemented by different parts of government; understanding the role of different government and nongovernment actors in supporting or undermining NCD prevention; and considering how the implementation of a new policy might fit into an existing system. Applying a systems lens enables the identification of gaps in the policy landscape and opportunities for improving synergy between policies or organizations *(19)*.

A systems lens can also inform participant recruitment for key informant interviews or focus groups. By having a good understanding of the system in question, practitioners can ensure that perspectives are gathered from relevant stakeholders across the system *(20)*.

Case study research, which allows for in-depth, multifaceted explorations of complex issues in their real-life settings, can also benefit from a systems lens *(21)*. Case study research is particularly well suited to this perspective, given that it also emphasizes complexity and holistic understanding. A systems lens can allow for the identification of underlying structural characteristics that are the same or differ across case studies and that may have significant repercussions for NCDs.

Applying a systems lens to research can provide added value by considering a comprehensive set of factors influencing NCDs; mapping how different actors and policies interact to support or undermine health; and engaging relevant stakeholders, yielding insights that enable so-called wicked problems (problems with a high level of complexity that are continually evolving and have multiple causes at different levels) to be tackled *(20)*.

2.3.2 CONCEPT MAPPING

Concept mapping is a qualitative approach to systems modelling. This is a relatively accessible way of exploring problems and solutions from a systems perspective and is also an effective tool for gathering stakeholder views and ensuring their engagement in a process.

A concept map may be drawn up during a single-day stakeholder workshop, although some studies may require multiple maps with different stakeholder groups or follow-up consultations. Concept maps may also be developed asynchronously, using input gathered from stakeholders through interviews. This can be useful where participants have time constraints and it is difficult to bring all participants together; it can also provide participants with space to voice perspectives they may find difficult to share more broadly *(22)*. Concept mapping can also be conducted online (Box 1), which can make it easier to collect perspectives from a large number of stakeholders, or stakeholders from many locations. Concept maps can provide insight into the various factors at play in NCD prevention and how these factors are associated with disease outcomes. Concept mapping is a useful means of avoiding piecemeal planning and uncoordinated policy actions *(26)*.

Box 1. Participatory approaches in the digital age

A key strength of many systems approaches is their participatory nature. Participatory approaches allow multiple perspectives on a system to be incorporated when trying to understand and intervene in systems. Given increasingly sophisticated and flexible platforms for digital communication, and particularly in light of the pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the resulting COVID-19, attempts have been made to develop online versions of these methods where participants can meet assemble in one virtual room. Concept mapping has a longer history of online formats, but online adaptations of group model-building are now also being undertaken. Determining whether an online format would work in a given context requires consideration of a number of factors:

- feasibility of in-person events
- quality of Internet connections
- participant access to suitable devices
- participant fluency with digital platforms.

Online approaches have many advantages in terms of reductions in cost, carbon footprint and time spent on travel. This can allow the participation of stakeholders who may otherwise have been excluded. However, it is also important to consider the potential downsides, including barriers to participation relating to poor or no Internet connectivity, or limited digital fluency, as well as potentially less lively discussion and debate in online formats.

Sources: Zimmermann et al., 2020 *(23)*; Wilkerson et al., 2020 *(24)*; Hayward et al., 2020 *(25)*.

2.3.3 COGNITIVE MAPPING

Cognitive mapping is a systems approach that leads to the creation of network diagrams representing relationships between factors *(27)*. This technique typically uses interviews to capture stakeholders' perspectives of a problem, and how they or their organizations relate to that problem *(22)*.

The interview process underpinning cognitive mapping often allows the interviewee to develop a more explicit, articulated understanding of the issue under discussion. Cognitive maps developed from individual interviews can be combined into a composite map representing the perspectives of different interview participants *(28)*. In these composite maps, the perspectives of different individuals are anonymized, allowing stakeholders to voice their perspectives without considering political ramifications, and to assess the perspectives put forward by others on their own merits, rather than their proponent's charisma or status *(28)*.

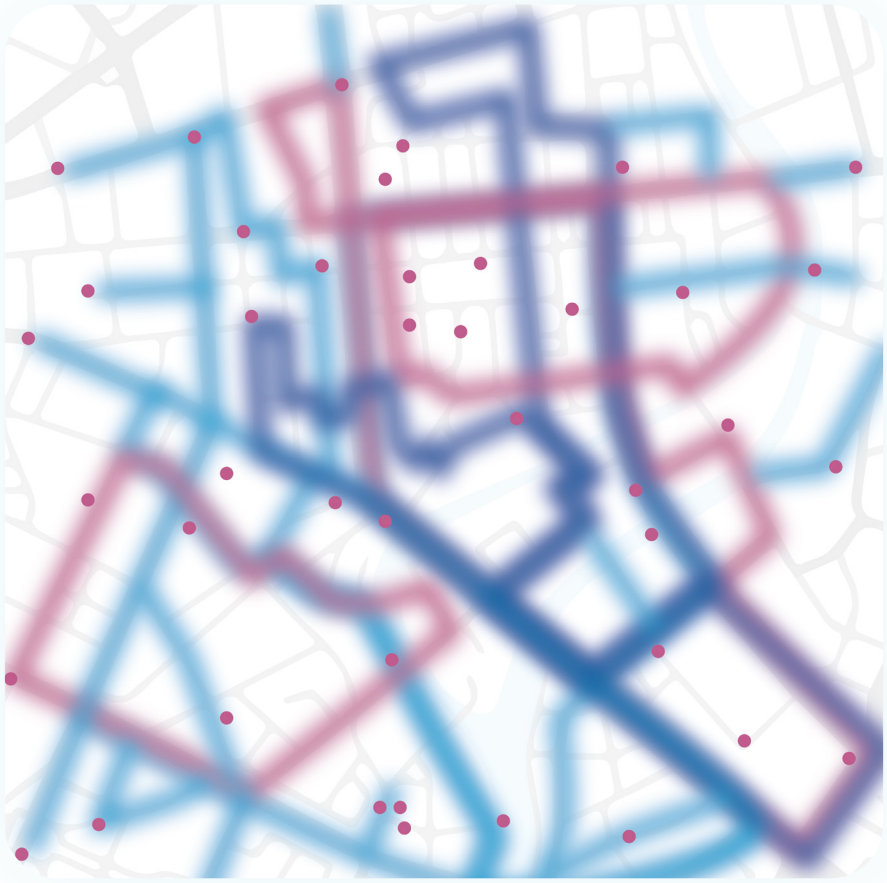
Cognitive mapping has traditionally been used in management studies or operational research, but recent literature has also applied it to understanding complex health problems, including in the context of NCD prevention policy *(19,22,29)*.

2.3.4 ABM

ABM is a quantitative approach to understanding systems behaviour and modelling the impacts of different policies. As an approach informed by systems thinking, ABM's advantage relative to other approaches to quantitative modelling lies in identifying potential unintended consequences of policies, and in comparing the impacts of different policy options when implemented within complex systems.

ABM is a disaggregated approach to modelling the behaviour of a system, simulating the behaviours and interactions of autonomous agents within specific environments. ABM can be used to model individual behaviours, health outcomes, knowledge and engagement in response to a proposed policy *(30)*. ABM can illustrate how simple rules governing individual behaviours translate into population-level impacts. This disaggregated approach can also shed light on mechanisms underlying the success or failure of policies *(30)*, with the potential to inform policy implementation in different contexts.

ABM can be informed by combinations of stakeholder input, as well as published data, theories and findings. The feasibility of developing such a model depends on the availability of data representing the different components of the model, or the capacity to collect the relevant data *(31)*. This type of modelling requires a relatively high level of expertise in systems mapping and computational methods.



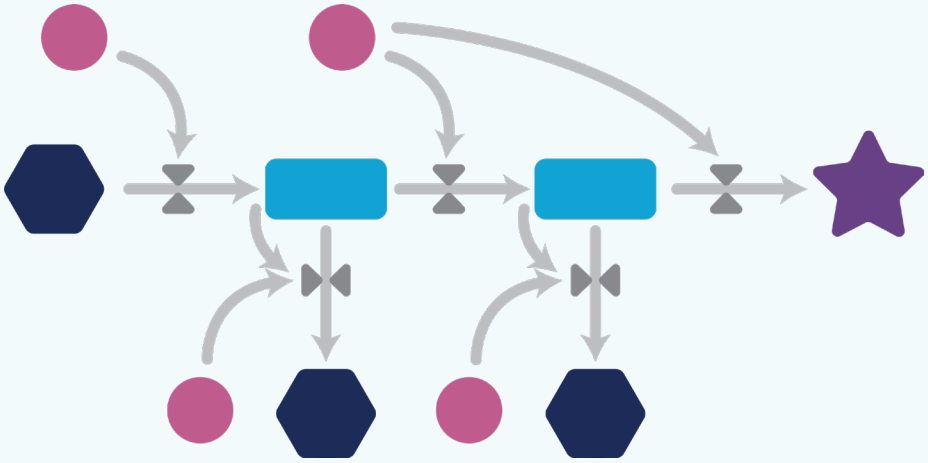
2.3.5 SDM

SDM is a typically quantitative approach to understanding systems behaviour and modelling the impacts of different interventions, although qualitative examples also exist. SDM can be used to test different policy options to identify the most effective, efficient and feasible solution. SDM provides insight as to how complex changes occur over time, examining how a change in one part of the system elicits changes across the system as a whole, and how this whole-system change can feed into future changes. SDM enables the identification of unexpected consequences that may emerge in a system over time.

Interactive SDM approaches may also be used as a catalyst to bring together different stakeholders involved in NCD prevention. These dynamic models allow stakeholders to test out different potential scenarios and see the impacts of different policy options on elements within the system. Such models can also be useful for provoking discussion around policy priorities and strategic directions, and ensuring all actors are working in a coherent way to best achieve desired outcomes *(32)*.

As many NCD prevention policies unfold in complex systems, provoking different kinds of change across the system, SDM can also be used to build understanding of how a policy works. Where a policy has been shown to achieve its desired outcome, this can provide insight as to whether and under what conditions the policy might be successfully replicated. Where a policy has been shown not to have had the desired effect, SDM can also help to clarify why this is the case *(33)*.

SDM can be informed by stakeholder input, datasets from different sources or published theories and findings. Qualitative models designed with stakeholder input can provide useful insight into the dynamics of a complex system. SDM can also be parameterized with published or surveillance data to provide quantitative estimates of the impacts of different policy options. SDM approaches require a relatively high level of expertise in systems mapping. Developing a model that produces quantitative estimates of the impacts of different policies also requires experience with computational approaches, as well access to and familiarity with specialized software. Hybrid models can also be developed for both SDM and ABM and with other methods such as qualitative comparative analysis (QCA) (Box 2).



Box 2. Combining systems approaches

The different systems approaches presented here are sometimes used in combination. In order to effectively represent the different characteristics and behaviours of complex systems, it is possible to develop hybrid models that incorporate SDM and ABM, as well as other modelling approaches. Different approaches to modelling can be selected to represent the dynamics of different system elements. Other methods presented here, such as concept mapping, network analysis and QCA have also been combined.

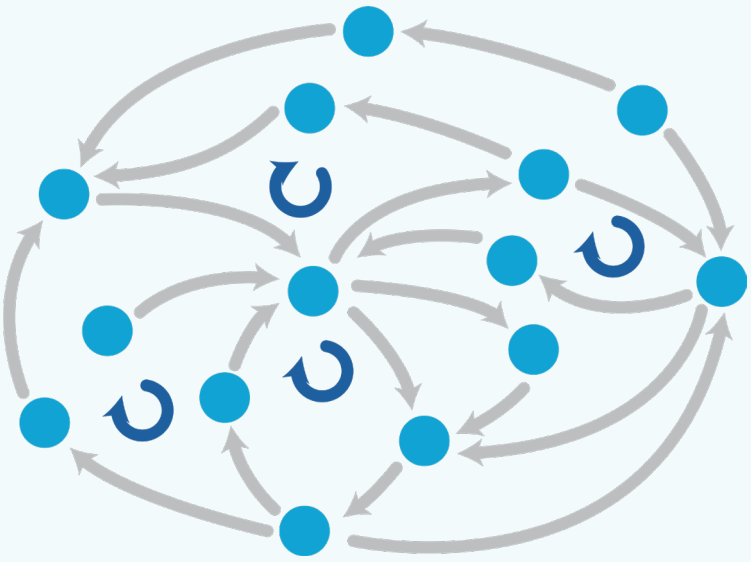
These approaches may be combined for different reasons, including making use of different types of data or representing different parts of a system. They may also be used sequentially, where the findings from one approach inform the design of a second.

Source: Barbrook-Johnson, Carrick, 2021 *(34)*.

2.3.6 CAUSAL LOOP DIAGRAMS

Causal loop diagrams (CLDs) map causal relationships between different elements within a system. CLDs can include a large number of variables across a system. They can provide increased understanding of how different factors inform policy decisions, and how policy systems fit together as a whole, as well as highlighting the relative importance of different factors and identifying points of leverage and resistance *(35)*.

CLDs are often built using stakeholder input, although document analysis and published findings may also be used. CLDs can be developed asynchronously, where a research team develops a CLD using data gathered from stakeholder interviews *(35)*, or synchronously during one or several participatory workshops *(36)*. Developing CLDs typically requires a reasonable amount of expertise in systems approaches, although it does not require the computational expertise and resource of quantitative modelling approaches.



2.3.7 GROUP MODEL BUILDING

Group model building (GMB) is a participatory approach to understanding systems *(37)*. It begins by bringing stakeholders together to articulate a problem and formulate hypotheses about how the system's behaviour is changing over time *(38)*. Quantitative analysis can then be undertaken to build a system dynamics model based on stakeholder input, which allows for quantitative modelling of different policy options. Alternatively, CLD models may be built based on stakeholder perspectives *(39)*.

In NCD prevention policy, stakeholders involved in this process can include policy-makers, technical experts and community members *(37)*. GMB workshops can take a day or less, although they do rely on bringing stakeholders together and on the presence of a facilitator trained in GMB methods. While GMB workshops have predominantly been undertaken in person, more recent adaptations have tested the use of these techniques through virtual platforms (see Box 1). GMB provides an opportunity for stakeholders to exchange views regarding a problem and collaboratively develop solutions to the problem in question. It is also an opportunity to develop consensus around an issue and to impart systems understanding to stakeholders *(25)*.

GMB has different uses in NCD prevention policy. GMB workshops can provide insight into how to intervene in the system by drawing insight from the different stakeholders who make up the system *(38)*. GMB can also be useful in providing a different perspective on how networks influence policy adoption, and in building consensus between stakeholders *(39)*. Finally, GMB can be useful in both designing policy evaluations, by identifying potential unintended consequences which need to be assessed, and in policy evaluations themselves, by highlighting impacts detected by community members *(36)*.

2.3.8 NETWORK ANALYSIS

Network analysis involves mapping connections between different people or organizations within a system. This approach can be useful for understanding the role that social and institutional networks play in supporting or undermining NCD prevention.

Network analysis allows influential individuals and organizations to be identified, yielding insights that can be useful in understanding how to move forward when trying to get a policy adopted *(40)*. It can help to identify informal networks of influence that may not be represented in organizational or legislative hierarchies *(41)*.

This approach can also be useful in evaluating the effectiveness of multisector collaboratives or bridging organizations. Given the complex causal origins of NCDs, many policy initiatives aimed at NCD prevention emphasize collaboration across sectors and organizations and a HiAP approach *(42,43)*. These approaches often rely on bridging organizations or a network structure to ensure policy coherence and coordinated action. Network analysis can be applied to evaluate the effectiveness of these connecting structures and identify disconnected individuals or organizations that need to be better integrated *(43)*. Network analysis can be used to make existing networks, composed of government institutions and nongovernmental organizations (NGOs) from multiple sectors, more efficient, effective and sustainable *(44)*.

In order to obtain the information required to perform a network analysis, members of a network are often surveyed to see how they relate to and interact with other organizations and individuals within the network, although relationships may also be inferred based on reviews of documents and publicly available information. These relationships are mapped and may be analysed quantitatively. Participants may also be asked to identify further network members, building an understanding of the extent of different networks that may not be formally documented *(41)*.

2.3.9 QCA

QCA has been applied to the evaluation of policies and interventions designed to target complex public health problems *(45,46)*. It is a way of analysing the contribution of different conditions to an outcome of interest. QCA begins by documenting the combinations of conditions that are associated with each case of an observed outcome. These conditions are then subjected to what is known as a minimization procedure: identifying the simplest set of conditions that can account for the presence (or absence) of the outcome *(47)*.

Some approaches to QCA can allow for conditions to be either present or absent, while others allow for conditions to be a matter of degree and vary along a spectrum *(47)*. QCA can be useful in policy evaluation, allowing multiple cases to be compared in order to determine which policy characteristics are most likely to contribute to policy success or failure.

