# Evolving Cities for Human Health and Wellbeing

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*Abstract*

Close collaboration between public health and urban planning professionals is necessary for the evolution of healthy cities. The present situation, where these professions are often isolated from one another, reflects the natural tendency for polycentric governance structures to develop in complex systems. But polycentric governance does not imply polycentric order.

The establishment of a well-balanced polycentric order requires a feedback systems approach. Feedback interactions play a dominant role in urban dynamics, but can be invisible to policy makers and managers. Actions taken in one sector can feedback, through other sectors, to amplify or undercut the original actions. Once this realised, it becomes obvious that systems thinking is needed if managers wish to create sustainable polycentric governance.

In this paper we briefly describe a practical approach to the development and application of systems thinking and analysis skills. Collaborative Conceptual Modelling (CCM) can support a research or management group's attempts to take account of two sets of critical interactions—feedback in their system-of-interest, and knowledge-sharing and knowledge-building interactions between the members of their group. These sets of interactions are nested, in that an analysis of feedback structures requires the co-production of knowledge.

We conclude by discussing CCM workshops where public health and urban planning professionals explored the challenge of developing healthy cities. The workshop resulted in the identification of a pair of system variables that together play a significant role in determining the state of a city's governance regime—*the extent to which urban policy and planning is integrative (systemic)* and *the extent to which the health sector is proactive*. These variables define a two-dimensional space that can be used to construct urban-evolution scenarios. In general terms, urban health and wellbeing can be expected to increase as urban governance evolves from fragmented-reactive to integrated-proactive. This evolution requires public health and urban planning teams to work closely together with long timescales in mind.

## 1. Introduction

Over the last 10,000 years there has been a steady increase in the size and complexity of human settlements. In more recent times, the migration of people from countryside to city has accelerated this trend. The point has now been reached where cities are among the most complex systems on the planet. While the initial growth of complexity confers some advantages on a society, too much complexity can cause significant management problems (Tainter 1988).

A modern city has too many parts, interacting in a myriad of ways, for it to be managed as a single entity. Some aspects of urban management do need to be over-arching. But mono-centric governance is impractical. It is simply not possible for a central authority to deliver policy and management outcomes that are creative and optimised for a wide variety of local groups, each with different and evolving needs. Just handling the overwhelming amount of data required to track the changing status of the citizens of every sub-group under their jurisdiction would require a massive bureaucracy—and even if such an operation were possible, centrally located decision makers would be constantly running well behind the *status quo*.

There is, therefore, a natural tendency for a city to develop a polycentric governance structure. Such arrangements, where responsibility and authority are devolved to semi-autonomous decision-making and management units, operating at a range of scales, offer many practical advantages. In particular, they can support the evolution of institutions and policies that are effective and robust, because they are based on a deep understanding of changing local conditions and needs. Polycentric governance can also support the development of a rich spectrum of creative and experimental management approaches that increase the adaptive capacity of the whole community. City environments that encourage the evolution of such conditions would resemble ecosystems—complex adaptive systems where multiple entities self-organise in novel and advantageous ways under environmental pressures.

Modern cities, of course, differ from ecosystems in important ways. Central to these differences is the ability of humans to conceive and implement behavioural 'policies' that are not bound by natural laws. Thus, despite the fact that cities are complex adaptive systems whose behaviour emerges from feedback interactions between their parts, there is a strong tendency for semi-autonomous governance units to go too far along the road to independence and develop into isolated management silos. Silo formation is widespread, and its effects include a reduction in the ability of city decision makers to see the cross-sector feedback forces that drive urban-policy failure (Proust et al. 2012). A particularly important case is the separation that exists today between agencies concerned with urban health and those involved in urban planning (Corburn 2009). Such silos tend to lock-in, in part because they foster the emergence of arcane local knowledge and languages that erect communication barriers between the people working in adjacent management domains (Newell 2012).

The problem is that *the growth of polycentric governance structures does not necessarily generate polycentric order*. The situation is nicely summarized in Ostrom et al. (1961: 831):

> The assumption that each unit of local government acts independently without regard for other public interests in the metropolitan community has only a limited validity. The traditional pattern of government in a metropolitan area with its multiplicity of political jurisdictions may more appropriately be conceived as a "polycentric political system." "Polycentric" connotes many centers of decision-making which are formally independent of each other. Whether they actually function independently, or instead constitute an interdependent system of relations, is an empirical question in particular cases. To the extent that they take each other into account in competitive relationships, enter into various contractual and cooperative undertakings or have recourse to central mechanisms to resolve conflicts, the various political jurisdictions in a metropolitan area may function in a coherent manner with consistent and predictable patterns of interacting behavior. To the extent that this is so, they may be said to function as a "system."

In this paper we outline processes that can help urban policy makers and managers to 'take a systems approach'. That is, to generate a polycentric order wherein decision makers can take advantage of the flexibility and community engagement that flows from a reliance on dispersed decision centres, while, at the same time, not losing sight of the critical feedback interactions that operate between these centres. We begin in §2 by outlining two sets of interactions that we suggest play a crucial role in attempts to develop effective polycentric urban governance. In §3 we describe *Collaborative Conceptual Modelling* (CCM), a practical systems-thinking approach that we have developed to help the members of heterogeneous management groups to operationalise these critical interactions and develop a useful shared understanding of the dynamics of their systems-of-interest. Finally, in §4 we use insights from CCM workshops to discuss the evolution of healthy cities.

## 2. Critical Interactions

From the point-of-view of urban dynamics, the behaviour of a city emerges from the interactions between many thousands of state variables. Clearly, it is not possible for all these variables to be taken into account in the crafting of policies and management practices. Decision makers react by paying attention to just those variables and interactions that they consider to be important. In making such selections, by accounting for some state variables and omitting others, they set state-space boundaries that enable them to focus attention on urban sub-systems within which their management tasks look more tractable. The danger, of course, is that they will overlook variables and interactions that play key roles in the dynamics of their system-of-interest. Establishing practical ways to select appropriate sub-sets of variables and interactions is a foundational process in efforts to create effective polycentric governance.

The selection of a governance sub-system is a highly context-specific task. This means that it is not possible to develop detailed operating instructions that can be applied by any group, in any circumstance. What can be done, however, is to establish generic system principles that can guide a group's efforts. Such principles can help the members of a management group to develop a coherent approach, while leaving them free to design detailed operational procedures tailored to their specific context. A shared understanding of basic system principles can also strengthen collaboration between different governance groups, an essential ingredient in the establishment of an over-arching polycentric order that can co-ordinate and moderate the efforts of the separate groups.

