Manuscript of article now published in Environment International, available online 25 April 2016:


Understanding the systemic nature of cities to improve health and climate change mitigation

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\textbf{Abstract.} Understanding cities comprehensively as systems is a costly challenge and is typically not feasible for policy makers. Nevertheless, focusing on some key systemic characteristics of cities can give useful insights for policy to advance health and well-being outcomes. Moreover, if we take a coevolutionary systems view of cities, some conventional assumptions about the nature of urban development (e.g. the growth in private vehicle use with income) may not stand up. We illustrate this by examining the coevolution of urban transport and land use systems, and institutional change, giving examples of policy implications. At a high level, our concern derives from the need to better

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understand the dynamics of urban change, and its implications for health and well-being. At a practical level, we see opportunities to use stylised findings about urban systems to underpin policy experiments.

While it is now not uncommon to view cities as systems, policy makers appear to have made little use so far of a systems approach to inform choice of policies with consequences for health and well-being. System insights can be applied to intelligently anticipate change – for example, as cities are subjected to increasing natural system reactions to climate change, they must find ways to mitigate and adapt to it. Secondly, systems insights around policy co-benefits are vital for better informing horizontal policy integration. Lastly, an implication of system complexity is that rather than seeking detailed, ‘full’ knowledge about urban issues and policies, cities would be well advised to engage in policy experimentation to address increasingly urgent health and climate change issues.

Keywords:
Urban system; coevolution; co-benefits; transport; health; mitigation
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1 Introduction

Urban policy makers face major challenges as they grapple with immediate problems such as improving mobility, providing land for new housing and maintaining population health, against a complex background of macro issues including climate destabilisation, growing income inequality, and fiscal constraint. Because of issue interconnection and system complexity, issue-by-issue policies to address such challenges often have little effect or even perverse effects, especially when policies are diluted by forces of conventional urban politics and corporate decisions. Many local governments also have limited policy autonomy, embedded as they are in a hierarchy of policy-making which is dominated by higher levels of government.

Urban system complexity requires simultaneous consideration of multiple issues, processes and outcomes. In such a setting, problems such as improving urban mobility or accessibility cannot be ‘solved’ as such, and policies struggle to produce net benefits. For example, a policy to restrain urban house price inflation by peripheral land development may encourage car dependence and over time reduce citizens’ health (Rydin et al., 2012; Satterthwaite, 2011) while locking in higher carbon emissions. Such a policy will likely contribute incrementally to climate change, worsening health globally, albeit slowly (Costello et al., 2011). Meanwhile, price restraint in the housing market could be achieved better by other policies such as housing intensification. The policy challenge, then, is to understand urban dynamics and wider implications sufficiently to make a net positive contribution to health and well-being.

The current political context in most countries emphasises economic growth and cities are under pressure to be seen to contribute to a national development
and innovation process (Bettencourt et al., 2007; Hodson and Marvin, 2011; LSE Cities, 2012; Shearmur, 2012). Moreover, the dominant economic paradigm in most countries privileges the market. This paradigm assumes that higher incomes contribute directly to social well-being, not recognising the reality of a more complex long-term relationship between economic activity (measured by GDP) and well-being (Kubiszewski et al., 2013). Simplistic assumed relationships divert attention from the complex determinants (such as health) of the well-being of citizens, the prudent use of resources (including ecosystem services) and avoidance of irreversible environmental risk (Newman and Matan, 2012; Quental et al., 2011; Williams, 2010). There are clear opportunities for policies to contribute to both economic development and population health and well-being (Howden-Chapman and Chapman, 2012; WHO, 2011), but these opportunities need to recognise the complexity of urban life.

Increased economic opportunities generated through urban agglomeration have lifted health and well-being enormously over time, driving global urbanisation. But urban development can adversely affect health: for example, the increasing dispersion of modern cities is associated with a trend to major unintended health impacts, through reduced levels of physical activity, and reduced air quality, typically due largely to motor vehicle emissions. The results include epidemics of obesity, diabetes, respiratory and cardiovascular disease, and depression (Burnett et al., 2014; Frank et al., 2004; Lindsay et al., 2011; MacDonald et al., 2010; WHO, 2011; Witten et al., 2011). Alongside these health trends, there is increasing recognition among the public health community of the significance of climate change as a key driver of long-term health outcomes (Costello et al., 2009; McMichael et al., 2009; Rydin et al., 2012).