QCA has the advantage of analysing multiple conditions, which can be particularly relevant for complex interventions. Necessary and sufficient causes of success may be identified, as can the combination of conditions that contribute to success. Further, the relative contributions of different conditions to success may also be explored.

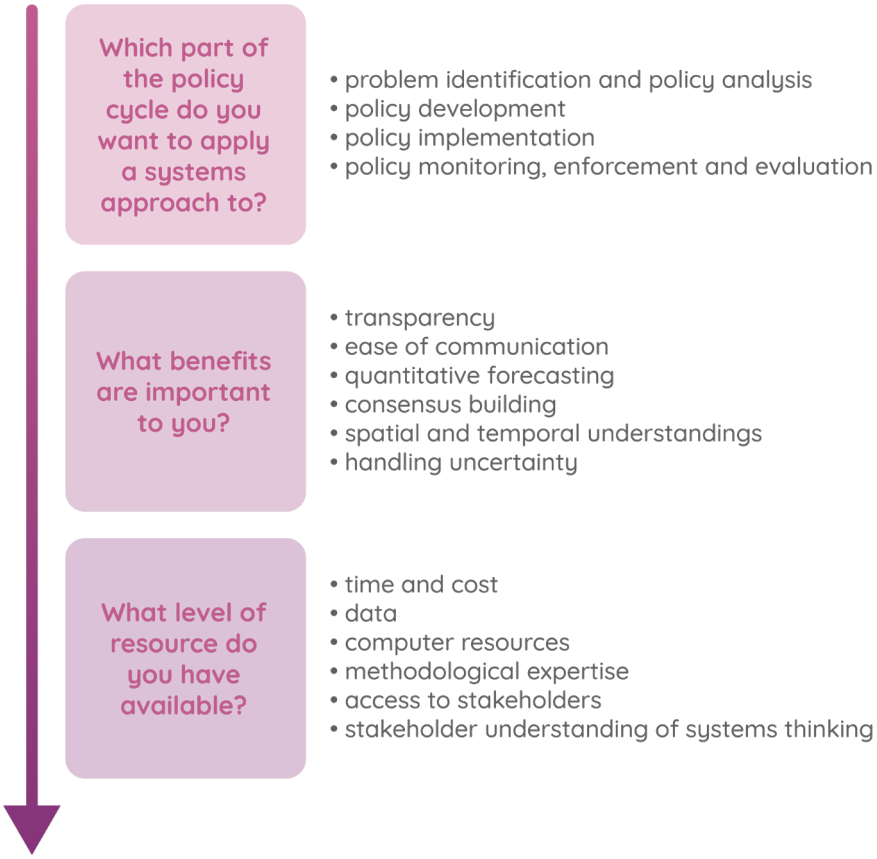
Against this, QCA may be less well adapted to taking into account change over time compared with some of the other methods presented in this guidance. Depending on the application, this may make it less adaptable for evaluating dynamic systems.

3. Bringing systems approaches into practice

3.1 Choosing a systems approach

Section 2 introduced some key principles underlying systems thinking, as well as describing the distinct approaches that have been applied throughout the NCD prevention policy process. This section introduces additional considerations when selecting a systems approach for use in a specific context (Fig. 1).

Fig. 1. Considerations when selecting a systems approach



The policy cycle stages describe different tasks that may need to be undertaken in the policy sphere, such as choosing between different policy options, or evaluating a policy that has been implemented. Depending on the task, some systems approaches may be better suited than others.

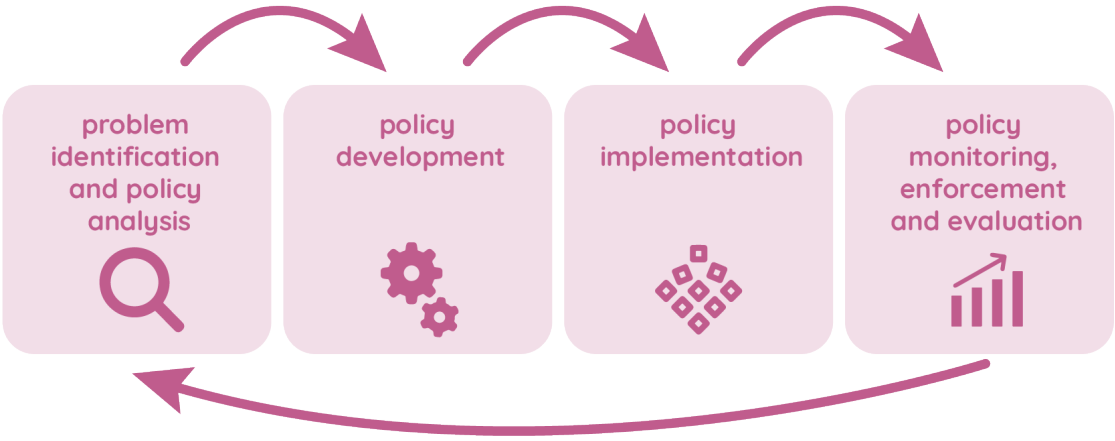
In addition, the systems approaches presented in this guidance vary in terms of the benefits they can provide, as well as in their resource implications. Deciding which benefits are most important and what resources can be devoted to the process are important considerations in selecting a systems approach.

3.1.1 TO WHICH PART OF THE POLICY CYCLE DO YOU WANT TO APPLY A SYSTEMS APPROACH?

When selecting a systems approach, it is worth considering what sort of task the approach is needed for. Policy-making may be thought of as a staged process or cycle of problem solving, moving from inputs, evidence about the problem to be solved and its potential solutions, through to outputs in the form of government actions, which can then be evaluated, generating further evidence about how best to solve different problems *(48)*.

Multiple versions of this policy process are in circulation, and systems thinking-informed approaches to understanding policy-making have emphasized its nonlinearity. Nevertheless, linear or cyclical models of the policy process remain in frequent use in policy and practice and can provide a pragmatic framework for thinking about the different tasks involved in policy work. The WHO policy cycle has been adopted for the purposes of this guidance *(49)*. This is broken down into four different stages (Fig. 2), to which various systems approaches may be applied. The stages of the policy cycle are defined in Table 2.

Fig. 2. The policy cycle



Source: adapted from WHO, 2010 *(49)*.

Table 2. Policy cycle stages

Policy cycle stage	Definition
Problem identification and policy analysis	Clarifying and framing the problem to be addressed, and assessing different policy options to identify the most effective, efficient and feasible solution
Policy development	Identifying a strategy for formulating the policy, setting up the framework needed to get it adopted and developing an understanding of how the policy will operate
Policy implementation	Following procedures for getting a policy enacted and translating the enacted policy into action
Policy monitoring, enforcement and evaluation	Monitoring the uptake and ensuring the full implementation of a policy and assessing the impact and outcomes of the policy; from this, policy improvements can be made if necessary

3.1.2 WHAT LEVEL OF RESOURCES IS AVAILABLE?

In addition to identifying the policy cycle stage that a systems approach is required for, it is important to reflect on the different types and level of resource that could be allocated to implementing the approach. These are defined in Table 3. As illustrated by the case studies presented in Section 4, there is substantial variation within each individual systems approach in terms of the complexity and resource required, as well as in the type of data used. The estimates below provide a broad idea of resource requirements and were informed by Voinov and colleagues' survey of practitioners involved in participatory modelling approaches *(50)* as well as inferences based on the authors' descriptions of the processes they undertook.

Table 3. Resources needed to implement systems approaches

Resource	Description
Time and cost	Systems approaches can require time and funds for implementation, sometimes requiring workshops, software and personnel with different types of expertise: ● GMB, which usually involves workshops, a multistep process and systems expertise, is coded as requiring a high level of time and funds ● other approaches are predominantly coded as requiring a medium level of time and funds ● CLDs and concept mapping, which may yield insights after a short workshop, are coded as requiring a low level of time and funds
Access to stakeholders	Many of these approaches use data derived from input from policy-makers and other stakeholders: ● GMB, which typically requires stakeholders to participate in a synchronous workshop (although these can sometimes be virtual), is coded as high, requiring stakeholder input with the added challenge of bringing people together ● qualitative approaches, which typically require stakeholder input, are coded as medium ● quantitative approaches that may be developed without stakeholder input were coded as requiring low access to stakeholders, although as illustrated in the case studies these do sometime require stakeholder input
Other data	Some systems approaches rely on other types of data instead of or in addition to stakeholder input; these data may either already exist or require collection: ● approaches that are likely to require the collection of tailored data are coded as having high data requirements ● approaches that require data but can often use existing data, such as health surveillance and published data, are coded as having medium data requirements ● approaches that typically do not require data other than stakeholder input are coded as having low data requirements

Table 3. contd

Resource	Description
Computer resources	Some systems approaches require specialized software to implement: ● approaches requiring software are coded as having a high requirement for this resource ● approaches not requiring software are coded as having a low requirement ● some software used in the case studies, such as R and Gephi, is available free of charge
Methodological expertise	All systems approaches require some level of methodological expertise; depending on the application, some approaches may be best served by the inclusion of a systems expert, while others may be carried out after shorter training sessions: ● computationally intensive approaches are coded as requiring a high level of expertise ● in-depth qualitative approaches are coded as requiring a medium level of expertise ● simpler qualitative approaches are coded as requiring a low level of expertise and may be undertaken after shorter training sessions
Stakeholder understanding of systems thinking	In addition to requiring methodological expertise in the form of modellers, researchers or workshop facilitators, some systems approaches also require stakeholders to have some level of understanding of systems thinking: ● participatory methods typically require stakeholders to have a higher level of understanding, as stakeholders are actively involved in developing or refining systems models; these methods are coded as requiring a medium level of understanding ● other methods, where the work of assembling systems components is not undertaken by stakeholders, are coded as requiring a low level of systems understanding on the part of stakeholders

3.1.3 DECISION AID TO INFORM THE SELECTION OF A SYSTEMS APPROACH

The decision aid (Table 4) summarizes the attributes of the systems approaches described in Section 2. For each approach, the decision aid indicates which stages of the policy cycle it is typically applied to, as well the level of different resources required and the associated benefits.

Each approach is linked to a page number in the following section, where a case study describing this approach applied to the specific policy cycle stage may be found.

Table 4. Costs and benefits of systems approaches throughout the NCD prevention policy cycle

Approach		Research with a systems lens	Concept mapping	Cognitive mapping	ABM	SDM	CLD	GMB	Network analysis	QCA
Systems approaches in action (page numbers)	Problem identification and policy analysis	25	26	27	28	29, 30				
	Policy development					32	33	34	35, 36	
	Policy implementation	38–40								
	Policy monitoring, enforcement and evaluation					42		43	44	45
Resources required	Time and cost									
	Access to stakeholders									
	Other data									
	Computer resources									
	Methodological expertise									
	Stakeholder understanding of systems thinking									
Benefits	Process easy to communicate (transparency)									
	Results easy to communicate (interpretability)									
	Provides quantitative estimates of policy impact									
	Supports consensus-building									
	Spatial representation									
	Temporal representation									
	Handling uncertainty									

For resources requirements: red: high; orange: medium; green: low.
For benefits: red: low; orange: medium; green: high.

3.2 Insights for using systems approaches in practice

In addition to considering the stage of the policy cycle appropriate for the task in hand, as well as the costs and benefits of different approaches, a number of general insights were drawn from the literature and exchanges with study authors. These are worth considering when implementing any of the systems approaches discussed in this guidance.

3.2.1 COMMUNICATING THE BENEFITS OF SYSTEMS APPROACHES TO JUSTIFY THE EFFORTS REQUIRED

- **Outline complex system characteristics in the problem being addressed.** Many complex systems are encountered in NCD prevention policy. Where this complexity is not considered, policies may have limited impact or lead to unintended consequences.
- **Emphasize the advantages of participatory processes.** A number of the approaches described in this guidance are participatory. Participatory processes can provide opportunities to encourage compromise and build consensus among stakeholders from different sectors, incorporate multiple perspectives and build systems understanding among the policy or community stakeholders who participate in the research *(18)*.
- **Identify opportunities to use systems approaches in the absence of conventional data.** In some cases, policy-makers may be interested in understanding the impact of different policies, but there is a lack of data to carry out a conventional outcome evaluation. Systems approaches can integrate different kinds of data to provide insight into whether a policy had the desired effect and if so why, or why not *(33)*.

3.2.2 CONSIDERING HOW TO COMMUNICATE PROCESS AND FINDINGS

- **Avoid jargon when working with stakeholders.** The jargon around systems thinking can present a barrier to engage stakeholders around processes and findings. For some audiences, it is worth considering whether the findings can be conveyed without reference to systems concepts.
- **Consider user-friendly ways of communicating findings.** It is worth thinking creatively about how to communicate findings developed using systems approaches. These can include interactive user interfaces that allow stakeholders to try out different policy scenarios for themselves. Findings can also be presented as a so-called rich picture *(51)*, which illustrates the main elements and relationships within a system, or through life stories, representing the journeys of hypothetical individuals as they move through different parts of a system *(52)*.

3.2.3 RECRUITING PARTICIPANTS AND FOSTERING ENGAGEMENT THROUGHOUT THE PROCESS

- **Ensure stakeholder buy-in.** Participation in interviews or workshops will require extra time and effort on the part of stakeholders. In addition, acting on the findings of a systems-informed project may mean stakeholders need to undertake more or different types of work. It is, therefore, crucial to build stakeholder buy-in to the project. This can involve a process of project co-development, ensuring that the focus of the project is one that stakeholders themselves see as important. Building relationships with stakeholders requires time and effort, but it is crucial to successful participatory processes.
- **Keep participants informed and connected.** Some systems approaches may require multiple rounds of input from stakeholders, and there is generally a need to maintain contact with participants throughout the research and knowledge-exchange processes. Developing a strategy to maintain connections with participants throughout this process, such as regular updates or a planned event to share findings, is key to project impact.
- **Adapt modes of participation to participant needs.** Consider asynchronous approaches (such as interviews as opposed to workshops) to allow participants with limited availability to engage. It can also be worth considering online approaches, and whether these will be feasible in a particular context.
- **Consider participant concerns when designing a project.** Some participants may feel uncomfortable sharing their perspectives in a workshop context, or may be willing to share only under condition of anonymity. Consider potential ramifications for participants when designing the approach to data collection.
- **Use networks to recruit participants.** Participant recruitment is always challenging, and recruiting participants working in policy may be particularly difficult. Strategies to address this include seeking an introduction to participants from a known individual, and asking participants to provide introductions to additional stakeholders: a snowball approach for recruitment.