There are at least two basic principles that urban decision makers need to understand and take into account at all times:

*1) The response of a complex system to management interventions emerges from feedback interactions between its parts.*

These critical interactions operate at all scales, affecting families and national governments alike. Efforts to understand feedback effects can help governance teams to minimise policy surprise and avoid policy failure (Forrester 1969; Sterman 2000). In addition, the realisation that cross-sector feedback plays a critical role in urban systems, yet is often invisible to decision makers, makes it clear that there is a limit to the operational separation that should exist between individual governance units. Rules based on the notion of 'cross-sector' feedback interactions need to be a part of the over-arching order necessary to ensure that a polycentric urban-governance structure is equitable and sustainable.

2) *The establishment of sustained, focused dialogue is a central task for any management team – no one person can see the whole system*.

This principle is designed to foster a second set of interactions that are necessary for effective polycentric governance. These are deep, on-going discussions that involve individuals attempting to develop a shared understanding of causation in their systems-of-interest. An isolated individual cannot build a satisfactory understanding of the dynamics of a complex system. If the perceptions and theories of many individuals (with different backgrounds, experiences, and worldviews) can be meshed synergistically, there is the possibility that a more encompassing, more coherent understanding can emerge. This is not a trivial task, given the challenges of establishing true rapport between individuals with different backgrounds, experiences, worldviews, and aims (Newell 2012). Nevertheless, the basic principle captures an inescapable operational constraint—close collaboration is necessary in any attempt to develop the shared understanding and over-arching rules that are needed to establish workable polycentric governance.

In the next section we introduce a practical approach that we have developed to help a governance group to establish the critical interactions described above. This approach, which we call *Collaborative Conceptual Modelling*, has grown out of some 30 years of theoretical studies and practical collaborative work with a wide range of community, student, academic, and professional groups (Newell & Proust 2012).

## 3. Collaborative Conceptual Modelling[1]

Collaborative Conceptual Modelling (CCM) is designed to provide practical ways of meshing the disparate worldviews of individuals to produce new, emergent understandings. The aim is to generate comprehensive worldviews that have a combination of breadth and depth that is typically beyond the reach of individuals working alone. It is a foundational principle of CCM that no one person or group can see the 'whole elephant'.

In developing CCM we have attempted to blend and balance insights and tools that have been developed, by many research groups, over decades of investigation into the nature and behaviour of complex adaptive systems, and the nature of human understanding and decision making. CCM draws on concepts from applied history (Proust 2004), complex adaptive systems (Axelrod and Cohen 1999), resilience thinking (Walker and Salt 2006), system dynamics (Sterman 2000; Meadows 2009), and cognitive science (Lakoff and Johnson 1980, 1999; Newell 2012). Concepts from system dynamics (hereinafter SD) are particularly important because of their practicality. In addition, an SD approach provides a powerful, fresh view of many management challenges because of its focus on feedback and endogenously generated forces (Richardson 2011). CCM takes SD tools, such as influence diagrams, causal-loop diagrams, and stock-and-flow maps and models, and embeds them in protocols that guide a management group through the process of wrestling with the complexity of their system-of-interest.

The name 'Collaborative Conceptual Modelling' has been chosen to emphasise several ideas that are fundamental to our approach. First, we intend the term 'modelling' to be interpreted broadly. We include the construction of cause-effect models that range from very simple, tacit mental models, through influence diagrams, causal-loop diagrams and stock-and-flow maps, to sophisticated computer-based dynamical models. Second, the term 'conceptual' serves to pick out a particular subset of the possible cause-effect models. While detailed, high-order models are important in some system dynamics investigations, in CCM we focus on the progressive development of influence diagrams, causal-loop diagrams, and low-order stock-and-flow model[2] (Proust and Newell 2006; Ghaffarzadegan et al 2011). The aim of a CCM exercise is to articulate, mesh, and extend the mental models

[1] Parts of this section come from the Working Paper by Newell and Proust (2012).
[2] The 'order' of a system dynamics model is the number of state variables (stocks) that it contains.

of the members of an adaptive group, rather than attempt to produce definitive predictions of future behaviour. Third, we use the term 'collaborative' to stress the necessity of teamwork in any attempt to take a comprehensive approach to adaptation. It is not possible to build useful system models, which take account of feedback interactions that cross the boundaries between conventional sectors and disciplines, without meshing the mental models of a group of experts with a wide range of backgrounds and experiences (Newell 2012). Here we use the term 'expert' inclusively, to refer to *anyone* who has observed and thought seriously about how some part of the system-of-interest works. Everyone is an expert in some aspect of the ecology of humans.

CCM is intended to provide coherent support to the growth of shared understanding and the development of robust adaptive plans. In seeking this coherence, it is necessary to identify the principal operations required, and to order them according to their logical dependencies. We assume the following ordering (Figure 1): Survival requires adaptation (including mitigation and innovation); successful adaptation requires a dynamical systems approach; a dynamical systems approach requires conceptual integration; conceptual integration requires focused dialogue (Newell 2012). These operations are nested. It is not possible to operate effectively at the higher levels without first operating effectively at the lower levels.

In Figure 2 we summarise the structure of the CCM process. The six boxes represent 'co-evolving' activities (see following sections). The activities are co-evolving in the sense that, while there is an overall need for a group to progress from Activity 1 through to Activity 6, it is often necessary to loop back and revisit earlier activities in the light of new understanding. The activities are divided into two phases whose scope is indicated by the outer curved lines in the diagram. Phase I comprises Activities 1 to 3. These activities are designed to foster focused dialogue, conceptual integration, and systems thinking (Newell et al. 2005; Newell 2012). Phase II comprises Activities 4 to 6. These activities are designed to support the group's efforts to develop a better understanding of the dominant dynamics of their system-of-interest, and to apply their new understanding and models to construct management scenarios that can guide policy making. Phase II is more challenging that Phase I, and requires a greater commitment of time and some involvement of experienced modellers.