Because of these multiple linkages, a framework is needed for understanding the connections between city characteristics on the one hand, and on the other, two critical twenty-first century preoccupations -- health and climate change mitigation. We bracket these together, not only because climate change increasingly
affects health, but because there is a strong affinity between the health of humans and the health of planetary systems: climate change is a sentinel indicator of planetary health (Whitmee et al., 2015). We argue that (a) cities need to be seen as complex systems, with a variety of characteristics affecting urban behaviour; and (b) urban systems need to be seen within a coevolutionary framework, in which urban systems coevolve with natural systems, infrastructure, technologies and institutions. These interact to determine in a dynamic way the outcomes of interest, in particular the health and well-being of citizens.

Seeing urban challenges through these two lenses can provide rich insights for policy analysis. It offers policy makers a better understanding of the problems they confront and why solutions which appeal in the short term subsequently fail. The two lenses also crystallise important urban system interconnections, and better illuminate urban transition paths.

While it is intuitively evident that cities are complex, interconnected systems, much policy is made without considering broader ramifications and dynamics (Banister, 2005), nor how a range of drivers such as institutional evolution affect urban outcomes. This is partly because of the reductionist reaction to considering complexity, and partly because there is too little empirical evidence about policy interactions and consequences. Accordingly, this paper seeks to be practical – it focuses on tangible illustrations, useful for policy, from the urban transport and land use sector, highlighting instances where, even with limited empirical evidence, characteristic urban system behaviour can be better understood and projected.

This paper is structured as follows. Section 2 briefly summarises characteristics of urban systems, and discusses how key sectors are interconnected. It also introduces a framework identifying how key elements of dynamic urban systems coevolve. Turning to policy, section 3 considers how policies can better recognise system characteristics of cities (especially transport and land use) and coevolutionary forces. Examples from various countries are given. Section 4
discusses how systems thinking on policy matters increases the potential of cities to be ‘transformed’ to yield better outcomes for health and climate change. Section 5 draws conclusions.

2 Cities as systems

2.1 Insights from the systems and coevolution literature

The general systems literature (Allen, 1997; Capra, 1996; Chapman, 2004; Dollfus and Durand Dastes, 1975; Elzen et al., 2004; Loorbach and Rotmans, 2006; Lovelock, 2006) typically characterises natural systems or human activity systems, whether communities or parts of organisms, as follows. First, systems are integrated wholes, where the whole, with its emergent properties, is more than the sum of its parts. Second, systems comprise nested (sub-)systems, at a range of scales. Third, systems have feedback processes among network elements, allowing self-regulation, self-organisation and learning in response to changing external conditions. Fourth, systems behave in a complex fashion, with non-linear behaviour, seldom stable or in equilibrium, and with interventions generating unintended consequences. Lastly, systems are able to be resilient, if adaptively managed.

Let us briefly consider the way in which cities exhibit these characteristics. First, a city is a ‘socio-ecological-technical’ whole, comprising strongly interconnected parts, driven by and contributing to social, ecological and technological forces (Monstadt, 2009). Within the city, nested integrated wholes exist, e.g. a city public transport network. Such wholes have important emergent properties, such as economic productivity and city identity.

The second system characteristic, nesting, is also evident. Cities exhibit interacting activity and governance at multiple scales – from the state to the household, and increasingly extending to international networks of cities as sites of influence on the life of a city. From a geographic perspective, the immediate region
is vital, but wider systems that provide resources, from food to communications, are also important (Tyler and Moench, 2012). Urban innovation niches nest within wider sociotechnical regimes and a wider institutional and economic landscape (Geels, 2011; Monstadt, 2009). In terms of governance, we see a wide variety of nested institutions (Bulkeley and Betsill, 2005; OECD, 2009), down to local home owners’ associations in the US (Seto et al., 2010). Nested systems are richly interconnected and evolving; for example, internet linkages facilitate interactions between individuals both vertically, up and down levels, and horizontally, across networks, making social and cultural linkages fluid and complex. At the same time, evolving technologies such as broadband networks can make new urban services possible, while making traditional governance more challenging (Wedel, 2009, p.39).

Complexity tends to increase with greater scale; indeed, easier communication and increasing returns to scale in knowledge appear to drive urban innovation (Glaeser, 2011b; Shearmur, 2012). Size, agglomeration and innovation are often connected (Kamal-Chaoui and Robert, 2009), which may help account for the often higher incomes and associated consumption levels of many in big cities.

Third, much urban activity is self-organising. For example, in a well-functioning city, largely self-regulating markets, employing myriad feedback mechanisms, respond to changing conditions such as socio-demographic shifts. City political systems are self-organising and often autonomous from national politics, frequently contesting the demands of the state (Magnusson, 2011).