3.2.4 ACKNOWLEDGE THE LIMITATIONS OF SYSTEMS APPROACHES

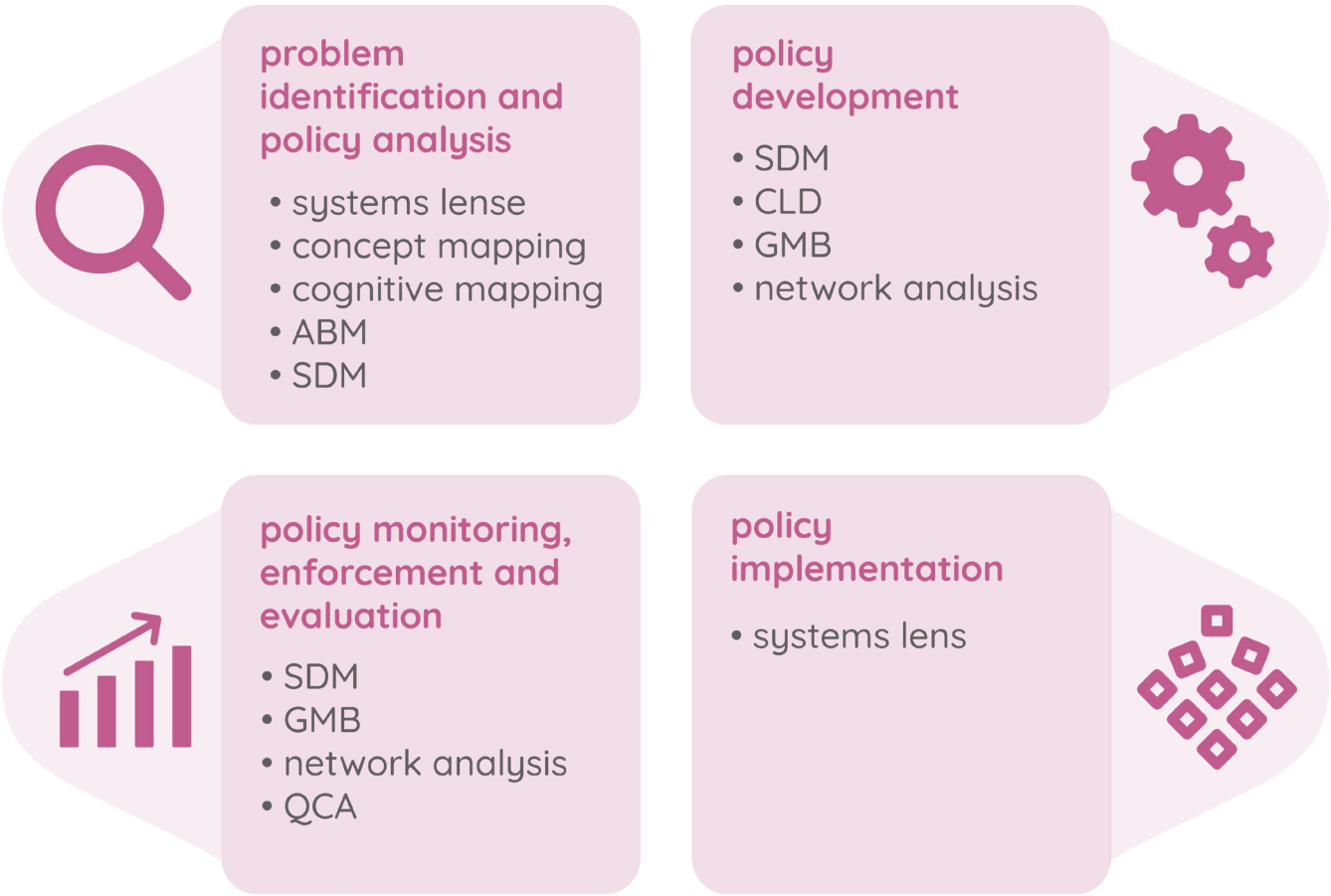
- **Be transparent about what systems approaches can and cannot do.** While systems approaches aim to incorporate a greater degree of complexity, the different approaches discussed here are still only a model of the real-world system they seek to represent. In creating these models, some nuance is necessarily lost, and not all elements of the system will be represented.
- **Use systems approaches to inform thinking, not dictate it.** Evidence from the various approaches and models described in this guidance has the advantage of being relatively dynamic, allowing policy-makers to explore different potential scenarios and helping to inform policy decisions in a tailored way. However, these methods also have their limitations, and the evidence they generate is shaped by the available data and assumptions inherent in the modelling process. Systems approaches should inform policy decisions and complement existing forms of evidence and decision-making processes.

4. Systems approaches in action: case studies from NCD prevention policy

Systems approaches have been used more extensively in some parts of the policy cycle than in others, with relatively extensive application in problem identification and policy analysis, and more limited application in policy implementation.

This section provides an overview of how systems approaches have been applied in different stages of the policy cycle in NCD prevention (Fig. 3). For each approach, a case study illustrating the application of this approach to the relevant policy cycle stage is presented. Additional examples of systems approaches applied to NCD prevention policy can be found in Annex 2.

Fig. 3. Systems approaches across the policy cycle

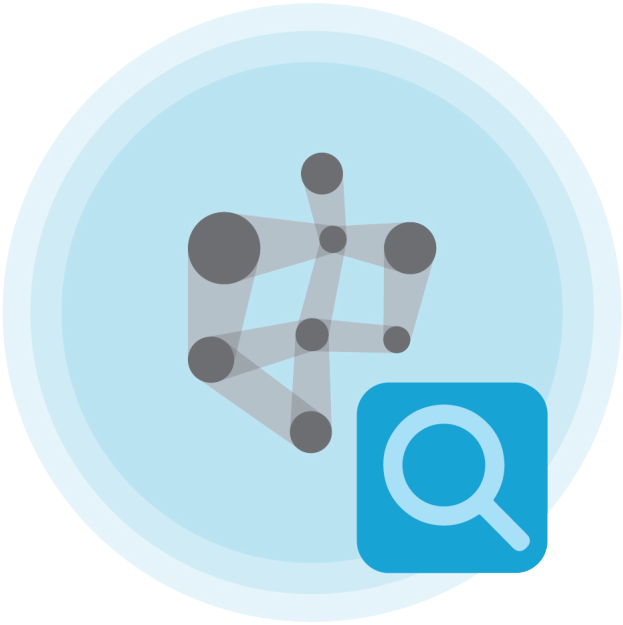


4.1 Problem identification and policy analysis

Problem identification and policy analysis involves clarifying and framing the problem to be addressed, and assessing different policy options to identify the most effective, efficient and feasible solution.

Incorporation of systems thinking into problem identification and policy analysis has been extensive. Qualitative approaches, such as concept mapping or qualitative research with a systems lens, have more frequently been applied in problem identification to map the landscape of existing policies and to understand the multiple factors that may contribute to chronic disease. Quantitative approaches such as ABM and SDM have more frequently been applied to policy analysis to compare the predicted impacts of different hypothetical interventions *(17)*.

The case studies included in this section represent the range of different applications of systems approaches to problem identification and policy analysis in NCD prevention policy. A more extensive list of examples can be found in Annex 2 (Table A2.1).



4.1.1 QUALITATIVE RESEARCH WITH A SYSTEMS LENS

Case study 1. Tackling problems with a high degree of complexity (so-called wicked problems) in health promotion: New Zealand

CONTEXT

Country: New Zealand

Level of government: national

Area of NCD prevention: NCD in population groups

A multiphase research project was undertaken to inform policy for enhancing food security and physical activity among Māori, Pacific and low-income people in New Zealand.

APPROACH

Specialist skills and knowledge: qualitative research with a systems lens

Tool: N/A

The authors used a complex systems lens to identify public policy interventions to tackle wicked health promotion problems. The study involved 56 key stakeholders, including members of the affected communities, policy-makers, academics and NGO workers. These stakeholders participated in focus groups, workshops and interviews to identify appropriate interventions to enhance food security and promote physical activity. The study also involved two comprehensive literature reviews identifying factors associated with food security and physical activity. Results suggest that food security and physical activity are the products of complex systems. Recognizing this can help policy-makers to identify key areas for intervention.

IMPLICATIONS

Benefit: identify structural drivers of obesity and opportunities for action through an inclusive process

Challenge: implementation will require the most effective actions to be prioritized

The use of a complex environmental approach identifies the numerous environmental influences on obesity by focusing the cause of increased obesity away from individuals and towards the context within which they live. The approach also allowed priority areas for action to be identified, including the availability of money within households; the cost of food; improvements in urban design; and culturally tailored physical activity programmes.

From this understanding, intervention recommendations could be developed, including providing healthy food subsidies, increasing the minimum wage, and enhancing open space and connectivity in communities. It was also recognized that tackling food security and physical activity required coordinated action, with multiple interventions to create sustained, system-level change.

While this project generated many possible interventions, these all have budget implications. A systems lens can be helpful in prioritizing the most effective actions to implement. By identifying actions that may have impacts at different levels, and have knock-on effects on different parts of the system, the most impactful solutions can be selected.

Source: Signal et al., 2013 *(20)*.

4.1.2 CONCEPT MAPPING

Case study 2. Whole-of-systems approaches to physical activity policy and practice in Australia: the ASAPa project overview and initial systems map

CONTEXT

Country: Australia

Level of government: national

Area of NCD prevention: physical activity

The ASAPa project (Australian Systems Approaches to Physical Activity) is a national initiative using a whole-of-systems approach to physical activity promotion at the population level.

APPROACH

Specialist skills and knowledge: concept mapping

Tool: N/A

As part of the project, concept mapping was used to create a conceptual physical activity system map of influences on physical activity in Australia; mechanisms for governance, translation and advocacy; and leverage points for policies and programmes. To develop the map, national meetings were convened with federal and State Government stakeholders to identify physical activity-related policies and programmes. Building on this input and supplemented by desktop research, researchers identified 110 policies relevant to physical activity. Based on these policies, the physical activity system map was developed and refined during workshops with both Government and nongovernmental stakeholders. This map was used to identify gaps between policies, and areas for strengthening and enhancing policy coherence. Given the multisectoral nature of physical activity, participants came from both within and outside Government, from sectors including health, sport, recreation and planning.

IMPLICATIONS

Benefit: participatory process emphasizing policy coherence across sectors

Challenge: maintaining stakeholder engagement throughout

This project facilitated the collaboration of actors across different sectors to create a physical activity system map for Australia, while sharing knowledge and engaging stakeholders from the outset. The map helped to identify gaps and points of weakness in the physical activity policy system by determining if previous policies were achieving their intended aims. It also provided stakeholders with the opportunity to visualize, identify and more clearly define their roles within the physical activity policy landscape by working collaboratively with a diverse group of actors.

A key challenge lay in keeping all of the stakeholders informed, connected and responsive. A breakdown in communication during this process could lead to uncoordinated policy actions and piecemeal planning across jurisdictions. Maintaining a coordinated strategic approach based on cross-sectoral partnerships is one way to prevent or lessen these risks.

This project used systems thinking to start to remedy decades of failed policies around physical activity by developing and promoting best practice approaches to cross-sectoral policy implementation. In doing so, it identified points of leverage for policy intervention while promoting engagement and partnerships between policy-makers and other stakeholders. Future work building on these findings will include the development of cross-sectoral surveillance systems and a whole-of-system approaches to physical activity.

Source: Bellew et al., 2020 *(26)*.

4.1.3 COGNITIVE MAPPING

Case study 3. Systemic barriers and equitable interventions to improve vegetable and fruit intake in children: interviews with national food system actors

CONTEXT

Country: New Zealand

Level of government: national

Area of NCD prevention: diet

In light of declining fruit and vegetable intake in New Zealand, with over half of children not meeting recommendations, this project was undertaken to understand what factors influence fruit and vegetable intake in children and identify potential policy actions to reverse this decline.

APPROACH

Specialist skills and knowledge: cognitive mapping interviewing

Tool: Vensim software

Cognitive mapping interviewing was used to explore the causal pathways within the food system that explain the barriers to fruit and vegetable intake in children, and to identify possible actions to reverse its decline. In order to obtain a holistic view of the food system, national stakeholders from different sectors, including the produce industry, the food distribution and retail sector, the Government and NGOs, were invited to participate. Researchers carried out semistructured interviews using cognitive mapping interviewing, which is a visual technique that captures a stakeholder's perspective of a problem and how they or their organization relate to it. The output of each interview is a map, illustrating a network of nodes and arrows. Individual maps were then combined to form a composite map representing different stakeholders' views and providing a holistic understanding of the issue.

IMPLICATIONS

Benefit: participatory method adapted to busy stakeholders

Challenge: less collaborative than other participatory methods

The use of cognitive mapping facilitated the effective engagement of participants. Participants were able to more easily visualize barriers and identify how different variables relate to each other.

Using a systems approach to understand the decline in fruit and vegetable intake among children provided new knowledge and insights from a broad range of actors across the food system. This diverse group of participants identified systemic barriers and proposed effective solutions to the complex public health issue of low fruit and vegetable intake in children by addressing health inequities at the systems level rather than at the individual level.

One of the challenges encountered in this study involved scheduling a meeting with 22 diverse national actors. GMB is a systems method that is often used to qualitatively exploring a complex issue involving different stakeholders. This method is more collaborative, allowing participants to develop ideas together for system-wide interventions. However, it also requires all participants to be in the same room, either in person or in an online setting.

Cognitive mapping interviewing enabled interviewers to overcome time constraints, making it easier to accommodate the availability of busy participants across different locations and times. It also gave participants the privacy to share their views more openly with interviewers, away from other stakeholders and interest groups.

Source: Gerritsen et al., 2019 *(22)*.

4.1.4 ABM

Case study 4. Assessing the role of access and price on the consumption of fruits and vegetables across New York City

CONTEXT

Country: United States of America

Level of government: local

Area of NCD prevention: diet

Most residents of New York City do not consume the recommended amount of fruit and vegetables. Further, difficulties related to access and the high prices of fruit and vegetables contribute to neighbourhood-level inequities in fruit and vegetable consumption.

APPROACH

Specialist skills and knowledge: ABM

Tool: Java coding language

ABM was used to explore what role access and price played in the consumption of fruits and vegetables in New York City, allowing modelling of how a range of hypothetical interventions targeting price and availability might impact consumption in different neighbourhoods. This analysis did not require the involvement of stakeholders. Instead, surveillance data and published findings were used to build a model of the urban environment of New York City.

IMPLICATIONS

Benefit: facilitated understanding of the complex drivers of diet selection

Challenge: relied on the existence of adequate and relevant data

This project used ABM to enable a holistic view of a complex individual practice: fruit and vegetable consumption. This approach facilitated an understanding of how different factors, such as individual characteristics, food environment and social influences, combine and interact to influence fruit and vegetable consumption, and it provided insight into how it might change in response to interventions playing out in the complex systems of neighbourhood food environments.

This approach also had the advantage of putting existing data and theories to novel use, without the need to collect further data. However, while it did not require stakeholder input, it did rely on the existence of relevant data and findings to build the model.

Source: Li et al., 2018 *(53)*.

4.1.5 SDM

Case study 5. Using community-based SDM to understand the complex systems that influence health in cities: the SALURBAL study

CONTEXT

Region: Latin America

Level of government: national

Area of NCD prevention: urban health (food environments and transport systems)

SALURBAL (Salud Urbana en America Latina) is a multicountry project spanning multiple institutions across Latin America and the United States. SALURBAL uses systems approaches to study how urban environments and policies impact health, health equity and environmental sustainability in Latin American cities.

APPROACH

Specialist skills and knowledge: SDM

Tool: Qualtrics and Vensim software

As part of the SALURBAL project, community-based SDM to understand how complex and interrelated factors within the food and transport systems impact health in Latin American cities; 62 stakeholders from across different sectors participated in three workshops to develop a shared understanding of these systems and to identify effective policy levers to improve health and the environment.

The workshops served as opportunities to engage local stakeholders, helping them to view problems through the lens of complex systems. Participants used their insights to prioritize research efforts and identify novel policy solutions that consider mechanisms of complexity. Workshops included a schedule of scripted activities moving from graphs of change over time to models derived from CLD and SDM and finally to ideas for both research and policy action.

IMPLICATIONS

Benefit: opportunity to engage stakeholders, embrace conflict and develop compromises

Challenge: lack of data to inform stakeholder insights and difficulties building consensus

This project prioritized early engagement of stakeholders to identify and explore policy options to advance urban health across Latin America. It also offered insights into the underlying mechanisms driving the multiple, interacting causal pathways that link food and transport systems to health.

There were several challenges during the workshops, including some participants who felt that their contribution was limited by the lack of available data; others were uncertain of how to best complete some of the activities to show differences between groups or changes in variables over time; and some had disagreements about the key variables to include and how they are connected. Some of the challenges and resistance were anticipated and others emerged during the workshops. The systems approach helped stakeholders to embrace conflict and disagreement – a common part of collaborative problem-solving processes – by encouraging a compromise between different perspectives to generate novel insights into complex health issues.

Source: Langellier et al., 2019 *(15)*.

Case study 6. Planning cardiovascular disease interventions in the United States

CONTEXT

Country: United States

Level of government: local

Area of NCD prevention: cardiovascular diseases

The Cancer, Cardiovascular and Pulmonary Disease Project aims to reduce the burden of NCDs through comprehensive prevention, early detection and treatment services. The project was administered by the El Paso County Public Health Department.

APPROACH

Specialist skills and knowledge: SDM

Tool: Vensim software

As part of the Project, an SDM for El Paso County was developed incorporating the burden of cardiovascular diseases (CVDs) for the County and tracking the effects of risk factors for CVD over time. This model was then used to forecast the impacts of different intervention strategies aimed at reducing the County's CVD burden.

The model was adapted from a model developed by the United States Centers for Disease Control and Prevention. Local and national health surveillance data, evidence and data from published literature, and several local data sources, were used to build the model for El Paso County. This model provided quantitative estimates of the impacts of different interventions, tailored to the local context.

The model allowed estimates of the local burden of CVD under current conditions to be compared with estimates of the burden if a range of prevention strategies were implemented, such as taxes and regulations, social marketing and neighbourhood improvements.

IMPLICATIONS

Benefit: inform decisions around which interventions would be most effective in a resource-limited setting

Challenge: requires adequate data to represent the various elements of the model

The model tracked the effects of risk factors; it tested, analysed and compared the impact of different interventions on reducing CVD prevalence over time; and it presented the results of these policy tests. The efficacy of different intervention strategies can be compared based on their ability to reduce NCDs, lower mortality and morbidity and their cost–effectiveness given the limited availability of resources.

SDM can help policy-makers to navigate complex decisions around how to allocate resources for NCD prevention most effectively. However, as seen in this case, developing quantitative models relies on having access to datasets to parameterize the different elements of the model. These models can often use existing datasets where these are available.

