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A role for low-order system dynamics models in urban health policy making

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ABSTRACT

Cities are complex adaptive systems whose responses to policy initiatives emerge from feedback interactions between their parts. Urban policy makers must routinely deal with both detail and dynamic complexity, coupled with high levels of diversity, uncertainty and contingency. In such circumstances, it is difficult to generate reliable predictions of health-policy outcomes. In this paper we explore the potential for low-order system dynamics (LOSD) models to make a contribution towards meeting this challenge. By definition, LOSD models have few state variables (≤5), illustrate the non-linear effects caused by feedback and accumulation, and focus on endogenous dynamics generated within well-defined boundaries. We suggest that experience with LOSD models can help practitioners to develop an understanding of basic principles of system dynamics, giving them the ability to 'see with new eyes'. Because efforts to build a set of LOSD models can help a transdisciplinary group to develop a shared, coherent view of the problems that they seek to tackle, such models can also become the foundations of 'powerful ideas'. Powerful ideas are conceptual metaphors that provide the members of a policy-making group with the *a priori* shared context required for effective communication, the co-production of knowledge, and the collaborative development of effective public health policies.

1. Introduction

Actions taken to address public-health problems have achieved notable successes during the 21st century (Rayner and Lang, 2015). Nevertheless, policy initiatives sometimes achieve only marginal or temporary success. Indeed, they can intensify the original problem, or even create completely new problems, especially over longer time frames (Sterman, 2006; Woolf and Braveman, 2011). A notable example is the rise of antibacterial resistant organisms worldwide (Levy and Marshall, 2004; Davies and Davies, 2010; Commonwealth of Australia, 2015; Brown and Wright, 2016).

It has long been recognised that complexity, diversity, and uncertainty make it difficult to manage social-ecological systems. The most intractable situations were dubbed 'wicked problems' by Rittel almost 50 years ago (Churchman, 1967: B141):

> Professor Horst Rittel of the University of California Architecture Department has suggested in a recent seminar that the term "wicked problem" refers to that class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing. The adjective "wicked" is supposed to describe the mischievous and even evil quality of these problems, where proposed "solutions" often turn out to be worse than the symptoms.

The most persistent and important public policy problems can be classified as wicked—they pose serious challenges to conventional scientific and management approaches (Kunz and Rittel, 1972; Rittel and Webber, 1973; Schön, 1983; Dryzek, 1987; Parsons, 2002; Head and Alford, 2015). According to Schön (1983: 42) such problems occupy "a swampy lowland where situations are confusing 'messes' incapable of technical solution". Profoundly complex problems cannot be approached effectively using 'instrumental reasoning' (involving traditional scientific approaches) alone, but need also the kind of 'inter-subjective reasoning' that grows only when there is close, continuing collaboration between competent practitioners (Schön, 1983; Senge, 1990; Dryzek, 1987; Plsek and Greenhalgh, 2001; Parsons, 2002; Després et al., 2004; Greenhalgh and Russell, 2009). At the other end of the complexity scale are relatively straightforward 'tame' problems that can be handled routinely with a manager's 'fast and frugal' heuristics (Gigerenzer et al., 1999). Between these extremes lies a vast realm of problems that are amenable to some level of instrumental reasoning. As urban systems become more complex, the dominant public-policy problems shift from tame to wicked, steadily increasing the collaborative demands placed on decision makers. Unfortunately, in the absence

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of a strong commitment to transdisciplinary dialogue, mounting complexity also tends to drive decision makers towards fragmented approaches.

According to conventional definitions, a polycentric social system contains “many decision centers having limited and autonomous prerogatives and operating under an overarching set of rules” (Aligica and Tarko, 2012). The development of multiple governance centers is a necessary and practical response to increasing urban size and complexity (Ostrom et al., 1961; Ostrom, 1972; Ostrom, 2010), but these centers do not necessarily operate according to the prescriptions of an overarching set of rules. Instead, semi-autonomous decision centers often become independent management ‘silos’ operating according to their own rules.

In many respects management silos are needed. By allowing the decomposition of complicated management tasks into manageable pieces they provide a way for individuals and teams to develop focused expertise and efficient processes. But, according to Tett (2015: 14):

> Isolated departments, or teams of experts, may fail to communicate, and thus overlook dangerous and costly risks. Fragmentation can create information bottlenecks and stifle innovation. Above all else, silos can create tunnel vision, or mental blindness ….

As expressed by Ackoff (1986) “A system is more than the sum of its parts; it is the product of their interactions. If taken apart, it simply disappears.” Extensive systems tend to be invisible to those who think in silos—the resulting fragmentation contributes to the prevalence of narrowly focused policies that can exacerbate the very problems that they are intended to solve (Dyball and Newell, 2015: 88). Awareness of these issues has led to increasing calls for transdisciplinary approaches in many fields (Lawrence and Després, 2004; Horlick-Jones and Sime, 2004; Lawrence, 2016). The public-health arena is no exception (Frenk, 1993; Lawrence, 2004; Choi and Pak, 2006, 2007; Sterman, 2006; Kreps and Maibach, 2008; de Savigny and Adam, 2009; Luke and Stamatakis, 2012; Corburn et al., 2014; Diez Roux, 2015; de Oliveira et al., 2015; Rayner and Lang, 2015; Whitmee et al., 2015).