However, urban analysts’ ability to predict sustainability outcomes arising out of socioeconomic trends and city policies is limited, because of the non-linearity of city systems and the complexity of the interrelationships.

Complexity, a fourth characteristic, means that city development is driven by a range of interacting processes, partly described by the coevolutionary framework presented below. Non-linear effects and chance events are important, and development paths are affected by feedback, inertia, and innovation (Arthur, 1989;
Developments at one scale are contingent on linked developments at other scales (Chapman, 2004). For example, cities are linked economically not only to their regional hinterlands, but into the global economic ‘ecosystem’ (Brown et al., 2008).

Lastly, cities can be resilient, although history demonstrates that this is not necessarily the case (Chelleri, 2012). Resilience in an urban context implies social-ecological adaptive capacity and the ability to reflect on and evaluate policies for long-term sustainability (Allan and Bryant, 2011; Nelson, 2010, p.115). Many cities suffer from fragmented or under-resourced institutions, but others with more strategic governance are able to adapt as conditions change (Bowen et al., 2012; Bulkeley, 2010; Newman et al., 2009). Frameworks for understanding cities’ resilience to climate change impacts, for example, are still evolving (da Silva et al., 2012; Davoudi et al., 2012) and cities are still struggling to adjust their policies and institutions to mitigate climate change.

A small but growing ‘system coevolution’ literature (e.g. Costanza et al., 1997; Foxon, 2011; Kallis and Norgaard, 2010) can augment this view of systems by viewing it more dynamically. Figure 1 presents a framework, building on Kallis and Norgaard’s pentagram of interacting elements, but adapted to urban systems. Four domains can be emphasised as critical to cities: natural systems, infrastructure, institutions, and technologies. Outcomes of interest in this paper are health and well-being, but also climate change mitigation. Interaction among system elements is represented by bidirectional arrows. This portrays the coevolution of the systems in question.
Newer technologies such as electric vehicles and bus rapid transit require infrastructure investment, and that investment influences technological evolution and application in a given city. Similarly, evolving institutions and business strategies can have a major effect on outcomes of interest. Examples of institutions
include planning legislation, urban spatial plans, policies affecting urban intensification, car sharing policies and strategies, and so on.

The natural systems most affecting cities are the atmosphere, air, water bodies, green spaces, and local soils: these affect not only quality of life but also climatic events, such as storms, and biological productivity in the city region. Infrastructure encompasses not only transport systems, but energy, housing and other aspects of the built environment.

These urban systems coevolve, and with the exception of natural systems, none is more fundamental than the others. For example, the provision of road infrastructure has influenced the development and application of motor vehicle technology and vice versa. Institutional strategies such as approaches to environmental management feed back to the resilience of natural systems, while natural system behaviour affects institutional responses. Institutions are more effective if they take a long-term, encompassing view (Levin et al., 2012). The interplay between natural and institutional-cultural systems (Boyden, 2004; Grimm et al., 2008) matter for addressing issues such as the degrading of productive and peri-urban landscapes, the management of urban water supply, local environmental effects such as urban biodiversity changes, and the urban heat island phenomenon. An increasingly important example is the behaviour of the climate system: as the atmosphere begins to exhibit greater volatility, institutions determining mitigation and adaptation policies, and business strategies, are forced to adjust; while at the same time, those policies feed back over time to affect the climate system.

Outcomes such as the well-being of citizens depend, of course, on institutional systems at levels beyond the city, including not only the region, the site of much strategic spatial planning (Healey, 2004), but also the larger national macroeconomic policy domain (Kaletsky, 2010; Rickards et al., 2014), and the global domain, with its institutions for attempting to manage globalisation, financial instability, migration crises, and so on.
2.2 Policy interaction and coevolution in the urban policy context

Bearing in mind these systemic features of cities, and their coevolution over time, there are two central propositions of this paper. First, that policies based on recognising and understanding significant system interactions (and not merely the main relationships identified in conventional analyses) can create better outcomes for cities, especially when cobenefits are analysed. Second, that resisting the pressure for urban policy to be a series of short-term political fixes, policy makers advancing the long-term health and well-being of their citizens need to anticipate the impact of critical coevolutionary drivers, such as the spread of new digital communication and transport technologies, energy decarbonisation to minimise anthropogenic climate change, and changes in socio-cultural and business practices associated with ongoing urbanisation.