Source: Loyo et al., 2013 *(32)*.

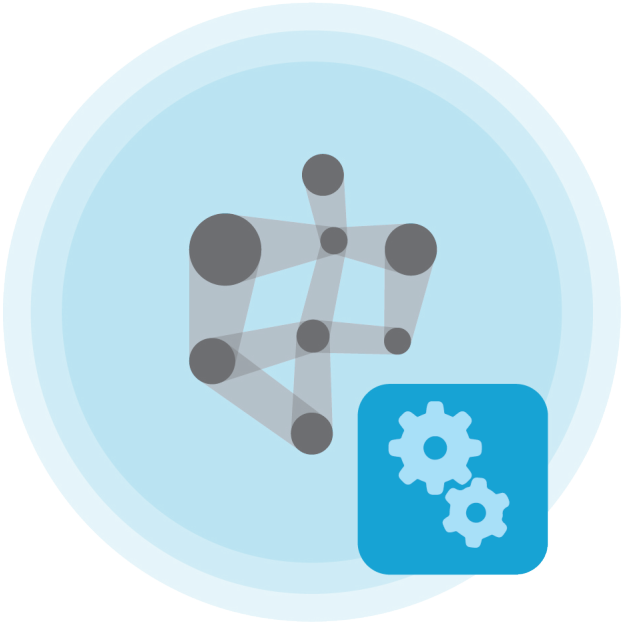
4.2 Policy development

Policy development involves identifying a strategy for formulating a policy, setting up the framework needed to get it adopted and developing an understanding of how the policy will operate.

Applications of systems thinking to policy development have principally focused on developing understandings of the roles that social and institutional networks play in policy adoption, and leveraging these networks through participatory approaches. Network analysis has frequently been used to understand the roles these networks play, providing insights to inform strategies for getting NCD prevention policy adopted *(40,41,54)*. Participatory methods such as GMB *(39)* and community-based SDM *(32)* have been used as an applied part of the policy process to build consensus between individuals and organizations whose work impacts NCDs.

Systems approaches may also be applied to understanding how a variety of factors, such as evidence, popular opinion and media coverage, inform policy decisions *(35)*.

The case studies included in this section represent the range of different applications of systems approaches to policy development in NCD prevention policy. A more extensive list of examples can be found in Annex 2 (Table A2.2).



4.2.1 SDM

Case study 7. From model to action: modelling chronic disease risks to align community action using SDM

CONTEXT

Country: United States

Level of government: local

Area of NCD prevention: CVD

In 2011, the Public Health Department in Austin, Texas partnered with the Centers for Disease Control and Prevention to pioneer an innovative, systems-based approach to understand the dynamic dimensions of health protection policies. This project led to the development of the System Dynamics Model for Chronic Disease Risk and Prevention.

APPROACH

Specialist skills and knowledge: SDM

Tool: not stated

The System Dynamics Model for Chronic Disease Risk and Prevention was used in a local government context to reduce CVDs. By aligning the prevention efforts of multiple stakeholders, the Model allowed for the optimal allocation of limited resources and it was used as a catalyst to bring stakeholders together and build consensus around which actions would be most effective in reducing CVD. Action laboratories were created where 56 local stakeholders from public health, health care, non-profit-making advocacy groups, businesses and schools learned about the Model, and ran simulations of intervention strategies. Stakeholders were encouraged to think more systemically about their organization's role, form coalitions and publicly commit to taking collective action to prevent CVDs.

IMPLICATIONS

Benefit: build consensus and develop coherent strategy for action

Challenge: this Model does not capture all real-world nuances

The systems approach benefited stakeholders as it provided a means to connect shared goals, explore the possibility for new alliances and support collaborations to help the community and reduce silo and competitive thinking. The approach was also beneficial to the community because stakeholders were able test various intervention scenarios via the Model to gain a better understanding of the potential consequences of different policy options. This modelling and the action laboratory convinced most stakeholders of the advantages of leveraging local expertise and synchronizing strategies with partners.

One of the challenges of moving from model to action is the differences across and gaps in local data as decisions are made at the community level. However, there are several attributes of systems thinking that allow this approach to overcome these challenges by synthesizing evidence, fostering collective thinking and building aligned relationships.

As the System Dynamics Model for Chronic Disease Risk and Prevention, like all models, could not capture all of the nuances of the real world, evidence from it was used to guide strategic thinking rather than dictate a preferred strategy.

Source: Loyo et al., 2013 *(32)*.

4.2.2 CLD

Case study 8. Understanding the LiveLighter obesity prevention policy processes: an investigation using political science and systems thinking

CONTEXT

Country: Australia

Level of government: local

Area of NCD prevention: obesity

The State Government in Victoria, Australia, had implemented LiveLighter, a contentious social marketing campaign aimed at reducing obesity; it featured graphic images designed to shock individuals and promote healthier eating behaviours.

APPROACH

Specialist skills and knowledge: CLD

Tool: Vensim software and NVivo10

The authors used CLDs to illustrate the dynamic influences on policy decision-making in the LiveLighter social marketing campaign adopted by the Victorian Government.

In semi-structured interviews, stakeholders provided detailed insight and first-hand experience into the policy processes related to LiveLighter. Documents pertaining to the policy processes were also analysed. Key influences on policy decisions were identified, including external events; evidence around the scale of the problem and the effectiveness of proposed solutions; resistance from some stakeholders; and the political capabilities of central policy actors.

IMPLICATIONS

Benefit: identify points of leverage and resistance

Challenge: jargon around systems thinking made stakeholder engagement difficult

CLDs and a complex systems lens provided numerous insights into the LiveLighter policy system. They highlighted how policy systems fit together; potential points of leverage and resistance; how policy variables are interconnected; and how to effectively influence policy change for obesity prevention. The use of CLDs also provided insights into the relative importance of the factors driving obesity prevention policy change and proved useful in identifying points of leverage and resistance that may be helpful in prioritizing actions.

Further opportunities for how CLDs could be applied to the policy process for obesity prevention include anticipating potential challenges that could arise and identifying opportunities for policy progress.

Despite the added insights yielded by the use of CLDs, the authors found that the jargon around systems thinking and the complexity of some of the concepts used presented a barrier to stakeholder engagement with the findings. Conveying the findings was sometimes easier when systems thinking terminology could be avoided. In addition to CLDs, the development of other tools, more accessible to untrained audiences, needs to be explored to communicate complex policy processes.

Source: Clarke et al., 2020 *(35)*.

4.2.3 GMB

Case study 9. Generating political commitment for ending malnutrition in all its forms: a system dynamics approach for strengthening nutrition actor networks

CONTEXT

Country: global

Level of government: global

Area of NCD prevention: diet

Political commitment is essential to ending all forms of malnutrition. Without commitment, the policies, programmes and resources needed to improve nutrition are unlikely to be adopted, effectively implemented or sustained. An essential driver of political commitment is the effectiveness of nutrition actor networks (NANs), which are defined as the web of individuals and organizations operating within a given country who share a common interest in improving nutrition, acting collectively to do so.

APPROACH

Specialist skills and knowledge: GMB

Tool: Vensim software

GMB was used to provide an understanding of the complexity and dynamic nature of political commitment around malnutrition and to derive new insights to inform and strengthen NANs in order to effectively drive political commitment. As part of this process, initial CLDs were developed based on a literature review. These CLDs modelled the interactions between political commitment and NAN effectiveness.

Following this, 14 nutrition experts participated in a 90-minute GMB workshop at the WHO headquarters in Geneva to discuss the initial models. The data collected from participants' critique and refinement of models in the GMB workshops were used to develop a final CLD.

IMPLICATIONS

Benefit: combines evidence from literature with a participatory approach and stakeholder input

Challenge: gathering stakeholders for in-person workshop

The GMB workshops fostered collaboration and cohesion among group members by allowing stakeholders to understand the functioning of complex systems. The GMB exercises also strengthened and refined the initial models developed based on the literature, while encouraging structured and evidence-informed conversations that integrated different insights and perspectives on how to strengthen NANs.

The systems thinking approach informed new actions and strategies to build and strengthen NANs within countries at the national and subnational levels. It demonstrated how NANs effectively generate and sustain political commitment among influential societal actors, thereby helping to advance public health nutrition agendas. This approach also highlighted nonlinear relationships between variables that would have been missed by linear approaches.

GMB workshops can be challenging because of the need to gather stakeholders for synchronous, and often in-person, workshops. In this case, the workshop coincided with other events for which stakeholders were assembled; preparatory work prior to the workshop further ensured that the best use was made of participants' time.

Source: Baker et al., 2019 *(39)*.

4.2.4 NETWORK ANALYSIS

Case study 10. Joining the dots: the role of brokers in nutrition policy in Australia

CONTEXT

Country: Australia

Level of government: national

Area of NCD prevention: diet

Despite years of advocacy, and the existence of a number of well-evidenced policy options to tackle poor nutrition, the number of public health nutrition policy actions taken in Australia remains limited.

APPROACH

Specialist skills and knowledge: network analysis

Tool: NodeXL software

Social network analysis was used to improve understanding of the inertia in public health nutrition policy in Australia. Starting with a small sample of key stakeholders in Australian nutrition policy, the study team identified a policy network composed of many actors. In total, 390 interconnected stakeholders were identified, providing information about their ties to other actors within the network.

This approach allowed key policy brokers to be identified, and their levels of influence over nutrition policy-making to be explored. Influential individuals were identified as those with relatively few degrees of separation, in terms of individual ties, from decision-makers. These ties could represent formal connections, based on institutional structures, or informal connections, such as informal communication or trust between actors.

This approach allowed the structure of the policy network to be described, identifying a dense cluster of nutrition professionals with limited connections to decision-makers. A single participant acted as a key broker between these two clusters. Policy brokers have the potential to share information and shape agendas across groups within the network, but they can also prevent other actors from participating in policy decisions.

IMPLICATIONS

Benefit: bring invisible networks to the surface

Challenge: difficult to obtain responses from stakeholders

Network analysis maps out policy networks and provides a visual depiction of relationships between brokers, making invisible patterns in networks visible. This approach allows for the identification and examination of lesser-known patterns within networks that may transcend hierarchical structure, providing more insight into an actor's relative power and capacity to influence policy decisions. Network analysis can highlight influential individuals who may need to be engaged in setting policy agendas, but it can also help with identifying when different groups of stakeholders are not communicating well with each other.

One of the challenges of working with an elite network of actors, in this case national policy actors, is obtaining a high response rate. In this study, individuals in political professions were hard to recruit. Strategies to address this include seeking an introduction to participants from a known individual, and minimizing the time required for participation.

Source: Cullerton et al., 2017 *(41)*.

Case study 11. Network influences on policy implementation: evidence from a global health treaty

CONTEXT

Country: global

Level of government: global

Area of NCD prevention: tobacco control

The Framework Convention on Tobacco Control (FCTC) is the first international public health treaty negotiated by WHO. It was formally adopted by the World Health Assembly in May 2003.

APPROACH

Specialist skills and knowledge: network analysis

Tool: R software

Valente and colleagues used social network analysis to examine how the implementation of the FCTC by national governments diffuses between countries. To do so, they determined whether implementation by a given country is in part a function of the implementation activities of other connected nations. This analysis used published data from the FCTC's implementation database, including treaty implementation reports over multiple years from the 179 countries that ratified the FCTC. Implementation was measured based on the number of actions a country implemented for each of the articles of the FCTC, including pricing and taxation; control of second-hand smoke; and packaging and labelling. Networks were characterized in several ways: geographical distance, trade (both general and of tobacco specifically) and communication and information exchange relating to tobacco control. Tracking changes in implementation over time, the team could identify network effects where implementation of the FCTC diffused between connected countries.

IMPLICATIONS

Benefit: identify the role of social and communication systems in the implementation of an international treaty

Challenge: acquiring and managing data

This project provides a good example of how systems thinking can be applied within the supranational context, analysing the space between adoption and implementation of international treaties and the role that international networks play.

Acquiring and managing data, and specifying the statistical models, were technically challenging parts of this work. This type of analysis requires a relatively high level of technical skill. A specific challenge was the overwhelming amount of data available in this space and at the country level. This was overcome by narrowing the focus to important variables.

The key principle demonstrated was that policies are adopted and implemented within the context of social and communication systems. Specifically, that country decisions to adopt and implement policies (in this case tobacco control) are a result of observing, imitating and learning from other country experiences.

Findings from this project may impact approaches to influencing national policy: identifying subnetworks within the global community and influential nations within them can be useful in targeting efforts.

Source: Valente et al., 2019 *(55)*.

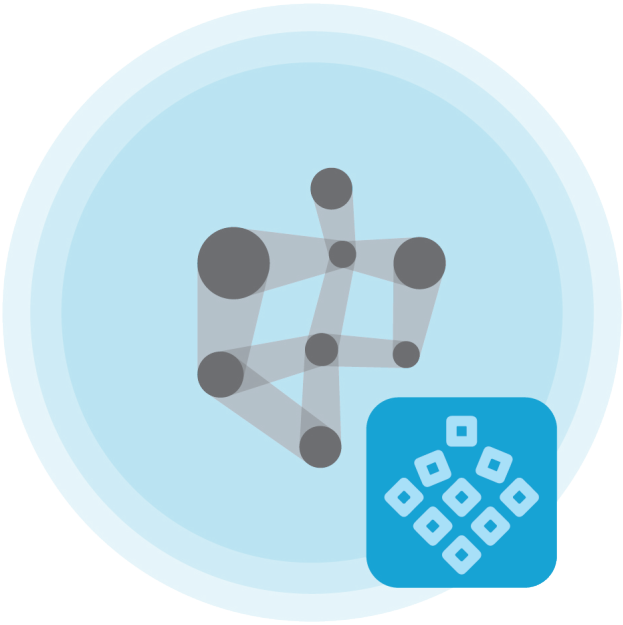
4.3 Policy implementation

Policy implementation involves following procedures for getting a policy enacted and translating the enacted policy into action.

While earlier stages of the policy cycle map out the blueprint of how policy should operate, policy implementation involves the on-the-ground work of making policy into reality. A systems perspective can be useful in policy implementation, particularly where policies must be implemented by a constellation of actors. A systems lens can also be useful for thinking about how policies are implemented in an existing system of actors, including those whose work may overlap with that of policy, such as NGOs invested in NCD prevention.

While explicit systems approaches are not widely documented in policy implementation for NCD prevention, qualitative and case study research with a systems lens has been undertaken *(42,56,57)*.

The case studies included in this section represent the range of different applications of systems approaches to policy implementation in NCD prevention policy and are also listed in Annex 2 (Table A2.3).



4.3.1 QUALITATIVE RESEARCH WITH A SYSTEMS LENS

Case study 12. Together stronger: boundary work within an Australian systems-based prevention initiative

CONTEXT

Country: Australia

Level of government: local

Area of NCD prevention: NCDs

Healthy Together Communities is a set of 12 systems-based, community-level prevention experiments aimed at reducing NCDs in Victoria, Australia.

APPROACH

Specialist skills and knowledge: qualitative research with a system lens

Tool: Nvivo qualitative data analysis software

A qualitative study used a systems lens to analyse boundary interactions between key actors within the local government and community health organizations across two Healthy Together Communities sites. The study was framed by the concept of so-called boundary work: the process of understanding how allowances and restrictions are made with regard to people, places and processes, and how the fluidity of these boundaries influences decisions within and across organizations and communities.

Twenty key informants from local government and community health organizations working with Healthy Together Communities as practitioners and managers participated in semi-structured interviews to generate qualitative data.

IMPLICATIONS

Benefit: provide insight into coordination of policy implementation across different agencies

Challenge: securing buy-in from all agencies

The insights into boundary interactions generated through this project can improve understanding of the ideas and practices that enable or constrain successful coordination among multiple stakeholders involved in policy implementation.

Applying a systems lens brings attention to boundary interactions, including various elements such as alignment, boundary spanning and boundary permeability across different actors involved in policy implementation. It also highlights interdependencies among key actors, which are influential when carrying out large-scale, multilevel prevention initiatives targeting NCDs. For example, reconfiguring boundaries to be more inclusive can create a shared understanding, leading to the generation of integrated and comprehensive solutions. More inclusive boundaries can also lead to the formation of key alliances among collaborators. This can ensure that the efforts of each partner are being used to optimal effect without redundancy or conflict in roles.

However, these collaborative efforts can lead to more or different work for the agencies involved, meaning that securing their buy-in presents a challenge. This can be partly overcome by identifying agencies that are more open to involvement, or connections between agencies that can be leveraged to promote involvement. In this case, for example, schools were more willing to engage than local government, making them priority partners for engagement.

Source: Roussy et al., 2020 *(56)*.