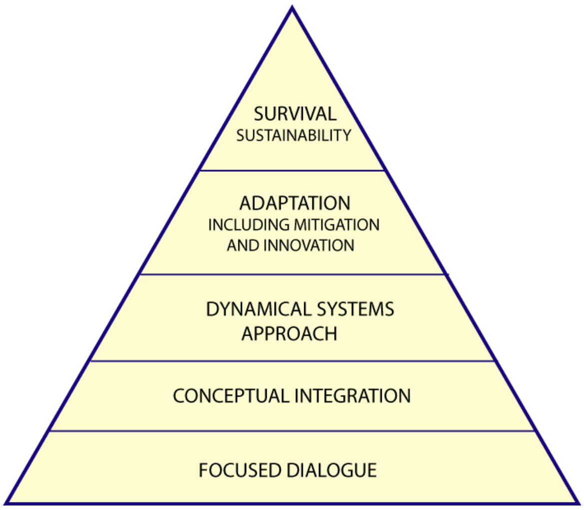


**Figure 1**. The CCM Hierarchy of Operations. This diagram summarises our assumptions concerning the principal processes required to develop effective adaptive plans, and the way that these processes are nested. We assume that operations higher up in the triangle require the support of operations lower down in the triangle. The CCM activities work up through this hierarchy.


**Figure 2.** The iterative structure of the Collaborative Conceptual Modelling approach

3.1. CCM Co-evolving Activity 1: *What is the challenge?*

As indicated by the focus question, the initial emphasis in CCM is on the 'challenge' rather than 'the problem'. This is done to keep the initial discussions more general than is often the case when the members of a group seek a tightly defined research question on which to base their collaborative work. Hasty acceptance of a specific research question can lead, for example, to premature convergence on a superficial problem, or to a focus on symptoms instead of fundamental problems. It can also give a misleading sense of unity among group members who, in reality, do not yet understand each other's point-of-view.

Because system-dynamics concepts are unfamiliar to many people, another challenge for group members is to develop a shared understanding of the nature and significance of the critical interactions described above (§2). This requires them to come to terms with some basic concepts from system dynamics. The pedagogical approach we use in CCM workshops is based on carefully designed conceptual metaphors (Lakoff and Johnson 1980; Newell 2012). In SD practice the *Bathtub Metaphor* is used to explain the difference between state variables (called 'stocks') and state-change processes (called 'flows'). A failure to recognise this distinction is one cause of confusion in discussion of the dynamics of complex systems (Sterman 2000). The clarity provided by the visual, intuitive nature of the stock-and-flow metaphor (Figure 3) is one of the reasons we use SD approaches in CCM.

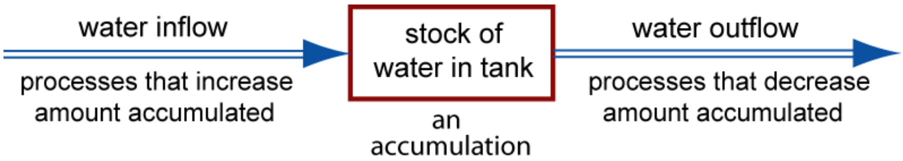


**Figure 3**. The *Water Tank Metaphor*. In this diagram the rectangle represents a stock (an accumulation, a state variable), and the arrows represent flows (state-change processes) that can change the level of the stock (the amount accumulated).

3.2. CCM Co-evolving Activity 2: *What is the story*?

A crucial step in building an understanding of a system's behaviour is to examine its past behaviour—in particular, its response to management interventions (Forrester 1961). In CCM we use the label 'dynamical history' to refer to historical studies that are designed to unearth the endogenous feedback structures that have driven system behaviour over time.

History is the study of past events, cultures and processes (Jordanova 2000). Its focus is on changes over time to reveal and explain the evolution of societies. In CCM we draw attention to the contribution that the practice of history can make to management in complex systems. Any attempt to understand change requires a base in historical data. At one end of the scale are oral histories and simple 'cause-and-effect stories'. Studies of documentary sources can reveal the cultural and social drivers of behaviour, thus providing the human dimension so often missing in traditional scientific and economic studies. At the other end of the scale, the assembly of quantitative historical data can be a critical step in the study of the dynamics of a complex system.

These history investigations can contribute information about the sources of dynamic complexity (delays and feedback effects), the multiple consequences of past actions, and the multiple drivers of current situations. They can help a group to build an understanding of historical contingency and path dependence, and to define baseline conditions for tracking change. The nature of urban settlements demands that decision makers tackle issues with strong cross-sector and cross-disciplinary elements. Decision makers must face the contemporary consequences of unwanted impacts from past decisions concerning urban living and sustainability.

Decision makers operate within complex adaptive systems, which have 'inertia'. The filling and draining of stocks causes delays in system response to management actions. It often takes a community a long time to recognise that a problem exists, and then there are further delays before they accept that remedial action is needed. Management responses are then often further delayed. The problems are further complicated when managers fail to take account of linkages in the wider urban system, and so overlook important feedback effects. These effects can produce unwanted outcomes in parts of the system far removed from one group's immediate view. Historical studies can help management group members to see the delays, and thus to understand better the operation of causation in the system (Figure 4).

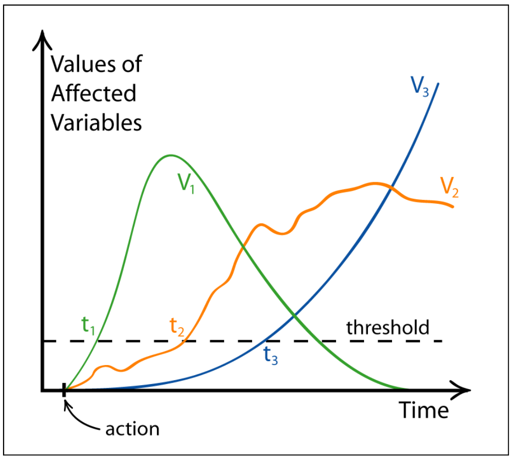


**Figure 4**. You can't do just one thing in a complex system. This diagram represents the multiple outcomes of past actions. The horizontal axis represents time and the vertical axis represents the change in the values of the variables ($V_1$ to $V_3$) that are affected by a particular management action. The curved lines represent time series for each variable. The symbols $t_1$, $t_2$, and $t_3$ represent the times at which the changes rise above the detection threshold. The intended outcome of the management action is an increase in the value of $V_1$. The expected change is detected at $t_1$, but then the values of $V_2$ and $V_3$ begin to increase and force down the value of $V_1$.