Interactions and cobenefits

A way of expressing the importance of the interplay among elements of a complex urban system is through identifying and valuing coimpacts (cobenefits and adverse side effects) of urban policy (Ürge-Vorsatz et al., 2014). Some urban policies can generate multiple cobenefits, and sometimes multiple adverse side-effects. Policies can also interact so that a particular policy may reinforce (or undermine) another.

A range of studies suggests that health impacts can be more important than conventional analysis has allowed for: health impacts ‘often dominate in terms of the importance of the different categories of cobenefits...’ (Ürge-Vorsatz et al., 2014, p.574). Accordingly, policy formulation which takes into account such cobenefits and adverse effects for health and well-being, including unintended consequences, will present a richer and more realistic picture of outcomes.

For example, intensification of housing can have a cobenefit of making public transport more economically viable, increasing access and associated well-being for
many. Similarly, more compact cities tend to have lower infrastructure costs per capita (Carruthers and Ulfarsson, 2003; Trubka et al., 2010), freeing city infrastructure budgets for other priorities, including supporting public transport. In both these ways, policies to intensify cities may not only mitigate climate risk and save on energy (Fuller and Crawford, 2011) but also have benefits in terms of transport system diversity and resilience, and health or well-being cobenefits for many citizens (Woodcock et al., 2009; Younger et al., 2008). Conversely, poorly targeted road building can have unintended consequences such as undesirable land use change, and socially, environmentally and even economically adverse effects (OECD, 2006).

Of course, housing intensification can have adverse side-effects if poorly handled (Howley et al., 2009). It may create noisy environments and harm air quality, through increased exposure to congested motor traffic. A Toronto study suggests that intensification can increase road congestion, if public transport is not upgraded at the same time (Filion and McSpurren, 2007). However, the adverse effects of intensification may be minimised, and air quality and noise levels managed, with options such as converting public transport to battery electric vehicles.

A second important aspect of the interplay of cobenefits is through the enabling of political alliances, or the ‘translation’ of interests’ (Rutland and Aylett, 2008; Trumbull, 2012), even when the individual parties seem weaker than concentrated corporate interests (Trumbull, 2012). Often policies are adopted mainly because of shorter-term local urban benefits, but have wider cobenefits in mitigating climate change. This matters politically, since mitigation policies are often unpopular, as benefits accrue largely to ‘others’ and future generations. The local, immediate benefits which drive change often include air quality improvements (Pittel and Rübbelke, 2008), reduced congestion, improved health and greater productivity. The Vision California case study (Calthorpe, 2011) illustrates how urban redesign offers both ‘livability’ benefits and contributes significantly to emissions abatement.
However, the extent of co-benefits in particular contexts can be difficult to pre-judge, and policy experimentation (Ansell, 2012; Walters and Holling, 1990) is needed to illuminate more contentious instances of urban change such as major reconfigurations of land use.

*Keeping long-term outcomes and coevolutionary drivers in mind*

To illustrate proposition (2) above, consider urban form, particularly the management of land for urban development. Governments have long recognised the need to regulate the land market in the collective interest; but questions consistently arise around what gives best long-term outcomes. A focus on short-term business growth, for example, will yield different outcomes from focusing on long-term urban sustainability and citizen health. Promoting greenfield development can interact with developments in related domains (particularly transportation) to affect health and sustainability outcomes (Filion and McSpurren, 2007). Greenfield development may appear to assist households by opening up low-cost housing sites on the urban periphery. But if a household chooses a dwelling further from the centre and if some household members are employed in the centre, then increased commuting costs may offset the saving in the cost of housing, and the household may be exposed to significant oil price risk (Center for Transit Oriented Development and Center for Neighborhood Technology, 2006). Some households lack capacity to take into account such factors, for example, through being cash-constrained and unable to afford more centrally located housing; they may therefore become exposed to economic risk in buying an outer suburban dwelling (Dodson and Sipe, 2008; Preval et al., 2010). Over time, social well-being may not be maximised by such choices.

Where households are encouraged to make such choices – by, for example, the US Federal Reserve Board’s expansionary policies of the early 2000s, and poor regulation of financial ‘innovation’ (Cortright, 2008) – then there will be a decline in both urban sustainability (due to greater vehicle carbon emissions) and economic
resilience. Evidence from US cities such as Atlanta suggests urban policies can obstruct the realisation of preferences for more compact, walkable and transit-friendly neighbourhoods (Levine and Frank, 2007), reducing resilience in the face of energy price volatility and climate change policy risk.