Case study 13. He Pikinga Waiora: supporting Māori health organizations to respond to pre-diabetes

CONTEXT

Country: New Zealand

Level of government: local

Area of NCD prevention: diabetes

Māori, the indigenous people of New Zealand, are at a high risk of developing pre-diabetes and type 2 diabetes, and there are significant health inequities between Māori and non-Māori populations in New Zealand.

APPROACH

Specialist skills and knowledge: qualitative research with a system lens

Tool: qualitative data analysis software

A systems lens was used to examine how Māori health organizations could leverage their organizational strengths and resources to negotiate barriers and constraints to the implementation of health-promoting policies. It also was used to identify strategic opportunities for consideration by Māori health organizations, funders and policy-makers to address health inequities related to type 2 diabetes. The project involved a range of data sources, including interviews with key informants from NGOs, a government funding organization and a primary care provider, along with a document review and a diabetes systems map.

A possible pathway to improved health outcomes for Māori lies in increasing intersectoral integration of health and social services to influence the social determinants of health and local environment. Recognizing the role of Māori health organizations, both as conduits for the community voice and influential partners in effecting change within the community, is also key to improving health.

IMPLICATIONS

Benefit: inclusive participatory process

Challenge: complex model difficult to communicate with outside stakeholders

Centring Māori perspectives, valuing their connections and voices within the community and engaging them as influential partners to effect system-wide change presents a strategic approach to address pre-diabetes and diabetes in Māori populations. These approaches will also help to reduce health inequities between Māori and non-Māori.

Using systems thinking led policy-makers and funders to consider how Indigenous organizations and their cultural perspectives can be interwoven into an intersectoral approach to deliver health and social services more equitably to these populations. In this case, the core concept of hauora (integrating physical, mental and emotional, social and spiritual well-being into a holistic framework) aligned with a whole-of-systems approach.

The benefits of this approach include encouraging greater community engagement with Indigenous organizations, considering multiple perspectives when implementing new strategies and interventions for communities, and ensuring that new interventions are successfully implemented within local contexts without exacerbating inequities.

As the aim of this project was to represent the complex drivers of type 2 diabetes, the model developed was visually complex, which may present communication barriers with outside stakeholders such as funders and policy-makers. Developing user-friendly approaches to presenting findings is key to making systems approaches useful to different audiences.

Source: Beaton et al., 2019 *(57)*.

4.3.2 CASE STUDY RESEARCH WITH A SYSTEMS LENS

Case study 14. The implementation of HiAP initiatives: a systems framework for government action

CONTEXT

Country: Finland

Level of government: national

Area of NCD prevention: population health

Governments that adopt a HiAP approach face the challenge of instituting governance structures and processes to facilitate policy coordination. Given the complexity of government institutions and the policy cycle, systems thinking has been proposed as a tool for understanding and evaluating the implementation of HiAP.

APPROACH

Specialist skills and knowledge: case study research with a system lens

Tool: systems framework of HiAP implementation

A systems framework was developed to analyse the implementation of HiAP, exploring how and why the practices of policy-makers (including politicians and civil servants) have been supportive or detrimental to implementing HiAP. This framework emphasized three subsystems within government: an executive subsystem, which included political leadership, agendas and ideologies; an intersectoral subsystem, including the management, mandate and financial arrangements dedicated to implementing HiAP; and an intrasectoral system, emphasizing forces at work within sectors of government including influential civil servants, and the history, objectives and relative power of specific sectors. These three subsystems interact with one another within the government system, which in turn interacts with an extragovernmental system, including NGOs, industry and researchers.

IMPLICATIONS

Benefit: managing and improving the complex process of implementing an HiAP initiative

Challenge: identifying a multidisciplinary team with a shared interest in systems

This systems framework is a tool for policy-makers and other public health actors managing HiAP implementation processes. Systems thinking offers an organized view of the complexities involved in the implementation of HiAP approaches. It reveals the underlying relationships between government subsystems and their components; anticipates the potential challenges and impacts of various strategies for HiAP implementation; and contextualizes the complex and emergent processes of implementation to explain how, why and under what circumstances system components work together to either advance or undermine HiAP initiatives. Finally, it considers the impact of external influences on government systems in HiAP implementation.

This project involved a team of researchers from different disciplines, one of whom had a background in systems thinking. Systems approaches can be time intensive and require team members to develop a certain level of theoretical understanding. As a result, selecting team members who were motivated to apply these approaches was key to the successful implementation of this project.

Source: Shankardass et al., 2018 *(42)*.

4.4 Policy monitoring, enforcement and evaluation

Policy monitoring, enforcement and evaluation involves monitoring the uptake of a policy, ensuring its full implementation and assessing its impact and outcomes. Improvements can then be made if necessary.

Applications of systems thinking to policy monitoring, enforcement and evaluation have principally focused on evaluation. Systems approaches have been used to help to understand how and why policies work or fail, going beyond simply evaluating whether a policy has worked or not. SDM, GMB, network analysis and QCA have all been applied to this end. Understanding the mechanism behind how a policy works or fails can be useful in determining whether and under what conditions a policy may be effectively replicated. This understanding can also provide data and lessons to be used to update adapt policies in order to better achieve desired outcomes.

The case studies included in this section represent the range of different applications of systems approaches to policy monitoring, enforcement and evaluation in NCD prevention policy. A more extensive list of examples can be found in Annex 2 (Table A2.4).

4.4.1 SDM

Case study 15. The public health responsibility deal: using a systems-level analysis to understand the lack of impact on alcohol, food, physical activity and workplace health subsystems

CONTEXT

Country: United Kingdom (England)

Level of government: national

Area of NCD prevention: alcohol, food, physical activity and workplaces

The Public Health Responsibility Deal was a public health initiative launched in England (United Kingdom) in 2011 that involved a public–private partnership organized around a series of voluntary agreements, where actors, including industry, committed to pledges to undertake actions of public health benefit.

APPROACH

Specialist skills and knowledge: qualitative SDM

Tool: N/A

Qualitative SDM was used to integrate different strands of an evaluation of the Responsibility Deal. The model was developed based on analyses of pledges and progress reports, as well as on qualitative data from interviews and organizational case studies. The Responsibility Deal and its interactions with industry were modelled as a system with causal pathways, structures, processes and feedback loops.

This systems approach provided insight around why the Responsibility Deal failed to meet its objectives: the production and uptake of pledges by industry were largely driven by industry interests, allowing the systems in which the Responsibility Deal was implemented to remain unchanged.

IMPLICATIONS

Benefit: enables the evaluation of an intervention occurring within a complex system

Challenge: lack of surveillance infrastructure

This approach highlighted how and why the Responsibility Deal failed to meet its objectives to improve public health. The systems within which it was operating remained resistant to change because the businesses leading the design of the pledges prioritized their private interests over public health interests.

There were three major challenges that would make a simple outcome evaluation (assessing whether the goals and objectives of the Responsibility Deal had been met) potentially misleading, if not impossible: (i) the lack of a suitable comparator or counterfactual; (ii) the lack of a baseline against which to analyse impact; and (iii) the low likelihood of proximal changes in population health relevant to the Responsibility Deal.

Evaluating the Responsibility Deal was challenging for these reasons and for the lack of surveillance infrastructure to quantitatively monitor the implementation of pledges. However, this systems approach integrated multiple data sources in order to conduct the evaluation, while also providing insight around the causal mechanisms behind the limited impact of the Responsibility Deal.

Source: Knai et al., 2018 *(33)*.

4.4.2 GMB

Case study 16. Systems thinking in 49 communities related to healthy eating, active living and childhood obesity

CONTEXT

Country: United States

Level of government: national

Area of NCD prevention: obesity

Healthy Kids, Healthy Communities was a national programme operating between 2008 and 2014 that aimed at implementing policy, system and environmental changes to support healthier communities for children and families, with special emphasis on reducing inequities in childhood obesity.

APPROACH

Specialist skills and knowledge: GMB

Tool: Vensim software

Brennan and colleagues produced CLDs and incorporated GMB techniques to evaluate Healthy Kids, Healthy Communities in 49 communities, in order to understand the community-level impacts and derive insights of relevance to policy-makers and other stakeholders.

GMB sessions actively engaged stakeholders, including residents, community-based organizations, businesses, researchers, elected officials and government agencies. Participants created and shared behaviour-over-time graphs that identified variables that affect or are affected by policy, system and environmental changes in their community. Each participant then shared his or her perceptions of the direction of influence in causal relationships and feedback loops among variables. Insights from these workshops were used to develop initial CLDs. Evaluators reviewed, refined and analysed the CLDs in Vensim.

IMPLICATIONS

Benefit: participatory approach to systems thinking allowing for community engagement

Challenge: conveying complex relationships to lay audiences

Relative to other tools for systems thinking, GMB using CLDs is more readily transferable to community setting because it requires less expertise, resource and data. The impacts of Healthy Kids, Healthy Communities on the community sites were complex, and this approach allowed for the illustration of complex relationships among variables within a system while also providing more transparent and recognizable benefits to lay audiences.

The benefits of using systems thinking tools include the facilitation of community engagement to assist in efforts that aim to define and characterize complex systems. This creates opportunities within the system to identify potential points of leverage for intervention and to develop a shared language and understanding between residents and community partners across various disciplines and sectors. More broadly, this approach may highlight the underlying causes of poor health outcomes, disparities and inequities that perpetuate resistance to interventions in addition to the community assets and resources that will yield the greatest return on investment.

Source: Brennan et al., 2015 *(36)*.

4.4.3 NETWORK ANALYSIS

Case study 17. Applying social network analysis to evaluate implementation of a multisector population health collaborative that uses a bridging hub organization

CONTEXT

Country: United States

Level of government: local

Area of NCD prevention: population health

WellConnect Southeast Minnesota Partnership (WellConnect) was established as a bridging hub organization in 2016 to connect organizations working to improve population health in Southeast Minnesota, and support the coordination of their actions. The aim of WellConnect was to serve as an administrator and connector that could organize the health promotion programming of community-based organizations under a single, parent brand.

APPROACH

Specialist skills and knowledge: network analysis

Tool: Gephi open-source software

Social network analysis was used to evaluate the implementation of WellConnect and track its network reach. The key characteristics of a bridging hub network were defined as: (i) network membership, (ii) network interaction, (iii) role and reach of the bridging hub, and (iv) network collaboration. In order to evaluate how WellConnect performed with regard to these characteristics, a survey was administered to community-based organizations. These organizations included health-care and community organizations in the public health, education, health promotion and social services sectors. A number of additional organizations who had not been invited to participate in the survey were identified as partners by respondents. These included grocery stores, ambulance services and small health-care and community-based services focused on meeting the needs of underserved groups.

IMPLICATIONS

Benefit: assess the value of a bridging hub and inform ongoing implementation efforts

Challenge: difficulty getting responses

The social network analysis was useful in evaluating the value and reach of the WellConnect bridging hub and informing ongoing efforts in implementation.

While WellConnect was in a good position to bridge health care and the community, a large number of actors at work in health promotion were not connected through the bridging hub. Bridging hubs are not likely to link, or even be aware of, all relevant organizations, particularly early on in their implementation. Social network analysis can be useful in systematically identifying additional relevant organizations that could be linked to the hub.

Despite the useful insights generated through this analysis, it was difficult to obtain responses from all organizations. Strategies to overcome this could include conducting in-person interviews, although this would be more resource intensive.

Source: Leppin et al., 2018 *(43)*.

4.4.4 QCA

Case study 18. Conditions for addressing environmental determinants of health behaviour in intersectoral policy networks: a fuzzy-set QCA

CONTEXT

Country: the Netherlands

Level of government: local

Area of NCD prevention: structural determinants of health

Improving population health relies on changing the social, physical, economic and political determinants of health practices. With this aim in mind, intersectoral policy networks have been advocated to allow for the pooling of resources to implement different policy instruments. In the Netherlands, a number of municipalities have established such networks.

APPROACH

Specialist skills and knowledge: fuzzy-set QCA

Tool: Tosmana software

Peters and colleagues used fuzzy-set QCA to evaluate 25 intersectoral policy networks, determining the contribution of network diversity (the range of different sectors connected by the network), network size, management strategies and budget to the success or failure of networks in achieving their goal: addressing the structural determinants of health practices related to overweight, smoking and the abuse of alcohol and drugs.

The analysis relied on data from web-based surveys completed by project leaders and partners and implementation professionals, as well as a review of project applications to obtain information related to budget.

IMPLICATIONS

Benefit: qualify the advantages of intersectoral collaboration by identifying conditions for success

Challenge: metrics for success difficult to identify

Network diversity, where more than half of network members were not within public health, was necessary in small networks or networks with small budgets. In networks that were either larger or had larger budgets, network diversity was less important. All networks were only effective when carefully managed. An important benefit of taking a systems perspective in this project was that it provided a better understanding of how various conditions influence the output of intersectoral policy networks in terms of types of implemented health promotion initiative. This allowed the advantages of intersectoral collaboration to be qualified, by specifying the conditions required to successfully address the structural determinants of health.

Several challenges were encountered in completing this project. Identifying the desired outputs of intersectoral networks, by which their success or failure could be evaluated, proved challenging, as well as identifying an appropriate way to measure these outputs. In addition, limited variation in practice and interventions made the comparative aspect challenging.

Source: Peters et al., 2017 *(58)*.

5. Next steps for systems thinking in NCD prevention policy

5.1 Some reflections on the state of systems thinking in policy for NCD prevention

The use of systems thinking in policy for NCD prevention is developing rapidly. Systems approaches provide a different way of thinking about and approaching NCD prevention. Instead of replacing existing knowledge and approaches, these methods can be used to complement them. Systems approaches include a number of accessible methods that can be applied in a range of contexts in NCD prevention policy.

The value of systems thinking for NCD prevention policy lies in the potential to contribute to the development of evidence-informed policy in a systematic way, and in ensuring coherence and collaborative processes in making and implementing policy. In order to ensure the continued application and development of systems thinking in this area, it will be crucial to ensure usability and buy-in from stakeholders and practitioners.

5.1.1 EMERGENT APPROACHES AND ROOM FOR KEEPING UP WITH RAPID DEVELOPMENT

Systems thinking in policy for NCD prevention, and in population health more broadly, is occurring increasingly in practice as researchers and practitioners acknowledge the value of systems thinking for their work. The large number of studies identified in developing this guidance (see Annex 2) illustrates the breadth of existing applications of systems thinking to making and understanding policy for NCD prevention. Many of these examples have been published since the late 2000s.

Most of the applications of systems approaches in NCD prevention policy have occurred at either the national or subnational level. The use of systems approaches to supranational policy has been limited *(39,55)*, and there is substantial room for development. The WHO Global Action Plan on Physical Activity 2018–2030 is one example of how systems thinking concepts can be applied in this context *(59)*. Collaboration between countries could enable the application of systems thinking to policies encompassing parts, or even all, of the WHO European Region.

5.1.2 SUPPORTING EVIDENCE-INFORMED POLICY

One of the key benefits of systems thinking for NCD prevention policy lies in facilitating the use of research evidence in policy, particularly where policies are aimed at solving complex problems with complex causes. Systems thinking can be useful in generating robust and dynamic evidence around which policies are the most effective, both in the policy-making process, for problem identification and policy analysis, and in policy evaluation once policy is implemented.

While robust evidence is crucial to developing effective NCD prevention policy, other forces are also at work in the policy-making process: networks, stakeholders' views, public opinion and institutional structures and connections. Systems thinking can also be a useful way of understanding these other drivers, and informing strategies to leverage policy infrastructure in support of NCD prevention. In this guidance, these applications are concentrated in policy development, where networks and strategies for getting policies adopted are emphasized.

5.1.3 FACILITATING COHERENCE IN MAKING AND IMPLEMENTING POLICY

A further key benefit of systems thinking for NCD prevention policy lies in ensuring policy coherence. Given the multiple drivers of NCDs, a HiAP approach is increasingly advocated. With different government departments making policies with implications for NCD prevention, and responsibility being shared across levels of government, a systems perspective can be useful in ensuring that all policies complement each other in reaching a shared goal *(19,26)*.

Different organizations may also share responsibility for implementing policy, not just making it. In addition, nongovernmental and commercial actors may also operate in the NCD prevention space. Understanding how the work of different branches of government, as well as bodies outside of government, fit together can help to highlight opportunities for greater synergy and collaboration, and address conflicts of interest *(56,57)*.

5.2 Where can systems thinking in policy for NCD prevention go from here?

5.2.1 UNDERSTANDING BARRIERS AND TRAINING NEEDS

As demonstrated in this guidance, there are numerous examples of systems approaches being applied in policy for NCD prevention. These approaches are at a stage where they can be usefully incorporated into practice. A next key step for amplifying the effective use of systems thinking in this area would be to develop an understanding of policy-makers' perspectives on the use of systems approaches directly as part of their work.