Most of the proposed transdisciplinary approaches stress the need to take a whole-systems approach, and call for collaborative efforts that lead to the development of a ‘shared understanding’, and a related ‘shared language’, between people with different worldviews, disciplines, experiences, roles and responsibilities. Once a group has a shared language, so the story goes, then they can work together to address the operational problems that most concern them. There are, however, significant social, institutional, and conceptual barriers to such integration (Bruce et al., 2004; Després et al., 2004; Newell et al., 2005; Newell, 2012).

In this paper we focus on the *conceptual barriers* to effective communication between the members of heterogeneous policy-making groups (Briassoulis, 2005: 65; Newell et al., 2005). In particular, we explore the potential for low-order system dynamics (LOSD) models to support the development of the shared languages required for effective transdisciplinary endeavours (Newell, 2012). We confine our attention to system dynamics (SD) models for reasons of economy in discussion, but in principle our conclusions should apply equally well to other systems-science approaches, such as network analysis and agent-based modelling (Luke and Stamatakis, 2012).

2. Low-order system dynamics (LOSD) models

The ‘order’ of an SD model indicates the number of state variables included in its structure. Thus, we define an LOSD model to be an SD model with a small number of stocks, preferably ≤5, and a correspondingly small number of feedback loops. According to Newell (2012) a simulation model must meet two criteria if it is to support efforts to overcome conceptual barriers to integration. First, it must be structurally simple. Second, it must provide dynamical insights that make sense to practitioners from a wide range of real-world contexts.

There are several types of standard LOSD models that meet these criteria. The simplest are the basic single-loop structures that Sterman calls ‘fundamental modes’ (Sterman, 2000: 108). These include the single-loop structures *Exponential Growth, Goal Seeking, Oscillation* (goal seeking with delays). Then there are the multi-loop ‘system archetypes’ such as *Limits to Growth*, *Success to the Successful*, *Fixes That Fail*, *Shifting the Burden*, *Eroding Goals*, *Accidental Adversaries*, *Escalation*, *Growth and Underinvestment*, and *Tragedy of the Commons* (Senge, 1990; Kim and Lannon, 1997; Meadows, 2009; Senge et al., 1994). We can also include commonly used models such as *Diffusion of Innovation* (including the SIR model of the spread of infectious diseases), and *Lotka-Volterra* predator-prey systems. There are also many cases where the creative blending of observation and theory has yielded tailored LOSD models with the potential to provide useful guidance to decision makers (see, among others, Mollison, 1984; Mendez et al., 1998; Earn et al., 2000; Lenton, 2000; Davies and Davies, 2010; Ulli-Beer et al., 2010; Blakers et al., 2011; Richardson, 2011; Ghaffarzadegan et al., 2011; Basu and Andrews, 2013; Miller and Newell, 2013; Dafilis et al., 2014; Alonso et al., 2015).

In the following example, we use the *Fixes That Fail* system archetype to illustrate the general nature of LOSD models. The archetype describes the tendency of communities to implement problem ‘solutions’ that eventually make the problem worse—a classic case of unintended and unwanted outcomes (Meadows, 2009: 112). In Fig. 1 we show the generic feedback structure of the archetype.

Many of the system archetypes were discovered when teams building extensive models of business processes noticed that the same basic feedback structures occurred over and over again in different contexts (Sterman, 1994). Because each system archetype behaves in a characteristic manner, it can provide immediate insights into the relationships between system structure and system behaviour (Sterman, 2000; Meadows, 2009). The *Fixes That Fail* structure can be used to describe, in general terms, a common form of policy resistance that occurs in all problem domains, at all scales. There are many urban health examples,

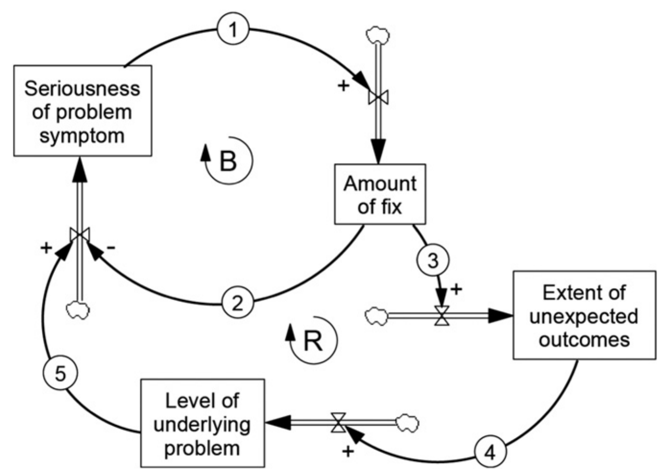

Fig. 1. Example of an LOSD model. This diagram shows the stock-and-flow structure of the *Fixes That Fail* system archetype. In this stock-and-flow diagram the rectangles represent the state variables of a system, and the double-lined arrows with ‘taps’ represent the processes or mechanisms by which a change in the level of one state variable affects the level of another state variable. The single-lined arrows represent influence or information links—these links have been numbered for ease of reference. Each of the influence links is assigned a ‘polarity’: A plus sign (+)/minus sign (-) indicates that an *increase* in the level of the variable at the tail of the arrow will cause the level of the variable at the head of the arrow to eventually *rise above*/*fall below* the value that it otherwise would have had (all else being equal). The encircled B indicates a balancing feedback loop that operates through Links 1 and 2. The encircled R indicates a reinforcing feedback loop operating through Links 1, 3, 4 and 5.