Institutional rules on urban form and design interact with transport to affect health and climate outcomes. They are key elements in the coevolution of the city, with important consequences. To illustrate, a New Zealand study found that more compact, mixed land-use neighbourhoods with better destination access and greater street connectivity showed higher physical activity levels among residents (Witten et al., 2012), which is important for health. A Beijing study found that diversity of land use, job density and exclusive cycle lanes were positively associated with bicycle use, and commuting time was inversely associated with it (Zhao, 2014): urban expansion has cut bicycle commuting, and car use has risen dramatically, as have emissions. Most recently, Sallis et al. (2015) reviewed a range of international evidence showing that when urban settings are designed to be ‘activity friendly’, a range of health benefits accrue, alongside environmental, and economic benefits. The importance of these factors for health and climate outcomes needs to be kept in mind as urban policies are adjusted to shape development, as the next section argues.

3 Enhancing urban policy by recognising systemic characteristics of cities

3.1 The evolving urban transport system

The previous section discussed better understanding system behaviour. In this section we illustrate how policies on urban transport and land use, as an interconnected system, can better recognise system and coevolutionary characteristics. We use systems insights around urban transport and land use policy to exemplify more integrated policy approaches.
Consider how transport mode choice depends on the transport ecosystem. Policies to foster public transport, which involves walking to the train or bus stop, require attention to the quality of the urban environment. Walkable cities also involve people living in the city at some density (Glaeser, 2011b), and walking in their local neighbourhood (Jacobs, 1961). However, public transport is far from suitable for all trips, and functions best as part of a diversity of transport modes, including not only active modes, but also car use such as car sharing for more complex journeys (Shaheen et al., 2009). Policies to encourage transport system diversity create choice, flexibility and adaptiveness to changing conditions, but require careful integration. For example, good quality, well-lit, attractive bus or train stations and mode interchanges (such as park and ride stations). In short, there is an important interplay between mode choice and the quality of the urban environment, and policy makers need to keep this interplay in mind when designing transport and urban space policies. Neglect of this interaction in the past has likely contributed to the decline in public transport mode share.

Historically, the eclipse of public transport and active transport in many cities reflected the interplay between technological change and business strategies. As automobile technology improved and fell in price, the eclipse of public transport was accelerated by a rewriting of the social connotations of collective as opposed to individualised travel – a revolution in user practices. The expansion of cities hindered active travel: in the UK, cycling fell from 11% of all passenger travel in 1952 to 0.5% by the mid-1990s (Davis et al., 2007). The decline of public transport was often deliberately fostered by the automobile industry, with for example, Los Angeles’ freeways portrayed as ‘liberating’ (Klein, 2008). Similarly, in Auckland, New Zealand, during the Cold War period, trams were represented as embodying ‘Stalinist’ centralist planning (Harris, 2010). The car-dominated monoculturing of Auckland’s transport system had the long-term effect of reducing its flexibility and resilience, and creation of congestion when land available for motorway expansion was exhausted. Automobility crowds out other forms of transport over time.
(Denniss and Urry, 2011). Active travel options are now marginalised in many cities, having ceased to appear safe as vehicle volumes increased (Jacobsen, 2003; Robinson, 2005), and modes became more socially differentiated, potentially reducing social cohesion.

The European city experience suggests that explicit policy effort with system interactions in mind can keep the transport ecosystem diverse (Ministry of Transport Public Works and Water Management and Fietsberaad, 2009). At least from the 1970s, European cities consciously encouraged active travel, constraining the growth of car use. Such cities took the view that losing an active travel culture would be damaging to the city, and difficult to reverse (Liu and Guan, 2005; Pucher et al., 2010). The policy decisions to support active travel were made even before research provided clear evidence of the health and other benefits (de Nazelle et al., 2011; Gössling and Choi, 2015; MacDonald et al., 2010; Rojas-Rueda et al., 2011). A transport ecosystem-sustaining approach requires authorities to consider the system dynamics of urban transport, including non-linear, threshold effects. Since active travel support measures are often ‘staged’, individual steps may be ineffective until other steps are complete, whereupon synergies emerge (Pucher et al., 2010).