The CCM approach integrates concepts from history and feedback dynamics. A dynamical history study provides the evidence base required for a systems study. It can help reveal the course of urban decision making and its impacts on system behaviour, and so can contribute to an understanding of the dynamics of the underlying system.

3.3. CCM CO-evolving Activity 3: *Can I see how you think*?

Our limited ability to 'see the whole' is one of the main impediments to the development of societies that are conflict-free, equitable and adaptive. We can increase our visual acuity most efficiently by working together. The approach used in Activity 3 is designed to help a governance group to define the state-space boundary of their system-of-interest, and develop a genuine shared understanding of the interactions that drive its behaviour. The activity depends on the use of a process that we call 'pair-blending' (Newell & Proust 2012).

CCM 'pair-blending' provides a way to compare and contrast group members' understanding of the dynamics of their system-of-interest. There are three steps:

First, each person constructs an individual influence diagram (Figure 5). The challenge is for that person to describe a causal structure that, in his or her opinion, plays a dominant role in the behaviour of the system. Participants are encouraged to regard their influence diagrams as tentative 'dynamic hypotheses', rather than 'true' descriptions of the structure of the system. They are, nevertheless, asked to adhere to a set of rules for the construction of their diagrams. The diagrams are built around a specific focus variable, following a procedure similar to that recommended by Vennix (1996: 120). Considerable stress is laid on the importance of expressing variable names clearly, using nouns or noun phrases to indicate that the entities so labelled are stocks (state variables) that are capable of a change of level (increase or decrease). The arrows represent flows (state-change processes). Participants are asked to minimise the number of variables (preferably ≤5), and to attempt to identify possible feedback loops in their selected sub-system.

Second, group members work in pairs to simplify their individual diagrams and combine them to form a single, blended diagram that incorporates the essential features of their two worldviews. Where possible we ask participants who have clearly different views of the system to work together. They are again advised to minimse the number of variables in their diagram down to a minimum (preferably ≤10). In practice this process works very well. After working alone to produce their individual diagrams, participants welcome the chance to share the challenge.

Third, each pair presents their blended diagram to the group for discussion and constructive criticism. Because (a) all pairs present influence diagrams, (b) all group members understand the 'shared visual language' provided by the diagrams, and (c) the diagrams represent differing views of the same system-of-interest, these presentations tend to generate rich 'focused dialogues' (Newell 2012) that help the group to move towards an integrated approach.

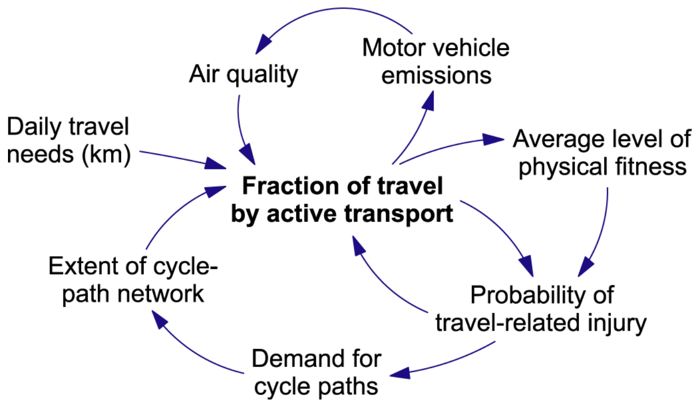


**Figure 5**. An influence diagram. The blocks of text represent system state variables (stocks) and the arrows represent state-change processes (flows) that can change the values of the variables. In CCM practice group members are encouraged to use language carefully when they are naming the variables. They are also encouraged to 'annotate' the arrows, using numerals (or other labels) and writing descriptions of the corresponding state-change processes. Provided that clear 'rules of grammar' are followed, the diagrams become part of a shared language that helps the group members to communicate effectively about their individual views of the way that causation operates in their system-of-interest.

3.4. CCM Co-evolving Activity 4: *What drives system behaviour*?

Activity 4 takes the group from systems thinking to system dynamics. This transition depends particularly on the initial use of 'system archetypes'. System archetypes are relatively simple feedback structures, with characteristic ways of behaving, that are found in a wide range of contexts (Senge 1990; Meadows 2009). An example is shown in Figures 6 and 7.

In Activity 4, the historical data, influence diagrams, and shared understanding developed in CCM Phase I are used to identify feedback structures that have the potential to provide an *endogenous* explanation of system behaviour. Conceptual models, which express the group's dynamic hypotheses concerning the way that their system-of-interest operates, are then constructed by elaborating one or more of the candidate structures. Depending on the needs and capacity of the group, these conceptual models can be presented as causal-loop diagrams, stock-and-flow maps, or low-order system-dynamics (LOSD) models. The process of identifying feedback structures that are relatively simple, but that are dynamically dominant, is a reductive process. In CCM a procedure called 'Feedback-Guided Analysis' is used to ensure that this reduction preserves key feedback structures (Newell 2015; an early application is described by Proust et al., 2012).

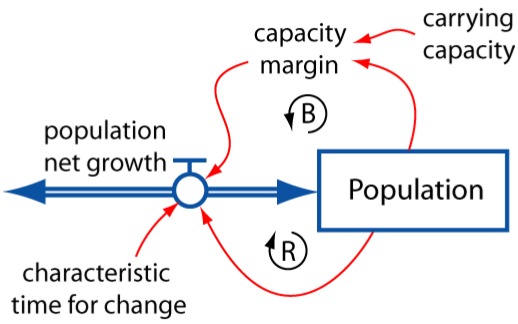


**Figure 6**. The structure of the *Limits to Growth* system archetype. In this stock-and-flow map the rectangle represents the number of individuals in a population, the double lined-arrow represents the inflow and outflow processes that can change that number, and the curved arrows represent influence links. The phrases 'carrying capacity', 'capacity margin', and 'characteristic time for change' represent ancillary variables. In this structure there is a reinforcing feedback loop (labelled R) and a balancing feedback loop (labelled B).