A thorough understanding of what policy-makers see as the barriers and facilitators to the use of specific systems methods would allow systems scholars to orient their work in a way that is relevant to supporting an evidence-informed policy cycle, and enable the development of the required skills and capacities. For example, potential barriers to the use of systems thinking in a policy context could include institutional cultures, with the work of different departments being somewhat siloed; convincing colleagues and stakeholders of the added value of systems thinking through the generation of robust evidence; and the lack of accessible, practitioner-relevant training in how specific methods can be practically applied.

The purpose of this guidance is to introduce practitioners to how systems thinking methods are being used throughout the policy cycle. However, the approaches used are diverse in terms of the specific method employed, required expertise and specific tools. Therefore, the development of such training, centred on user needs and priorities, could be an important step forward.

Finally, in developing this guidance we identified a lack of evaluation of effectiveness of systems approaches in NCD prevention policy. This has also been identified in previous work on related topics *(17,60)* and remains an important gap in the evidence. Systems approaches may add value to the policy process by leading to the implementation of more effective, evidence-informed policy, but also by making the policy process more transparent, inclusive and democratic. Both of these avenues must continue to be explored to assess the contribution systems thinking can bring to policy-making.

5.2.2 SHARING SKILLS AND KNOWLEDGE TO SUPPORT SUSTAINED DEVELOPMENT FOR SYSTEMS THINKING

While there is still room for growth in this area, and many approaches are emerging, this guidance illustrates the substantial number of applied examples of systems thinking in the policy process for NCD prevention. Sharing learning, data and approaches between practitioners across the WHO European Region will also be an important avenue for progress.

References

1. Systems thinking for health systems strengthening. Geneva: World Health Organization; 2009 (https://apps.who.int/iris/handle/10665/44204, accessed 27 September 2021).

2. Haynes A, Garvey K, Davidson S, Milat A. 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. 2019;9:65–76. doi: 10.15171/IJHPM.2019.86.

3. Egan M, McGill E. Applying a systems perspective to preventive health: how can it be useful? 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;13:343–6. doi: 10.34172/ijhpm.2020.120.

4. Clifford Astbury C, McGill E, Egan M, Penney TL. Systems thinking and complexity science methods and the policy process in non-communicable disease prevention: a systematic scoping review protocol. BMJ Open. 2021;11(9):e049878. doi: 10.1136/bmjopen-2021-049878.

5. Rusoja E, Haynie D, Sievers J, Mustafee N, Nelson F, Reynolds M et al. Thinking about complexity in health: a systematic review of the key systems thinking and complexity ideas in health. J Eval Clin Pract. 2018;24(3):600–6. doi: 10.1111/jep.12856.

6. Meadows DH. Thinking in systems: a primer. White River Junction (VT): Chelsea Green Publishing; 2008 (https://www.chelseagreen.com/product/thinking-in-systems/, accessed 27 September 2021).

7. Reynolds M, Gates E, Hummelbrunner R, Marra M, Williams B. Towards systemic evaluation. Syst Res Behav Sci. 2016:33(5);662–73. doi: 10.1002/sres.2423.

8. Evans WN, Farrelly MC. The compensating behavior of smokers: taxes, tar, and nicotine. Rand J Econ. 1998:29;578–95. PMID: 11794360.

9. Sterman JD. Learning from evidence in a complex world. Am J Public Health. 2006;96:505–14. doi: 10.2105/AJPH.2005.066043.

10. Senge PM. The fifth discipline: the art and practice of the learning organization. New York: Currency Doubleday; 2006.

11. Rose G, Khaw K-T, Marmot M. Rose's strategy of preventive medicine: the complete original text. Oxford: Oxford University Press; 2008 (https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780192630971.001.0001/acprof-9780192630971, accessed 27 September 2021).

12. Russell E, Johnson B, Larsen H, Novilla MLB, van Olmen J, Swanson RC. Health systems in context: a systematic review of the integration of the social determinants of health within health systems frameworks. Rev Panam Salud Publ. 2013;34:461–7. PMID: 24569976.

13. Swanson RC, Cattaneo A, Bradley E, Chunharas S, Atun R, Abbas KM et al. Rethinking health systems strengthening: key systems thinking tools and strategies for transformational change. Health Policy Plan. 2012;27(Suppl 4):iv54–61. doi: 10.1093/heapol/czs090.

14. Langellier BA, Yang Y, Purtle J, Nelson KL, Stankov I, Roux AVD. Complex systems approaches to understand drivers of mental health and inform mental health policy: a systematic review. Adm Policy Ment Health. 2019;46(2):128–44. doi: 10.1007/s10488-018-0887-5.

15. Langellier BA, Kuhlberg JA, Ballard EA, Slesinski SC, Stankov I, Gouveia N et al. 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.

16. Ghaffarzadegan N, Lyneis J, Richardson GP. How small system dynamics models can help the public policy process. Syst Dyn Rev. 2011;27:22–44. doi: 10.1002/sdr.442.

17. Atkinson J-AM, Wells R, Page A, Dominello A, Haines M, Wilson A et al. Applications of system dynamics modelling to support health policy. Public Health Res Pract. 2015;25(3):e2531531. doi: 0.17061/phrp2531531.

18. Hovmand P. Community based system dynamics. New York: Springer-Verlag; 2014.

19. Nau T, Lee KC, Smith B, Bellew W, Reece L, Gelius P et al. Toward whole-of-system action to promote physical activity: a cross-sectoral analysis of physical activity policy in Australia. J Phys Act Health. 2019;16:1029–38. doi: 10.1123/jpah.2019-0122.

20. Signal LN, Walton MD, Ni Mhurchu C, Maddison R, Bowers SG, Carter KN et al. Tackling "wicked" health promotion problems: a New Zealand case study. Health Promot Int. 2013;28:84–94. doi: 0.1093/heapro/das006.

21. Crowe S, Cresswell K, Robertson A, Huby G, Avery A, Sheikh A. The case study approach. BMC Med Res Methodol. 2011;11:100. doi: 10.1186/1471-2288-11-100.

22. Gerritsen S, Harré S, Swinburn B, Rees D, Renker-Darby A, Bartos AE et al. Systemic barriers and equitable interventions to improve vegetable and fruit intake in children: interviews with national food system actors. Int J Environ Res Public Health. 2019;16(8):1387. doi: 10.3390/ijerph16081387.

23. Zimmermann N, Pluchinotta I, Salvia G, Touchie M, Stopps H, Hamilton I et al. Moving online: reflections from conducting system dynamics workshops in virtual settings. Syst Dyn Rev. 2021;37(1):59–71. doi: 10.1002/sdr.1667.

24. Wilkerson B, Aguiar A, Gkini C, De Oliveira IC, Trellevik L-KL, Kopainsky B. Reflections on adapting group model building scripts into online workshops. Syst Dyn Rev. 2020;36(3):358–72. doi: 0.1002/sdr.1662.

25. Hayward J, Morton S, Johnstone M, Creighton D, Allender S. Tools and analytic techniques to synthesise community knowledge in CBPR using computer-mediated participatory system modelling. NPJ Digit Med. 2020;3:1–6. doi: 10.1038/s41746-020-0230-x.

26. Bellew W, Smith BJ, Nau T, Lee K, Reece L, Baumanet A. Whole of systems approaches to physical activity policy and practice in Australia: the ASAPa project overview and initial systems map. J Phys Act Health. 2019;17(1):1–6. doi: 0.1123/jpah.2019-0121.

27. Eden C. Cognitive mapping. Eur J Oper Res. 1998;36(1):1–13. doi: 10.1016/0377-2217(88)90002-1.

28. Ackermann F, Eden C, Cropper S. Getting started with cognitive mapping. Kendal: Banxia Software; 1992 (https://banxia.com/pdf/de/GettingStartedWithCogMapping.pdf, accessed 27 September 2021).

29. Giles BG, Findlay CS, Haas G, LaFrance B, Laughing W, Pembleton S. Integrating conventional science and aboriginal perspectives on diabetes using fuzzy cognitive maps. Soc Sci Med. 2007;64(3):562–76. doi: 10.1016/j.socscimed.2006.09.007.

30. Kasman M, Hammond RA, Heuberger B, Mack-Crane A, Purcell R, Economos C et al. Activating a community: an agent-based model of Romp & Chomp, a whole-of-community childhood obesity intervention. Obesity. 2019;27:1494–502. doi: 10.1002/oby.22553.

31. Badham J, Chattoe-Brown E, Gilbert N, Chalabi Z, Kee F, Hunter RF. Developing agent-based models of complex health behaviour. Health Place. 2018;54:170–7. doi: 10.1016/j.healthplace.2018.08.022.

32. Loyo HK, Batcher C, Wile K, Huang P, Orenstein D, Milstein B. From model to action: using a system dynamics model of chronic disease risks to align community action. Health Promot Pract. 2013;14(1):53–61. doi: 10.1177/1524839910390305.

33. Knai C, Petticrew M, Douglas N, Durand MA, Eastmure E, Nolte E et al. The public health responsibility deal: using a systems-level analysis to understand the lack of impact on alcohol, food, physical activity, and workplace health sub-systems. Int J Environ Res Public Health. 2018;15(12):2895. doi: 10.3390/ijerph15122895.

34. Barbrook-Johnson P, Carrick J. Combining complexity-framed research methods for social research. Int J Soc Res Methodol. 2021;1–14. doi: 10.1080/13645579.2021.1946118.

35. Clarke B, Swinburn, B, Sacks G. Understanding the LiveLighter obesity prevention policy processes: an investigation using political science and systems thinking. Soc Sci Med. 2020;246:112757. doi: 10.1016/j.socscimed.2019.112757.

36. Brennan LK, Sabounchi 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.

37. 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.

38. Bérard C. Group model building using system dynamics: an analysis of methodological frameworks. Electron J Bus. 2010;8(1):13–24.

39. Baker P, Brown AD, Wingrove K, Allender S, Walls H, Cullerton K et al. Generating political commitment for ending malnutrition in all its forms: a system dynamics approach for strengthening nutrition actor networks. Obes Rev. 2019;20(Suppl 2):30–44. doi: 10.1111/obr.12871.

40. Luke DA, Wald LM, Carothers BJ, Bach LE, Harris JK. Network influences on dissemination of evidence-based guidelines in state tobacco control programs. Health Educ Behav. 2013;40(1):33S–42S. doi: 10.1177/1090198113492760.

41. Cullerton K, Donnet T, Lee A, Gallegos D. Joining the dots: the role of brokers in nutrition policy in Australia. BMC Public Health. 2017;17:307. doi: 10.1186/s12889-017-4217-8.

42. Shankardass K, Muntaner C, Kokkinen L, Shahidi FV, Freiler A, Oneka G et al. The implementation of Health in All Policies initiatives: a systems framework for government action. Health Res Policy Syst. 2018;16(1):26. doi: 10.1186/s12961-018-0295-z.

43. Leppin AL, Okamoto JM, Organick PW, Thota AD, Barrera-Flores FJ, Wieland ML et al. Applying social network analysis to evaluate implementation of a multisector population health collaborative that uses a bridging hub organization. Front Public Health. 2018;6:315. doi: 10.3389/fpubh.2018.00315.

44. Hunter RF, Wickramasinghe K, Ergüder T, Bolat A, Arı HO, Yıldırım HH et al. National action plans to tackle NCDs: role of stakeholder network analysis. BMJ. 2019;365:l1871. doi: 10.1136/bmj.l1871.

45. Blackman T, Wistow J, Byrne D. Using qualitative comparative analysis to understand complex policy problems. Evaluation. 2013;19:126–140. doi: 10.1177/1356389013484203.

46. Gerrits L, Pagliarin S. Social and causal complexity in qualitative comparative analysis (QCA): strategies to account for emergence. Int J Soc Res Methodol. 2020;0:1–14. doi: 0.1080/13645579.2020.1799636.

47. Rihoux B, Ragin CC. Configurational comparative methods: qualitative comparative analysis (QCA) and related techniques. London: SAGE; 2009.

48. Howlett M, Cashore B. Conceptualizing public policy. In: Engeli I, Allison CR, editors. Comparative policy studies: conceptual and methodological challenges. London: Palgrave Macmillan; 2014: 17–33.

49. Health systems financing: the path to universal coverage. Geneva: World Health Organization; 2010 (https://apps.who.int/iris/handle/10665/44371, accessed 27 September 2021).

50. Voinov A, Jenni K, Gray S, Kolagani N, Glynn PD, Bommel P et al. Tools and methods in participatory modeling: selecting the right tool for the job. Environ Model Softw. 2018;109:232–55. doi: 10.1016/j.envsoft.2018.08.028.

51. Conte KP, Davidson S. Using a "rich picture" to facilitate systems thinking in research coproduction. Health Res Policy Sys. 2020;18:14. doi: 10.1186/s12961-019-0514-2.

52. Freebairn L, Atkinson J-A, Osgood ND, Kelly PM, McDonnell G, Rychetnik L. Turning conceptual systems maps into dynamic simulation models: an Australian case study for diabetes in pregnancy. PLOS ONE. 2019;14:e0218875. doi: 10.1371/journal.pone.0218875.

53. Li Y, Zhang D, Thapa JR, Madondo K, Yi S, Fisher E, et al. Assessing the role of access and price on the consumption of fruits and vegetables across New York City using agent-based modeling. Prev Med. 2018;106:73–8. doi: 10.1016/j.ypmed.2017.10.014.

54. Browne J, de Leeuw E, Gleeson D, Adams K, Atkinson P, Hayes R et al. A network approach to policy framing: a case study of the national Aboriginal and Torres Strait Islander health plan. Soc Sci Med. 2017;172:10–18. doi: 10.1016/j.socscimed.2016.11.011.

55. Valente TW, Wipfli H, Vega Yon GG. Network influences on policy implementation: Evidence from a global health treaty. Soc Sci Med. 2019;222188–197. doi: 10.1016/j.socscimed.2019.01.008.

56. Roussy V, Riley T, Livingstone C. Together stronger: boundary work within an Australian systems-based prevention initiative. Health Promot Int. 2020;35(4):671–81. doi: 10.1093/heapro/daz065.

57. Beaton A, Manuel C, Tapsell J, Foote J, Oetzel JG, Hudson M. He Pikinga Waiora: supporting Māori health organisations to respond to pre-diabetes. Int J Equity Health. 2019;18:3. doi: 10.1186/s12939-018-0904-z.

58. Peters DTJM, Verweij S, Grêaux K, Stronks K, Harting J. Conditions for addressing environmental determinants of health behavior in intersectoral policy networks: a fuzzy set qualitative comparative analysis. Soc Sci Med. 2019;195:34–41. doi: 10.1016/j.socscimed.2017.08.036.

59. Global action plan on physical activity 2018–2030: more active people for a healthier world. Geneva: World Health Organization; 2018 (https://apps.who.int/iris/handle/10665/272722, accessed 27 September 2021).

60. Rouwette EAJA, Vennix JAM, van Mullekom T. Group model building effectiveness: a review of assessment studies. Syst Dyn Rev. 2002;18:5–45. doi: 10.1002/sdr.229.

Annex 1. Resources around systems thinking and health

Applying dynamic simulation modeling methods in health care delivery research: the SIMULATE checklist. Lawrenceville (NJ): International Society for Pharmacoeconomics and Outcomes Research; 2017 (https://www.ispor.org/heor-resources/good-practices/article/applying-dynamic-simulation-modeling-methods-in-health-care-delivery-research---the-simulate-checklist, accessed 28 September 2021).

De Savigny D, Blanchet K Adam T. Applied systems thinking for health systems research: a methodological handbook. London: McGraw-Hill Education; 2017.

Egan M, McGill E, Penney T, Anderson de Cuevas R, Er V, Orton L et al. NIHR SPHR guidance on systems approaches to local public health evaluation. Part 1: introducing systems thinking. London: National Institute for Health Research School for Public Health Research; 2019 (https://sphr.nihr.ac.uk/wp-content/uploads/2018/08/NIHR-SPHR-SYSTEM-GUIDANCE-PART-1-FINAL_SBnavy.pdf, accessed 28 September 2021).

Egan M McGill E, Penney T, Anderson de Cuevas R, Er V, Orton L et al. NIHR SPHR guidance on systems approaches to local public health evaluation. Part 2: What to consider when planning a systems evaluation. London: National Institute for Health Research School for Public Health Research; 2019 (https://sphr.nihr.ac.uk/wp-content/uploads/2018/08/NIHR-SPHR-SYSTEM-GUIDANCE-PART-2-v2-FINALSBnavy.pdf, accessed 28 September 2021).

Evidence scan: complex adaptive systems. London: The Health Foundation; 2010 (https://www.health.org.uk/sites/default/files/ComplexAdaptiveSystems.pdf, accessed 28 September 2021).

