

**The author replies**  
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The insightful comments by Salem, Saldiva et al., Galea, Dora, Carvalho and Capon & Siri highlight several important points that are worth our reflection as we consider the utility of systems thinking and the tools of simulation modeling in urban health.

Several commentators emphasize the value of systems thinking as a conceptual approach that extends well beyond the use of specific systems simulation tools. Salem challenges us to use systems thinking to better understand the processes (often rooted in social, economic, historic, and political conditions) that shape health and health inequalities in cities. He also highlights how systems thinking forces us to be more deliberate and specific in our definition of “urban” (and what it means to live in urban areas) and also to grapple with the inherent complexity in understanding health-related processes. Galea also notes that the main value in systems approaches is likely to lie in how we conceptualize health determinants and articulate how they operate together to affect health in cities, with special attention to context dependency. Carvalho emphasizes the development of dynamic conceptual models that integrate very different types of factors and processes as the key benefit and value of a systems approach. Capon & Siri challenge us to think broadly and develop dynamic conceptual models not only of health in cities but also models that articulate the interrelations between human health and ecosystems more broadly.

An important element of the use of systems approaches is the ability to incorporate and integrate various types of information (as noted by Carvalho) and also community and stakeholder input, enhancing co-production of knowledge (as alluded to by Capon & Siri and Dora). But these approaches also raise many challenges and necessarily highlight the many limitations of the information and data available, as noted by Dora. Ideally, this will stimulate the design of new studies and the collection of new data to fill many gaps in understanding that are likely to emerge as we develop conceptual systems models and begin to attempt their formal simulation.

Examples are critical to understanding the potential of systems thinking and analytical approaches in urban health. Several commentators provide valuable examples. Saldiva et al. illustrate how systems approaches can be used to understand the drivers of cardiovascular disease in urban areas. Capon & Siri use the example of the health and ecological consequences of promoting electric cars as an example of a policy for which systems thinking may yield useful insights. They note the value of systems thinking in fully understanding why interventions have not worked as expected or why attempts to stem health trends like the obesity epidemic have been largely disappointing. Dora challenges us to use these approaches to answer relevant policy questions and provide useful evidence for policymakers and communities as they evaluate alternative strategies and policies to improve health in cities.

An important theme that arises in several of the commentaries is whether the advent of systems thinking and systems approaches will or should replace the other analytical tools we use to understand the drivers of health in cities or to evaluate the impact of policies and interventions. Certainly I agree with Carvalho when she notes that fully embracing systems thinking will be a paradigm shift in the sense that it will challenge the reductionist and often biomedical paradigm still dominating the vast majority of health research. However, as Carvalho also notes, simplification is imperative in science, even in the face of complexity. But the simplification required for the simulation of systems is very different from the simplification we engage in when we analyze an observational study or conduct a randomized trial. Nevertheless, the traditional tools of population health inquiry that we use to make sense of empirical observations (observational studies, randomized trials, natural experiments, and the analytical approaches associated with them) will still be useful in interrogating aspects of systems. The problem arises when we reify these approaches so that they are interpreted as accurate and full representations of reality rather than simplifications that can sometimes be useful in understanding some aspects of how the world works. Moreover, information from these “reductionist” approaches will still be necessary to inform dynamic conceptual models and to parameterize and validate formal simulation models.

As noted by Galea, context dependency is certainly a hallmark of many of the phenomena we study and, indeed, a feature of the world itself! Our job as scientists is to specify how that context dependency works so that we can obtain knowledge that is generalizable to other contexts. Otherwise our work is reduced to descrip-

tion of specific cases, which may be interesting but will not provide the generalizable knowledge we need to identify useful policies and interventions. Our task is to enhance understanding of the key elements and drivers of the systems that generate health in cities, and for this we need to specify and articulate which context dependencies are important and how they operate. The nature of our task requires us to combine systems thinking in the broad and conceptual sense with a range of tools and analytical approaches, including formal systems simulation modeling, as well as other qualitative and quantitative ways of interrogating the reality we seek to change. This will ensure that the empirical information we obtain is placed in context and its implications fully understood, and also that the systems (both conceptual and simulations) models we develop go beyond speculation and are informed by and grounded in reality.