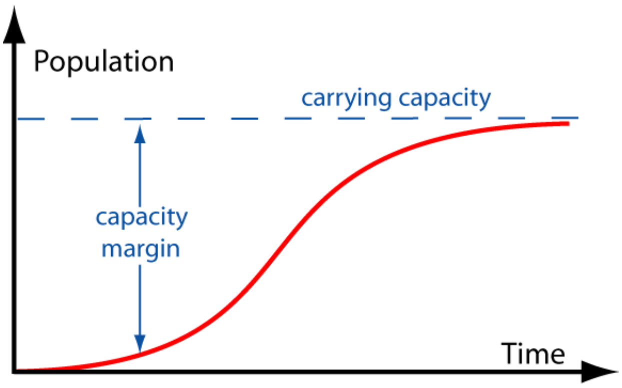


**Figure 7**. The 'S-shaped growth' that is characteristic of the *Limits to Growth* archetype. The horizontal axis represents time, and the vertical axis represents the number of individuals in the population. When population levels are low the reinforcing feedback loop dominates, and population grows exponentially. As population approaches the carrying capacity of the region, however, the balancing loop becomes dominant and growth slows. In this idealised case, growth ceases as the population reaches the carrying capacity.

3.5. CCM Co-evolving Activity 5: *Where are the leverage points*?

The identification of leverage points, where a relatively small local change can produce major effects throughout the system, is a principal aim of CCM studies. Meadows (2009: Chapter 6) provides an introductory discussion of the nature of leverage points. She presents a classification expressed in stock-and-flow language, and ordered according to effectiveness. In Table 1, which is adapted from Meadow's discussion, the system leverage points are listed in order of *increasing* power in practice:

**Table 1.** Meadow's Leverage-Point Scale

| **Leverage Point** | **Description** |
|---|---|
| 1. Numbers | Constants and parameters such as subsidies, taxes, and standards |
| 2. Buffers | The size of stabilising stocks and inventories relative to their flows |
| 3. Stock-and-flow structures | Physical systems and the way that they interact |
| 4. Delays | The length of time delays relative to the rates of system change |
| 5. Balancing Feedback Loops | The strength of stabilising loops relative to the strength of the changes that they oppose |
| 6. Reinforcing Feedback Loops | The strength (gain) of the change-amplifying loops |
| 7. Information Flows | The structure of who does and who does not have access to information |
| 8. Rules | Policies and laws, including incentives, punishments, and constraints |
| 9. Self Organisation | The ability of the system to change its own structure |
| 10. Goals | The purpose or function of the system |
| 11. Paradigms | The mind-set out of which the system arises. This mind-set determines the system's goals, structures, rules, delays, and parameters |

CCM Activities 1 to 4 are designed to generate the insights required to identify potential leverage points. Very often these leverage points operate through relatively simple, but dominant, feedback structures.

3.6. CCM Co-evolving Activity 6: *Can we have new eyes*?

The guiding question of CCM Activity 6 carries two messages which are encapsulated in the well-known quotation from Marcel Proust (1871–1922):

> [t]he only true voyage of discovery, the only really rejuvenating experience, would be not to visit strange lands but to possess other eyes, to see the universe through the eyes of another, of a hundred others, to see the hundred universes that each of them sees . . .

First, the guiding question serves to remind us that we all see the word through the lenses of our mental models. Both perception and decision making are model-dependent (Chalmers 1976). If we want to see more clearly, if we want to make better decisions, then we need better models—more realistic and more reliable understandings of how the world works. These understandings can exist as private mental models that tacitly guide an individual, or they can be expressed as formal theoretical frameworks that provide a coherent approach for a range of interacting management groups (Newell 2015).

Second, the guiding question indicates that, no matter how much effort we put in, we may not succeed in having new eyes. It is not enough to visit strange lands if we do not learn from the experience. The CCM activities are designed to help a management group to produce new knowledge (new models, new theories). The central process, that colours all the activities, involves (a) the articulation of an individual group member's perception of how and why the system-of-interest has behaved as it has over time, and (b) the meshing of these individual perceptions to produce a more powerful, shared understanding. Nevertheless, as stressed by Newell (2012), the development of a genuine, deep, shared understanding is rare, even in groups established to take an interdisciplinary or trans-disciplinary approach. The difficulty of developing good communication between group members is widely under-estimated. It requires, at the very least, the development of a shared language—a task that requires considerable creativity and time.

In Activity 6 group members are encouraged to consider what new insights they have gained from each other. They are then invited to work together to articulate over-arching concepts that capture, to the satisfaction of all members, principles that can guide their efforts to develop effective adaptive plans. A key aspect of this process is a focus on the development of ‘powerful ideas’—shared metaphors that clarify the meaning attached to abstract concepts (Newell 2012). This ‘theory development’ process is initiated by a discussion of the following basic principles, which the group then tailors to fit their particular situation of interest:

1. A systems approach is necessary for the design of robust adaptive plans.
2. A systems approach requires sustained, focused dialogue—no one person can see the whole system.
3. Feedback interactions are important sources of dynamically complex behaviour in any social-ecological system.
4. Any action taken in a dynamically complex system will have multiple outcomes, some wanted and some unwanted. The unwanted outcomes are usually delayed and therefore often not correctly associated with the triggering action.
5. Historical studies, over multiple time scales, are essential in any attempt to understand the behaviour of a dynamically complex system.
6. The behaviour of a dynamically complex system cannot be optimised by optimising the behaviour of its parts taken separately.
7. The boundary of any policy-relevant system will cut across the boundaries of traditional disciplines and governance centres.

Finally, group members are prompted to think in terms of a range of possible futures. The development of ‘systemic scenarios’ can support this process. Scenarios are usually built following the approach developed by the Royal Dutch/Shell Group in the 1980s (Schwartz 1991; van der Heijden 1996; de Geus 1997). The development of a *systemic* scenario follows these standard steps, but places more emphasis than usual on the dynamics of the group’s system-of-interest. Such an approach can help group members to develop ‘feedback eyes’. Feedback effects, such as those described by the system archetypes (Senge 1990), can undercut apparently sound polices (Sterman 2000; Meadows 2009). An ability to see such feedback structures, and so anticipate unwanted system effects, can reduce the chances of policy failure.

## 4. Seeking the Healthy City

In the ideal city all citizens would be healthy and happy. Of course, modern cities are far from this ideal. While urban areas do offer services and opportunities that are not available in rural areas, they are complex and stressful environments that can cause (or exacerbate) a wide range of physical and mental illnesses. In general, public health problems intensify as urban populations grow and cities sprawl (Frumpkin 2002). It is urgent, therefore, that ways are developed to understand the drivers of these trends and to design effective strategies to counter them. Historical studies have shown that one crucial issue is the separation that has developed steadily between public health and urban planning over the last 100 years. As expressed by Corburn (2009):

> How can modern city planning, a profession that emerged in the late nineteenth century with a goal of improving the health of the least-well-off urban residents but lost this focus throughout the twentieth century, return to its health and social justice roots? What are the connections among contemporary city planning processes, not just physical outcomes, and health equity? What new political processes can help reconnect planning and public health with a focus on addressing the social determinants of health inequities in cities?