Selecting a dynamic simulation modeling method for health care delivery research: part 2. Lawrenceville (NJ): International Society for Pharmacoeconomics and Outcomes Research; 2015 (https://www.ispor.org/heor-resources/good-practices/article/selecting-a-dynamic-simulation-modeling-method-for-health-care-delivery-research---part-2, accessed 28 September 2021).

Systems thinking for health systems strengthening. Geneva: World Health Organization; 2009 (https://apps.who.int/iris/handle/10665/44204, accessed 27 September 2021).

Annex 2. Additional examples of systems thinking in action

Table A2.1. Problem identification and policy analysis

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Atkinson et al., 2017 *(1)*	Alcohol	Local	Australia	ABM	AnyLogic
Auchincloss et al., 2011 *(2)*	Diet	Local	United States	ABM	Recursive Porous Agent Simulation Toolkit (Repast) version 3
Castillo-Carniglia et al., 2018 *(3)*	Alcohol	Local	United States	ABM	–
Hammond et al., 2020 *(4)*	Tobacco	Local	United States	ABM	Tobacco Town is an agent-based simulation model
Li et al., 2018 *(5)*	Diet	Local	United States	ABM	Programmed using Java
Orr et al., 2015 *(6)*	Obesity	National	United States	ABM	Not available
Widener et al., 2013 *(7)*	Diet	Local	United States	ABM	Not specified; GIS software; ABM software
Zhang et al, 2014 *(8)*	Diet	Local	United States	ABM	Not available
Clarke et al., 2018 *(9)*	Obesity	Local	Australia	CLD	NVivo software and Vensim software
Littlejohns et al., 2018 *(10)*	Obesity	National	Australia	CLD	NVivo software and Vensim PLE software

Table A2.1. contd

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Tan et al., 2019 *(11)*	Public health	National	Malaysia	CLD	–
Wutzke et al., 2017 *(12)*	NCDs	National	Australia	CLD	–
Gerritsen et al., 2019 *(13)*	Diet	National	New Zealand	Cognitive mapping	Vensim software
Giles et al., 2007 *(14)*	Diabetes	National	Canada	Cognitive mapping	–
Bellew et al., 2020 *(15)*	Physical activity	National	Australia	Concept mapping	Not available
Cambon et al., 2013 *(16)*	Public health	National	Canada	Concept mapping	Concept System (version 4.0.1) software
Stankov et al., 2017 *(17)*	CVD	Regional	Australia	Concept mapping	The Concept System Global MAX software
Guariguata et al., 2020 *(18)*	Obesity	Regional	Caribbean Region	GMB	Vensim PLE software
Witter et al., 2020 *(19)*	NCDs	Local	Sierra Leone	GMB	Not available
Buck et al., 2019 *(20)*	Sedentary behaviour	Regional	Europe	Network analysis	R, bnlearn and igraph packages
El-Sayed et al., 2012 *(21)*	Obesity	National	England (United Kingdom)	Network analysis	Not available
Loitz et al., 2017 *(22)*	Physical activity	Regional	Canada	Network analysis	–
Mazzocchi et al., 2020 *(23)*	Public health	National	Italy	Network analysis	–
McGetrick et al., 2019 *(24)*	NCD	National	Canada	Network analysis	Meerkat Lite software
Peters et al., 2017 *(25)*	Alcohol abuse, physical inactivity, unhealthy diets	National	Netherlands	Network analysis	UCINET

Table A2.1. contd

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Yancey et al., 2010 *(26)*	Physical activity	Local	United States	Other[b]	Not available
Honeycutt et al., 2015 *(27)*	NCD	Local	United States	Other (custom systems dynamics model: PRISM)	Prevention Impacts Simulation Model
Freebairn et al., 2020 *(28)*	Diabetes	National	Australia	Other (hybrid dynamic simulation model)	AnyLogic
Gao et al., 2014 *(29)*	Diabetes	Local	Canada	Other[c]	AnyLogic
Johnston et al., 2014 *(30)*	Obesity	National	United States & Canada	Other (interventions-level framework)	Not available
Crespo et al., 2020 *(31)*	Diabetes	Local	Chile	Other (spatial micro-simulation and a self-organizing map)	R kohonen package
Abdollahiasl et al., 2014 *(32)*	Drug (pharmaceuti-cal) policy	National	Iran (Islamic Republic of)	SDM	Vensim software
Atkinson et al., 2020 *(33)*	Suicide prevention	Local	Australia	SDM	Stella Architect software
Carrete et al., 2017 *(34)*	Obesity	National	Mexico	SDM	STella Architect software
Cavana and Clifford 2006 *(35)*	Tobacco	National	New Zealand	SDM	ithink dynamic simulation software
Cavana and Tobias 2008 *(36)*	Tobacco	National	New Zealand	SDM	ithink dynamic simulation software
Conte et al., 2020 *(37)*	Public health	National	Australia	SDM	Soft Systems Method ology
Hirsch et al., 2010 *(38)*	CVD	Local	United States	SDM	Vensim software
Kang et al., 2018 *(39)*	Chronic kidney disease	Local	United States	SDM	Vensim software

Table A2.1. contd

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Langellier et al., 2019 *(40)*	Urban health[d]	Regional	Latin America	SDM	Qualtrics
Roberts et al., 1982 *(41)*	Tobacco	National	United States	SDM	Not available
Roberts et al., 2018 *(42)*	Obesity	National	Australia	SDM	iThink v10 software
Soler et al., 2016 *(43)*	Obesity and tobacco	Local	United States	SDM	–
Tobias et al., 2010 *(44)*	Tobacco	National	New Zealand	SDM	ithink dynamic simulation software
Yarnoff et al., 2019 *(45)*	CVD	National	United States	SDM	Prevention Impacts Simulation Model
Brown et al., 2019 *(46)*	Physical activity	Local	Australia	Systems lens	The Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) and Melbourne travel survey data
Castillo-Carandang et al., 2020 *(47)*	CVD	National	Southeast Asian region	Systems lens	–
Pérez-Escamilla et al., 2017 *(48)*	Obesity	National	Latin America	Systems lens	–
Signal et al., 2012 *(49)*	NCD	National	New Zealand	Systems lens	Not available
van den Driessen Mareeuw et al., 2015 *(50)*	Public health	National	Netherlands	Systems lens	ATLAS ti
Nau et al., 2019 *(51)*	Physical activity	National	Australia	Systems lens (policy audit)	Not available

[a]Level of government: local, national, regional or global.
[b]A graphical, computer-based decision-support tool to help decision makers to evaluate policy options relating to physical activity.
[c]Hybrid simulation model: SDM agent-based and discrete event modelling.
[d]Food environments and transport systems.

Table A2.2. Policy development

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Pineo et al., 2020 *(52)*	Urban planning	Local	United States	CLD	Not available
Clarke et al., 2020 *(53)*	Obesity	Local	Australia	CLD	NVivo10 qualitative analysis software and Vensim software
Racine et al., 2020 *(54)*	Physical activity	Local	France	Concept mapping	Concept Systems Global Max software
Baker et al., 2019 *(55)*	Diet	Global	Global	GMB	Vensim software
Waqa et al., 2017 *(56)*	Obesity	National	Fiji	GMB	Vensim software
Browne et al., 2016 *(57)*	Aboriginal health	Local	Australia	Network analysis	Gephi network mapping software (open source)
Cullerton et al., 2016 *(58)*	Obesity	National	Australia	Network analysis	NODEXL; Harel–Koren–Fast multi-scale algorithm; Clauset–Newman–Moore algorithm
Cullerton et al., 2017 *(59)*	Diet	National	Australia	Network analysis	NodeXL
de Bruin et al., 2018 *(60)*	Obesity and diabetes	National	New Zealand	Network analysis	Social network analysis software NodeXL Pro and Qualtrics survey software
Heo et al., 2018 *(61)*	Health equity	Local	South Korea	Network analysis	UCINet
Luke et al., 2013 *(62)*	Tobacco	Local	United States	Network analysis	Pajek Software; R (statnet package)

Table A2.2. contd

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Merrill et al., 2010 *(63)*	Public health	Local	United States	Network analysis	Not available
Oliver et al., 2012 *(64)*	Public health	National	United Kingdom	Network analysis	UCINET software and visualised using Netdraw
Oliver et al., 2017 *(65)*	Public health	Local	England (United Kingdom)	Network analysis	UCINet
Valente et al., 2019 *(66)*	Tobacco	Global	Global	Network analysis	R- AER, Amelia R packages
Zwald et al., 2019 *(67)*	Physical activity	Regional	United States	Network analysis	–
Daly-Smith et al., 2020 *(68)*	Physical activity	National	United Kingdom	SDM	–
Freebairn et al., 2017 *(69)*	Alcohol, diabetes	National	Australia	SDM	–
Pineo et al., 2020 *(52)*	Public health	Global	Australia and United States	SDM	NVivo qualitative data analysis software
Loyo et al., 2013 *(70)*	CVD	Local	United States	SDM with action workshop	Modelling tool not stated; no tool for workshop
Fisher et al., 2014 *(71)*	Public health	Regional	Australia	Systems lens	QSR NVivo 10 software

[a]Level of government: local, national, regional or global.

Table A2.3. Policy implementation

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Beaton et al., 2019 *(72)*	Diabetes	Regional	New Zealand	Systems lens	Not available
Roussy et al., 2019 *(73)*	Obesity	National	Australia	Systems lens	QSR Nvivo (version 11)
Shankardass et al., 2018 *(74)*	HiAP	National	Finland	Systems lens	Not available

[a]Level of government: local, national, regional or global.

Table A2.4. Policy monitoring, enforcement and evaluation

Record	Application			Approach	
	Focus	Level[a]	Country	Method name	Tool used (if any, e.g. software, kit)
Brennan et al., 2015 *(75)*	Obesity	National	United States	CLD	Vensim software
Garney et al., 2020 *(76)*	CVD	National	United States	Network analysis	UCINet
Leppin et al., 2018 *(77)*	Population health	Local	United States	Network analysis	Gephi network mapping software (open source)
Scheele et al., 2018 *(78)*	Health equity	Local	Scandinavia	Network analysis	Nvivo (thematic analysis of interview transcripts)
Peters et al., 2017 *(79)*	Environmental determinants of health	Local	Netherlands	QCA	Tosmana software; R - QCA package
Knai et al., 2018 *(80)*	Physical activity	National	United Kingdom	SDM	–
Liu et al., 2015 *(81)*	Obesity	National	United States	SDM	–
Macmillan et al., 2020 *(82)*	Physical activity	National	New Zealand	SDM	–
Powell et al., 2017 *(83)*	Obesity, physical activity	Local	United States	SDM	–
Knai et al., 2018 *(84)*	Public health	Global	Global	SDM, agent-based model and CLD	–
Kokkinen et al., 2019 *(85)*	Public health	Global	Global	Systems	

[a]Level of government: local, national, regional or global.

References

1. Atkinson JA, Knowles D, Wiggers J, Livingston M, Room R, Prodan A et al. Harnessing advances in computer simulation to inform policy and planning to reduce alcohol-related harms. Int J Public Health. 2018;63(4):537–46. doi: 10.1007/s00038-017-1041-y.

2. Auchincloss AH, Riolo RL, Brown DG, Cook J, Diez Roux AV. An agent-based model of income inequalities in diet in the context of residential segregation. Am J Prev Med. 2011;40:303–11. doi: 10.1016/j.amepre.2010.10.033.

3. Castillo-Carniglia A, Pear VA, Tracy M, Keyes KM, Cerdá M. Limiting alcohol outlet density to prevent alcohol use and violence: estimating policy interventions through agent-based modeling. Am J Epidemiol. 2019;188:694–702. doi: 10.1093/aje/kwy289.

4. Hammond RA, Combs TB, Mack-Crane A, Kasman M, Sorg A, Snider D et al. Development of a computational modeling laboratory for examining tobacco control policies: Tobacco Town. Health Place. 2020;61:102256. doi: 10.1016/j.healthplace.2019.102256.

5. Li Y, Zhang D, Thapa JR, Madondo K, Yi S, Fisher E et al. Assessing the role of access and price on the consumption of fruits and vegetables across New York City using agent-based modeling. Prev Med. 2018;106:73–8. doi: 10.1016/j.ypmed.2017.10.014.

6. Orr MG, Kaplan GA, Galea S. Neighbourhood food, physical activity, and educational environments and black/white disparities in obesity: a complex systems simulation analysis. J Epidemiol Community Health. 2016;70:862–7. doi: 10.1136/jech-2015-205621.

7. Widener MJ, Metcalf SS, Bar-Yam Y. Agent-based modeling of policies to improve urban food access for low-income populations. Appl Geogr. 2013;40:1–10. doi: 10.1016/j.apgeog.2013.01.003.

8. Zhang D, Giabbanelli PJ, Arah OA, Zimmerman FJ. Impact of different policies on unhealthy dietary behaviors in an urban adult population: an agent-based simulation model. Am J Public Health. 2014;104:1217–22. doi: 10.2105/AJPH.2014.301934.

9. Clarke B, Swinburn B, Sacks G. Understanding health promotion policy processes: a study of the government adoption of the achievement program in Victoria, Australia. Int J Environ Res. 2018;15:2393. doi: 10.3390/ijerph15112393.

10. Littlejohns LB, Baum F, Lawless A, Freeman T. The value of a causal loop diagram in exploring the complex interplay of factors that influence health promotion in a multisectoral health system in Australia. Health Res Policy Syst. 2018;16:126. doi: 10.1186/s12961-018-0394-x.

11. Tan DT, Siri JG, Gong Y, Ong B, Lim SC, MacGillivray BH et al. Systems approaches for localising the SDGs: co-production of place-based case studies. Glob Health. 2019;15(1):85. doi: 10.1186/s12992-019-0527-1.

12. Wutzke S, Roberts N, Willis C, Best A, Wilson A, Trochim W. Setting strategy for system change: using concept mapping to prioritise national action for chronic disease prevention. Health Res Policy Syst. 2017;15:69. doi: 10.1186/s12961-017-0231-7.

13. Gerritsen S, Harré S, Swinburn B, Rees D, Renker-Darby A, Bartos AE et al. Systemic barriers and equitable interventions to improve vegetable and fruit intake in children: interviews with national food system actors. Int J Environ Res. 2019;16:1387. doi: 10.3390/ijerph16081387.

14. Giles BG, Findlay CS, Haas G, LaFrance B, Laughing W, Pembleton S. Integrating conventional science and aboriginal perspectives on diabetes using fuzzy cognitive maps. Soc Sci Med. 2007;64:562–76. doi: 10.1016/j.socscimed.2006.09.007.

15. Bellew W, Smith BJ, Nau T, Lee K, Reece L, Bauman A. Whole of systems approaches to physical activity policy and practice in Australia: the asapa project overview and initial systems map. J Phys Act Health. 2020;17:68–73. doi: 10.1123/jpah.2019-0121.

16. Cambon L, Minary L, Ridde V, Alla F. A tool to analyze the transferability of health promotion interventions. BMC Public Health. 2013;13:1184. doi: 10.1186/1471-2458-13-1184.

17. Stankov I, Howard NJ, Daniel M, Cargo M. Policy, research and residents' perspectives on built environments implicated in heart disease: a concept mapping approach. Int J Environ Res. 2017;14:170. doi: 10.3390/ijerph14020170.

18. Guariguata L, Rouwette EAJA, Murphy MM, Ville AS, Dunn LL, Hickey GM et al. Using group model building to describe the system driving unhealthy eating and identify intervention points: a participatory, stakeholder engagement approach in the Caribbean. Nutrients. 2020;12(2):384. doi: 10.3390/nu12020384.

19. Witter S, Zou G, Diaconu K, Senesi RGB, Idriss A, Walley J et al. Opportunities and challenges for delivering non-communicable disease management and services in fragile and post-conflict settings: perceptions of policy-makers and health providers in Sierra Leone. Confl Health. 2020;14(1):3. doi: 10.1186/s13031-019-0248-3.

20. Buck C, Loyen A, Foraita R, Van Cauwenberg J, De Craemer M, Mac Donncha C et al. Factors influencing sedentary behaviour: a system based analysis using Bayesian networks within DEDIPAC. PLOS One. 2019;14(1):e0211546. doi: 10.1371/journal.pone.0211546.

21. El-Sayed AM, Seemann L, Scarborough P, Galea S. Are network-based interventions a useful antiobesity strategy? An application of simulation models for causal inference in epidemiology. Am J Epidemiol. 2013;178(2):287–95. doi: 10.1093/aje/kws455.

22. Loitz CC, Stearns JA, Fraser SN, Storey K, Spence JC. Network analysis of inter-organizational relationships and policy use among active living organizations in Alberta, Canada. BMC Public Health. 2017;17:649. doi: 10.1186/s12889-017-4661-5.