Clearly, a rapprochement between public health and urban planning is a critical ingredient in efforts to improve urban health (Corburn 2004, 2009; Frumpkin 2002). From a CCM perspective, this endeavour requires the evolution of strong collaborations between professionals in the two domains, and a commitment on their part to taking a systems approach to urban governance. To understand the importance of systems thinking in this context, consider the balancing act required to create a management structure characterised by polycentric order. Such a structure can be defined to be "a social system of many decision centres having limited and autonomous prerogatives and operating under an over-arching set of rules" (Aligica and Tarko 2012: 237). If the over-arching rules are too prescriptive, they will inhibit creativity in the individual governance centres and so reduce the chances that policies will emerge that are tailored to local conditions. If, on the other hand, the rules are too weak, they will provide little guidance and no brakes on the development of management silos. A systems approach provides over-arching conceptual frameworks that call for, and can guide, strong integrative efforts, without dictating specific actions. That is, it can influence practitioners' goals, but leave them free to select which paths they will follow towards those goals.

In 2012 we ran two community workshops in Sydney, Australia, to gain insights into the practical challenges of establishing health-planning collaborations. Participants were drawn from a wide range of practitioners with experience of contemporary urban health and planning issues. They included managers and policy makers from public health, urban planning and development, and local government in the Western Sydney region. See Appendix 1.

## 4.1 The CCM Workshops

The CCM workshops were run under the auspices of the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) Climate Adaptation Flagship as part of their Urbanism, Climate Adaptation and Health Cluster. In Workshop 1, *Critical Public Health Issues and Drivers*, we explored the principal state variables and feedback structures that set the context for potential collaboration between urban planning and public health professionals in Western Sydney. Participants used the CCM Pair-Blending method (§3.3) to express their individual views of system structure and then worked in cross-sector pairs to blend their views. Their blended influence diagrams were then used to guide a discussion of cross-sector feedback in the area. Our examination of the challenge of building robust public health policy was guided by discussion of the *Fixes that Fail* and *Success to the Successful* system archetypes (Senge 1990). In Workshop 2, *Strategies for Public Health in Western Sydney*, the insights from Workshop 1 were used to take the initial steps towards a useful scenario matrix.

## 4.2 The Scenario Matrix

The scenario variables selected on the basis of the workshop discussions are listed in Table 2. Each of these 'policy variables' can be thought of as measuring the relative strengths of a pair of competing governance paradigms. The scenario matrix is displayed in Figure 8. The labels *Mediway*, *Siloville*, *Patchburg* and *Welton* are the names of hypothetical cities that represent the conditions prevailing in each quadrant of the matrix.

In Figure 8 the horizontal axis measures the strength of the community's belief in the need for an integrative, cross-sector approach to urban policy and planning, rather than urban governance that is left to specialists working in management silos. We will call this the 'integrative planning' policy variable, and represent it in Figure 9 using the symbol *IP*. The variable on the vertical axis measures the strength of the community's belief in the need for proactive urban health policies, rather than a medical services approach that is predominantly reactive. We will call this the 'proactive health' policy variable, and represent it in Figure 9 using the symbol *PH*.

**Table 2**. Scenario Matrix Axes

| **Axis** | **Urban Policy Variable** | **Basic Effects of Changes in Level** |
|---|---|---|
| Horizontal | The extent to which urban policy and planning is *integrative* rather than *fragmented*.<br><br>Represented by the symbol *IP* (integrated policy) which runs from 0 to 1. | A fragmented approach to urban policy and planning leads to the proliferation of administrative silos and to policy conflict. Cross-sector feedback is largely ignored. A move to integrative approaches shifts the balance towards policy coherence and an increased commitment to the development of effective cross-sector feedback and robust adaptive plans. |
| Vertical | The extent to which the health sector is *proactive* rather than *reactive*.<br><br>Represented by the symbol *PH* (proactive health) which runs from 0 to 1. | A reactive health sector is primarily concerned with the provision of medical and pharmaceutical services, and sees individual health as a community responsibility. A move to a more proactive health sector shifts the balance away from medical services, towards the establishment of a healthy community. Proactive health professionals see individual health as a responsibility shared between the community and the individual. |

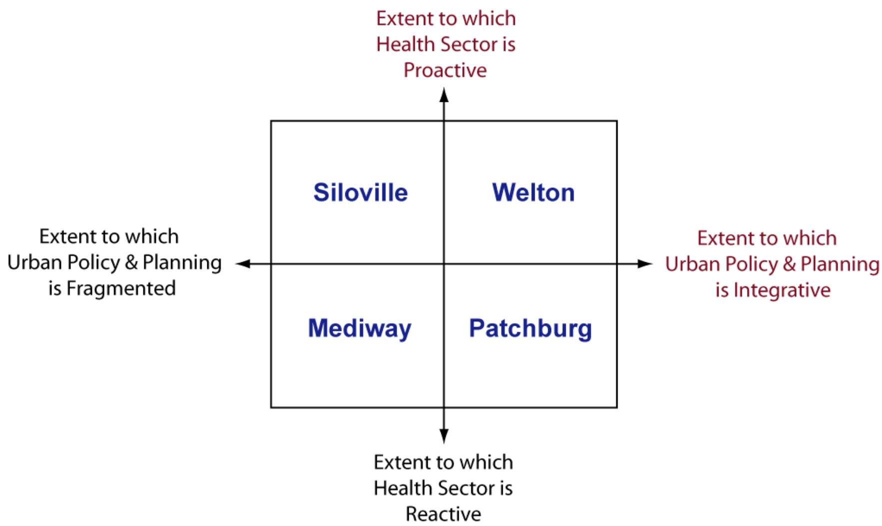


**Figure 8**. The scenario matrix developed on the basis of the workshop discussions. The state variables are defined in Table 2. The axes are represented using double-ended arrows to help clarify the nature of the state variables. Each quadrant is labelled with the name of a hypothetical city.

There are four hypothetical cities, representing the conditions in each quadrant of the scenario matrix :

*Mediway* has a reactive health sector, and fragmented urban policy and planning. Health professionals consider health to be their exclusive domain. Individual citizens are seen as consumers of medical and hospital services. Pharmaceutical companies are riding high. There is only weak feedback between the health sector and the urban policy and planning sector. There is little pressure on either sector to collaborate. The future is heavily discounted. Maladaptive technology dependence continues to grow.

*Siloville* has a proactive health sector, but fragmented urban policy and planning. Public health professionals strongly promote the health and economic virtues of a future-focused approach, and see the attainment of individual health as a responsibility to be shared between the individual and the community. They understand the phenomenon of maladaptive technology dependence, and see the human health and environmental benefits of passive indoor climate control, public transport and active travel, and urban food production. They are, however, frustrated by the lack of support from urban policy makers, who are intent on preserving their traditional administrative silos, and who are stimulated by intra-department conflict.

*Patchburg* has a reactive health sector, but a strongly integrative approach to urban policy and planning. The city's forward-looking urban planners see the importance of a cross-sector approach, wherein actions are guided by the principle that decisions made in one sector can have significant impacts in other sectors. They work closely with population-health professionals. They are, however, frustrated by the overall intransigence of the majority of the health providers who see only the need for more hospitals, more extensive medical research, better drugs, and ambulance lanes on the freeways. Policy development is patchy in Patchburg.

*Welton* is an ideal city with a strongly integrative, systems approach to urban governance. This city has all the good traits of *Siloville* and *Patchburg*, and none of the bad traits. There is a strong future focus, and the provision of resources and services is no longer the exclusive domain of separate sectors. Trans-disciplinary teams manage urban policy and planning. They celebrate their successes, but take full responsibility for the unexpected, unwanted outcomes of their decisions. They understand system principles and recognise the potency of that invisible force—feedback. As a result the urban community is highly adaptive and takes a critical approach to the assessment of new technologies. All is well in *Welton*.

Some of the basic characteristics of the scenario cities are listed in Table 3.

4.3 Urban Evolution for Heath and Wellbeing

In Figure 9 we represent possible evolutionary scenarios. The numbered arrows represent the *IP-PH* trajectories that the hypothetical cities follow as they evolve. *Mediway* is the start point of all trajectories because it represents the typical state of large cities at the beginning of the 21st century.

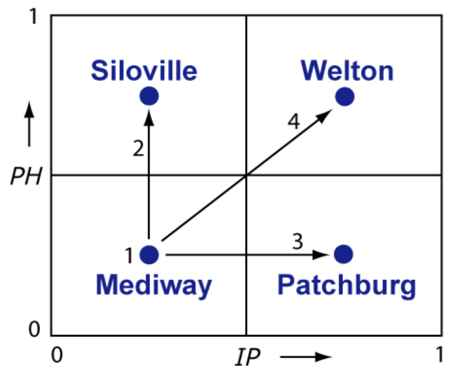


**Figure 9**. Evolutionary trajectories in *IP-PH* state-space. The horizontal axis, labelled *IP*, represents the extent to which the urban policy and planning sector is integrative. The vertical axis, labelled *PH*, represents the extent to which the health sector takes a proactive approach (Table 3).

Trajectory 1 (*Mediway* to *Mediway*). This trajectory is a single point in *IP-PH* space. That is, while *Mediway* does evolve, it does not move significantly along either the *IP* or *PH* axes.[3] This is the business-as-usual scenario.

[3] We assume that, as *Mediway* evolves, its trajectory extends along dimensions that are orthogonal to the (*IP*, *PH*) plane. It must be remembered that the *IP-PH* space represents only a two-dimensional slice of the multi-dimensional state space of a city.

Trajectory 2 (*Mediway* to *Siloville*). This trajectory represents those aspects of urban evolution that are driven by a paradigm shift in the health sector, from reactive to proactive.

Trajectory 3 (*Mediway* to *Patchburg*). This trajectory represents those aspects of urban evolution that are driven by a paradigm shift in the urban planning sector, from fragmented to integrative.

Trajectory 4 (*Mediway* to *Welton*). This trajectory represents effects of paradigm shifts in both the health and urban planning sectors. While Trajectory 4 is shown as a straight line, which represents the case where the two sectors evolve at the same rate, in reality it is likely to curve through either *Siloville* or *Patchburg*.

When fully documented, these scenarios will tell the stories of the evolution of four cities, as recounted by an historian living in the future. The development of these detailed narratives has yet to be undertaken. It is a major task that requires significant involvement of researchers, experienced policy makers, and other community members.

*4.4 Pedagogical Use of Scenarios*

Scenario building is effective because it involves clothing the underlying abstract conceptual framework with captivating stories. From the pedagogical point-of-view, this process works best when the target group is involved in the development of the scenarios. The educational approach called 'constructionism' rests on the basic principle that individuals learn best by 'making', by tinkering, by doing something (Martinez and Stager 2013). This idea resonates with the ancient Chinese proverb that is usually rendered into English as *I hear and I forget; I see and I remember; I do and I understand*. There is good modern evidence that the principle is correct (see, for example, Papert 1980; Kolb 1984; Martinez and Stager 2013). It is supported by the demonstration that human conceptual systems are 'embodied'—that is, based on metaphorical projections of real-world, bodily experiences (Lakoff and Johnson 1999; Newell 2012). Translated into the scenario-building domain this principle underlies the importance of having the users (policy makers, decision makers, engaged community members) do the building.

It is involvement in the process of development, of wrestling with the complexity, that provides the most valuable learning opportunities. It is possible, for example, to use fully developed scenarios as training materials in workshops, or to disseminate them in publications or on the internet. But such approaches do not have the re-framing power of direct involvement in scenario creation. While the stories might be captivating, the reader will have no ownership, and his/her gains in understanding will be limited. The process of wrestling with the challenge of producing a number of coherent story lines, that draw together a wide range of issues and opinions, can have a deep and lasting impact on the participants' worldviews.

Involvement in the construction of scenarios can improve urban decision making in several ways. First, it can help a community to develop 'memories of the future' (Newell and Proust 2012: 16). This term, which was coined by neurobiologist David Ingvar (1985), refers to the heightened sensitivity to significant variables and events that comes from the activity of *seriously* imagining a range of plausible futures. Second, provided that the scenarios are based on systemic models, it can help community members to grasp the importance of cross-sector feedback effects in complex systems. In particular, it can alert them to the very real possibility that initiatives taken in one sector can undercut those taken in another sector. For example, in modern cities is not uncommon for there to be several, unconnected departments that have responsibility for different aspects of the same sector (such as *transport*). In such cases there can be serious conflicts between these departments, both because they favour apparently incompatible initiatives (such as *road* versus *rail*) and because they are in competition for the same funds.