23. Mazzocchi G, Marino D. Rome, a policy without politics: the participatory process for a metropolitan scale food policy. Int J Environ Res. 2020;17(2):479. doi: 10.3390/ijerph17020479.

24. McGetrick JA, Raine KD, Wild TC, Nykiforuk CIJ. advancing strategies for agenda setting by health policy coalitions: a network analysis of the Canadian Chronic Disease Prevention Survey. Health Commun. 2019;34:1303–12. doi: 10.1080/10410236.2018.1484267.

25. Peters DTJM, Raab J, Grêaux KM, Stronks K, Harting J. Structural integration and performance of inter-sectoral public health-related policy networks: an analysis across policy phases. Health Policy. 2017;121:1296–302. doi: 10.1016/j.healthpol.2017.10.001.

26. Yancey AK, Cole BL, McCarthy WJ. A graphical, computer-based decision-support tool to help decision makers evaluate policy options relating to physical activity. Am J Prev Med. 2010;39:273–9. doi: 10.1016/j.amepre.2010.05.013.

27. Honeycutt AA, Wile K, Dove C, Hawkins J, Orenstein D. Strategic planning for chronic disease prevention in rural America: looking through a PRISM lens. J Public Health Manag Pract. 2015;21:392–9. doi: 10.1097/PHH.0000000000000062.

28. Freebairn L, Atkinson J, Qin Y, Nolan CJ, Kent AL, Kelly PM et al. "Turning the tide" on hyperglycemia in pregnancy: insights from multiscale dynamic simulation modeling. BMJ Open Diabetes Res Care. 2020;8:e000975. doi: 10.1136/bmjdrc-2019-000975.

29. Gao A, Osgood ND, An W, Dyck RF. A tripartite hybrid model architecture for investigating health and cost impacts and intervention tradeoffs for diabetic end-stage renal disease. In: WSC '14: Proceedings of the 2014 Winter Simulation Conference. Piscataway (NJ): IEEE Xplore; 2014: 1676–87 (https://ieeexplore.ieee.org/abstract/document/7020018, accessed 16 November 2021).

30. Johnston LM, Matteson CL, Finegood DT. Systems science and obesity policy: a novel framework for analyzing and rethinking population-level planning. Am J Public Health. 2014;104:1270–8. doi: 10.2105/AJPH.2014.301884.

31. Crespo R, Alvarez C, Hernandez I, García C. A spatially explicit analysis of chronic diseases in small areas: a case study of diabetes in Santiago, Chile. Int J Health Geogr. 2020;19:24. doi: 10.1186/s12942-020-00217-1.

32. Abdollahiasl A, Kebriaeezadeh A, Dinarvand R, Abdollahi M, Cheraghali AM, Jaberidoost M et al. A system dynamics model for national drug policy. DARU J Pharm Sci. 2014;22(1):34. doi: 10.1186/2008-2231-22-34.

33. Atkinson J-A, Skinner A, Hackney S, Mason L, Heffernan M, Currier D et al. Systems modelling and simulation to inform strategic decision making for suicide prevention in rural New South Wales (Australia). Aust N Z J Psychiatry. 2020;54(9):892–901. doi: 10.1177/0004867420932639.

34. Carrete L, Arroyo P, Villaseñor R. A socioecological view toward an understanding of how to prevent overweight in children. J Consum Mark. 2017;34:156–68. doi: 10.1108/JCM-01-2016-1660.

35. Cavana RY, Clifford LV. Demonstrating the utility of system dynamics for public policy analysis in New Zealand: the case of excise tax policy on tobacco. Syst Dyn Rev. 2007;22(4):321–48. doi: 10.1002/sdr.347.

36. Cavana RY, Tobias M. Integrative system dynamics: analysis of policy options for tobacco control in New Zealand. Syst Res Behav Sci. 2009;25(5):675–94. doi: 10.1002/sres.934.

37. Conte KP, Davidson S. Using a "rich picture" to facilitate systems thinking in research coproduction. Health Res Policy Syst. 2020;18:14. doi: 10.1186/s12961-019-0514-2.

38. Hirsch G, Homer J, Evans E, Zielinski A. A system dynamics model for planning cardiovascular disease interventions. Am J Public Health. 2010;100(4):616–22. doi: 10.2105/AJPH.2009.159434.

39. Kang H, Nembhard HB, Ghahramani N, Curry W. A system dynamics approach to planning and evaluating interventions for chronic disease management. J Oper Res Soc. 2018;69:987–1005. doi: 10.1057/s41274-017-0279-3.

40. Langellier BA, Kuhlberg JA, Ballard EA, Slesinski SC, Stankov I, Gouveia N et al. 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.

41. Roberts EB, Homer J, Kasabian A, Varrell M. A systems view of the smoking problem: Perspective and limitations of the role of science in decision-making. Int J Biomed Comput. 1982;13(1):69–86. doi: 10.1016/0020-7101(82)90051-4.

42. Roberts N, Li V, Atkinson J-A, Heffernan M, McDonnell G, Prodan A et al. Can the target set for reducing childhood overweight and obesity be met? A system dynamics modelling study in New South Wales, Australia. Syst Res Behav Sci. 2019;36(1):36–52. doi: 10.1002/sres.2555.

43. Soler R, Orenstein D, Honeycutt A, Bradley C, Trogdon J, Kent CK et al. Community-based interventions to decrease obesity and tobacco exposure and reduce health care costs: outcome estimates from communities putting prevention to work for 2010–2020. Prev Chronic Dis. 2016;13(4):150272. doi: 10.5888/pcd13.150272.

44. Tobias MI, Cavana RY, Bloomfield A. Application of a system dynamics model to inform investment in smoking cessation services in New Zealand. Am J Public Health. 2010;100(7):1274–81. doi: 10.2105/AJPH.2009.171165.

45. Yarnoff B. Estimating the relative impact of clinical and preventive community-based interventions: an example based on the community transformation grant program. Prev Chronic Dis. 2019;16:E87. doi: 10.5888/pcd16.180594.

46. Brown V, Barr A, Scheurer J, Magnus A, Zapata-Diomedi B, Bentley R. Better transport accessibility, better health: a health economic impact assessment study for Melbourne, Australia. Int J Behav Nutr. 2019;16:89. doi: 10.1186/s12966-019-0853-y.

47. Castillo-Carandang NT, Buenaventura RD, Chia Y-C, Van DD, Lee C, Duong NL et al. Moving towards optimized noncommunicable disease management in the ASEAN region: recommendations from a review and multidisciplinary expert panel. Risk Manag Healthc Policy. 2020;13:803–19. doi: 10.2147/RMHP.S256165.

48. Pérez-Escamilla R, Lutter CK, Rabadan-Diehl C, Rubinstein A, Calvillo A, Corvalán C et al. Prevention of childhood obesity and food policies in Latin America: from research to practice. Obes Rev. 2017;18:28–38. doi: 10.1111/obr.12574.

49. Signal LN, Walton MD, Ni Mhurchu C, Maddison R, Bowers SG, Carter KN et al. Tackling 'wicked' health promotion problems: a New Zealand case study. Health Promot Int. 2013;28(1):84–94. doi: 10.1093/heapro/das006.

50. van den Driessen Mareeuw F, Vaandrager L, Klerkx L, Naaldenberg J, Koelen M. Beyond bridging the know-do gap: a qualitative study of systemic interaction to foster knowledge exchange in the public health sector in The Netherlands. BMC Public Health. 2015;15:922. doi: 10.1186/s12889-015-2271-7.

51. Nau T, Lee K, Smith BJ, Bellew W, Reece L, Gelius P et al. Toward whole-of-system action to promote physical activity: a cross-sectoral analysis of physical activity policy in Australia. J Phys Act Health. 2019;16(11):1029–38. doi: 10.1123/jpah.2019-0122.

52. Pineo H, Zimmermann N, Davies M. Integrating health into the complex urban planning policy and decision-making context: a systems thinking analysis. Palgrave Commun. 2020;6:1–14. doi: 10.1057/s41599-020-0398-3.

53. Clarke B, Swinburn B, Sacks G. Understanding the LiveLighter obesity prevention policy processes: an investigation using political science and systems thinking. Soc Sci Med. 2020;246:112757. doi: 10.1016/j.socscimed.2019.112757.

54. Racine A, Garbarino JM, Corrion K, D'Arripe-Longueville F, Massiera B, Vuillemin A. Perceptions of barriers and levers of health-enhancing physical activity policies in mid-size French municipalities. Health Res Policy Syst. 2020;18:62. doi: 10.1186/s12961-020-00575-z.

55. Baker P, Brown AD, Wingrove K, Allender S, Walls H, Cullerton K et al. Generating political commitment for ending malnutrition in all its forms: a system dynamics approach for strengthening nutrition actor networks. Obes Rev. 2019;20:30–44. doi: 10.1111/obr.12871.

56. Waqa G, Moodie M, Snowdon W, Latu C, Coriakula J, Allender S et al. Exploring the dynamics of food-related policymaking processes and evidence use in Fiji using systems thinking. Health Res Policy Syst. 2017;15:74. doi: 10.1186/s12961-017-0240-6.

57. Browne J, de Leeuw E, Gleeson D, Adams K, Atkinson P, Hayes R. A network approach to policy framing: a case study of the National Aboriginal and Torres Strait Islander Health Plan. Soc Sci Med. 2017;172:10–18. doi: 10.1016/j.socscimed.2016.11.011.

58. Cullerton K, Donnet T, Lee A, Gallegos D. Exploring power and influence in nutrition policy in Australia. Obes Rev. 2016;17:1218–25. doi: 10.1111/obr.12459.

59. Cullerton K, Donnet T, Lee A, Gallegos D. Joining the dots: the role of brokers in nutrition policy in Australia. BMC Public Health. 2017;17:307. doi: 10.1186/s12889-017-4217-8.

60. de Bruin WE, Stayner C, Lange M de, Taylor RW. Who are the key players involved with shaping public opinion and policies on obesity and diabetes in New Zealand? Nutrients. 2018;10(11):1592. doi: 10.3390/nu10111592.

61. Heo H-H, Jeong W, Che XH, Chung H. A stakeholder analysis of community-led collaboration to reduce health inequity in a deprived neighbourhood in South Korea. Glob Health Promot. 2018;27(2):35-44. doi: 10.1177/1757975918791517.

62. Luke DA, Wald LM, Carothers BJ, Bach LE, Harris JK. network influences on dissemination of evidence-based guidelines in state tobacco control programs: Health Educ Behav. 2013;40(Suppl 1):33S–42S. doi: 10.1177/1090198113492760.

63. Merrill J, Keeling JW, Carley KM. A comparative study of 11 local health department organizational networks. J Public Health Manag Pract. 2010;16:564–76. doi: 10.1097/PHH.0b013e3181e31cee.

64. Oliver K, Everett M, Verma A, de Vocht F. The human factor: re-organisations in public health policy. Health Policy. 2012;106(1):97–103. doi: 10.1016/j.healthpol.2012.03.009.

65. Oliver KA, de Vocht F, Money A, Everett M. Identifying public health policymakers' sources of information: comparing survey and network analyses. Eur J Public Health. 2017;27(Suppl 2):118–23. doi: 10.1093/eurpub/ckv083.

66. Valente TW, Pitts S, Wipfli H, Vega Yon GG. Network influences on policy implementation: evidence from a global health treaty. Soc Sci Med. 2019;222:188–97. doi: 10.1016/j.socscimed.2019.01.008.

67. Zwald ML, Eyler AA, Haire-Joshu D, Handy SL, Harris JK, Moreland-Russell S et al. Network influences on the development and implementation of active transportation policies in six U.S. cities. Prev Med. 2019;118:176–83. doi: 10.1016/j.ypmed.2018.10.026.

68. Daly-Smith A, Quarmby T, Archbold VSJ, Corrigan N, Wilson D, Resaland GK et al. Using a multi-stakeholder experience-based design process to co-develop the Creating Active Schools Framework. Int J Behav Nutr. 2020;17:13. doi: 10.1186/s12966-020-0917-z.

69. Freebairn L, Rychetnik L, Atkinson J-A, Kelly P, McDonnell G, Roberts N et al. Knowledge mobilisation for policy development: implementing systems approaches through participatory dynamic simulation modelling. Health Res Policy Syst. 2017;15:83. doi: 10.1186/s12961-017-0245-1.

70. Loyo HK, Batcher C, Wile K, Huang P, Orenstein D, Milstein B. From model to action: using a system dynamics model of chronic disease risks to align community action. Health Promot Pract. 2013;14:53–61. doi: 10.1177/1524839910390305.

71. Fisher M, Milos D, Baum F, Friel S. Social determinants in an Australian urban region: a "complexity" lens. Health Promot Int. 2016;31:163–74. doi: 10.1093/heapro/dau071.

72. Beaton A, Manuel C, Tapsell J, Foote J, Oetzel JG, Hudson M. He Pikinga Waiora: supporting Māori health organisations to respond to pre-diabetes. Int J Equity Health. 2019;18:3. doi: 10.1186/s12939-018-0904-z.

73. Roussy V, Riley T, Livingstone C. Together stronger: boundary work within an Australian systems-based prevention initiative. Health Promot Int. 2020;35(4):671–81. doi: 10.1093/heapro/daz065.

74. Shankardass K, Muntaner C, Kokkinen L, Shahidi FV, Freiler A, Oneka G et al. The implementation of Health in All Policies initiatives: a systems framework for government action. Health Res Policy Syst. 2018;16(1):26. doi: 10.1186/s12961-018-0295-z.

75. Brennan LK, Sabounchi 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.

76. Garney WR, Patterson MS, Garcia K, Muraleetharan D, McLeroy K. Interorganizational network findings from a nationwide cardiovascular disease prevention initiative. Eval Program Plann. 2020;79:101771. doi: 10.1016/j.evalprogplan.2019.101771.

77. Leppin AL, Okamoto JM, Organick PW, Thota AD, Barrera-Flores FJ, Wieland ML et al. Applying social network analysis to evaluate implementation of a multisector population health collaborative that uses a bridging hub organization. Front Public Health. 2018;6:315. doi: 10.3389/fpubh.2018.00315.

78. Scheele CE, Little I, Diderichsen F. Governing health equity in Scandinavian municipalities: the inter-sectorial challenge. Scand J Public Health. 2018;46:57–67. doi: 10.1177/1403494816685538.

79. Peters DTJM, Verweij S, Grêaux K, Stronks K, Harting J. Conditions for addressing environmental determinants of health behavior in intersectoral policy networks: a fuzzy set Qualitative Comparative Analysis. Soc Sci Med. 2017;195:34–41. doi: 10.1016/j.socscimed.2017.08.036.

80. Knai C, Petticrew M, Douglas N, Durand MA, Eastmure E, Nolte E et al. The public health responsibility deal: using a systems-level analysis to understand the lack of impact on alcohol, food, physical activity, and workplace health sub-systems. Int J Environ Res. 2018;15(12):2895. doi: 10.3390/ijerph15122895.

81. Liu S, Osgood N, Gao Q, Xue H, Wang Y. Systems simulation model for assessing the sustainability and synergistic impacts of sugar-sweetened beverages tax and revenue recycling on childhood obesity prevention. J Oper Res Soc. 2016;67(5):708–21. doi: 10.1057/jors.2015.99.

82. Macmillan A, Smith M, Witten K, Woodward A, Hosking J, Wild K et al. Suburb-level changes for active transport to meet the SDGs: causal theory and a New Zealand case study. Sci Total Environ. 2020;714:136678. doi: 10.1016/j.scitotenv.2020.136678.

83. Powell KE, Kibbe DL, Ferencik R, Soderquist C, Phillips MA, Vall EA et al. Systems thinking and simulation modeling to inform childhood obesity policy and practice. Public Health Rep. 2017;132:33S–38S. doi: 10.1177/0033354917723601.

84. Knai C, Petticrew M, Mays N, Capewell S, Cassidy R, Cummins S et al. Systems thinking as a framework for analyzing commercial determinants of health. Milbank Q. 2018;96(3):472–98. doi: 10.1111/1468-0009.12339.

85. Kokkinen L, Freiler A, Muntaner C, Shankardass K. How and why do win-win strategies work in engaging policy-makers to implement Health in All Policies? A multiple-case study of six state- and national-level governments. Health Res Policy Syst. 2019;17:102. doi: 10.1186/s12961-019-0509-z.

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WHO European Office for the Prevention and Control of Noncommunicable Diseases

9, Leontievsky pereulok
125009 Moscow, Russian Federation
Tel: +7 (495) 787 21 17
Email: NCDoffice@who.int
Website: www.euro.who.int/en/NCDoffice

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