**Table 3**. Selected Characteristics of the Scenario Cities

| | **Mediway** | **Siloville** | **Patchburg** | **Welton** |
|---|---|---|---|---|
| Urban policy and planning | Fragmented $IP < 0.5$ | Fragmented $IP < 0.5$ | Integrated $IP > 0.5$ | Integrated $IP > 0.5$ |
| Health sector | Reactive $PH < 0.5$ | Proactive $PH > 0.5$ | Reactive $PH < 0.5$ | Proactive $PH > 0.5$ |
| Level of collaboration between urban planning and health sector | Low | Medium | Medium | High |
| Focus on cross-sector feedback | Low | Medium | Medium | High |
| Urban planners discount the future | Yes | Yes | No | No |
| Health sector discounts the future | Yes | No | Yes | No |
| Locus of responsibility for health* | C | C + I | C | C + I |
| Dominant cooling technology** | RAC | Mixed | Mixed | PICC |
| Dominant food production location | Distant | Mixed | Mixed | Local |
| Dominant urban travel mode | Private vehicles | Mixed | Mixed | Public and active |
| Population in 2050 | 10 million | 10 million | 7 million | 5 million |
| Limits on population growth | No | No | Yes | Yes |
| Community strength, social capital | Low | Medium | Medium | High |
| Limits on urban sprawl | No | No | Yes | Yes |
| Commitment to market processes for land-use decisions | High | High | Medium | Low |
| Commitment to economic growth as principal goal | High | High | Medium | Low |
| Adaptive capacity of community | Low | Medium | Medium | High |

* C = community, I = individual.
** RAC = refrigerated air conditioning, PICC = passive indoor climate control (Proust et al. 2012)

## 5. Conclusion

In this paper we have briefly described Collaborative Conceptual Modelling (CCM), a practical approach to the development and application of systems thinking and analysis skills. CCM encompasses six co-evolving activities that can support a research or management group's attempts to take account of two sets of critical interactions—feedback interactions between selected parts of their system-of-interest, and knowledge-sharing and knowledge-building interactions between the members of the group. These sets of interactions are nested, in that an analysis of feedback structures requires the co-production of knowledge. No one person can see the whole system, but everyone is an expert in some aspect of the human experience.

We conclude by reporting part of the output from CCM workshops where public health and urban planning professionals explored the challenge of developing healthy cities. The workshop resulted in the identification of two system variables that together play a significant role in determining the state of a city's governance regimes—*the extent to which urban policy and planning is integrative (systemic)* and *the extent to which the health sector is proactive*. The way that these variables change over time can be used to track the evolution of urban governance from fragmented-reactive to integrated-proactive. In general terms, improvement in urban health and wellbeing requires public health and urban planning teams to work more closely together and consider longer timescales for change.

The establishment of closer collaboration between public health and urban planning professionals is a critical enabling factor in the evolution of healthier cities. We suggest that the present situation, where these professions often operate in separate management silos, reflects the natural tendency for polycentric governance structures to develop in complex systems. The problem is that polycentric governance does not necessarily involve polycentric order.

The establishment of a well-balanced polycentric order, where local management groups have maximum freedom to produce innovative policies that are finely tuned to local conditions, but that are constrained and co-ordinated by over-arching rules and goals, requires a feedback systems approach. Feedback interactions play a dominant role in urban dynamics, but can be invisible to policy makers and managers who are not systems thinkers. Actions taken in one sector can propagate around unseen pathways, looping through other sectors, to come back and amplify or undercut the original actions. Once this possibility is glimpsed, it becomes obvious that management by silos cannot work. Urban environments are far too complex, far too connected. That realisation is enough to show the way forward—systems thinking is an essential part of the over-arching conceptual framework that managers need if they are to create sustainable polycentric governance.

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**Appendix 1.** Workshop Participants

| Participant | Role /Agency |
|---|---|
| Anthony Capon | Director, UNU International Institute for Global Health |
| Jeff Spickett | Curtin University |
| Helen Brown | PhD scholar, Curtin University |
| Timothy Baynes | CSIRO Ecosystem Sciences, Riverside Park, North Ryde |
| Peter Sainsbury | Director, Population Health, South Western Sydney & Sydney Local Health Districts, NSW Health |
| Mark Thornell | Deputy Director, Population Health, South Western Sydney & Sydney Local Health Districts, NSW Health |
| Janice Biggs | Public Health Officer trainee, NSW Health |
| Kleete Simpson | Public Health Officer trainee, NSW Health |
| Gösta Liljeqvist | Public Health Officer trainee, NSW Health |
| Kay Tennant | Co-ordinator, Healthy Built Environments Program Centre for Population Health, Cumberland Hospital, North Parramatta |
| Elizabeth Millen | NSW Health – South Western Sydney Area Health Service, Liverpool |
| Kerry Bartlett | CEO, Western Sydney Region of Councils (WSROC), Blacktown |
| Karin Bishop | Deputy CEO, Western Sydney Region of Councils (WSROC), Blacktown |
| Bianca Lewis | Senior Project Officer, Impacts and Adaptation, NSW Office of Environment and Heritage, Dept Premier and Cabinet, Sydney |
| Louise Crabtree | Research Fellow, School of Humanities and Communication Arts, Bankstown Campus, University of Western Sydney, Penrith |
| Monica Zarafu | Project Manager Transport, Ryde City Council |
| David Lilley | Project Manager, Planning and Research Renewal, NSW Land & Housing Corporation, Department of Finance & Services, Sydney |
| Tara Day | Senior Consultant, Social Sustainability and Stakeholder Engagement, GHD Consultants, Sydney |
| David Mason | NSW Department of Primary Industries, Urban Agriculture, Richmond |
| Ian Knowd | School of Social Sciences and Psychology, Kingswood Campus, University of Western Sydney |
| Louise McKenzie | PhD scholar, Built Environment, University of NSW |
| Claire Boulangé | PhD scholar, University of Melbourne |
| Maria Whipp | Specialist Policy Advisor, Metropolitan and Regional Strategies, Department of Planning and Infrastructure, Sydney |
| Diana Griffiths | Senior Associate, Integrated Design & Planning, ARUP |