Transport policies are evolving rapidly, driven by technology change and a concern about climate change, and business strategies and government institutions are responding to changing economic opportunities and user practices. Policies are starting to recognise that a ‘tipping point’ may have occurred in a number of developed country cites, if recently declining car use (‘peak car’) is indicative (Newman and Kenworthy, 2011; Puentes and Tomer, 2008). US vehicle miles travelled (VMT) reached a plateau in 2004, declining since mid-2007. Australian and New Zealand patterns are similar: VKT (vehicle kilometres) per capita have fallen in New Zealand since 2004 by 8% (Lyons et al., 2014). Key influences appear to have been fuel prices, the global financial crisis, population aging and a cultural shift linked to digital communications. Despite this change in pattern, in Auckland, with
its ongoing rapid population growth, the institutional feedback mechanism from changing practices to corrective investment in public and active transport has been weakened by central government reluctance to rethink a road-oriented transport policy model. A short-term consequence has been unnecessarily high levels of congestion and carbon emissions. Nevertheless, recently, Auckland Council has made the idea of a ‘quality compact city’ a defining feature of the direction in which it wishes Auckland to evolve (Auckland Council, 2011; Cameron, 2011), recognising the interaction with the quality of its transportation system, and its importance for health and climate change mitigation.

In short, more policy makers are now recognising the system characteristics of urban transport when considering transition paths and policies for long-term health and sustainability. Sound policies both anticipate and recognise evolutionary changes, and work with the grain of system interactions. Active travel measures, for example, will be more cost-effective in reducing carbon emissions if combined with complementary public transport investment or ‘smart growth’ initiatives such as encouraging location-efficient school siting (Barias et al., 2005; WHO, 2011; Wright and Fulton, 2005).

3.2 Urban evolution towards zero carbon transport

Over the next few decades, urban transport systems need to contribute to an economy-wide transition to zero net carbon emissions (Foxon, 2011; Rogelj et al., 2015). Transport, land use and energy systems are tightly interlinked at the city level, with significant policy implications. Urban transport has long been dependent on imported oil supplies: oil is currently the source of around 95% of transportation energy (Urry, 2010). But as services have become the dominant sector in most industrialised countries, industry’s energy needs have shrunk, and transport systems have absorbed a greater share of the economy’s energy, and produced a larger share of carbon emissions. Globally, transport accounts for more than a fifth (7.3 billion tonnes) of energy related CO₂ emissions (IEA, 2015). Despite climate stability fears, it has so far proved very difficult for industrialised economies to wean their
transport sectors off fossil fuels (Committee on Climate Change, 2009; Davis et al., 2007; EEA, 2011, p.56).

This partly reflects the close ties between transportation energy use and the embedded form of the built environment (Dantas et al., 2006) including the design of buildings (IPCC, 2007). Urban form does, however, evolve over time (National Research Council, 2009) particularly in the commercial building sector (Ewing et al., 2011). Improving the location efficiency of buildings is vital for a city’s long-term energy use and emissions: a US study reports that for an average office building built to modern energy codes, more than twice as much energy is used by commuting to the building than by the building itself (Wilson and Navaro, 2007). Another US study found that the central parts of urban areas where housing is high density use less domestic energy (home heating plus electricity), as housing design responds to density (Glaeser and Kahn, 2008). This reinforces the carbon advantage of these high density and mixed land use areas (Marshall, 2008).

Reducing urban carbon emissions, then, requires more activist land use planning: Wright and Fulton (2005), for example, argue that a strategy for developing country cities focused simply on low-carbon fuels would miss carbon savings and opportunities for cobenefits (such as congestion and accident reduction) that a broader strategy addressing urban design and public transport would provide.

In future, transport and energy technologies and policies will become more integrated, with the rise of both hybrid and fully battery-powered electric vehicles (EVs). Carbon savings will depend on the source of the electricity. Currently, around two-thirds of electricity globally is generated by fossil fuels (IEA, 2010), and the carbon footprint from manufacturing EVs is significant, so overall lifetime carbon savings from EVs may be substantially less than imagined by some (Low Carbon Vehicle Partnership, 2011). In a few countries with high proportions of renewable electricity generation (e.g. Iceland, New Zealand), the lifetime carbon savings from
EVs will be greater, especially if EVs are recharged off-peak, reducing requirements for power station peak capacity. These trends underline the evolving interplay between the energy and transport systems, local regulatory policies, user practices and business strategies.

EVs have the potential to substantially improve urban air quality and increase the capability of people with disability to function in cities. But their overall social and health implications are not entirely positive. Like other private motor vehicles, EVs facilitate sedentary habits. Their adoption could also increase the number of injuries involving vehicles; and their widespread use could validate political pressure to expand the roading system with the effect of increasing severance and congestion, and damaging the urban fabric. EV availability might be used to justify inaction on urban sprawl (Marshall, 2008). More positively, EV uptake could, especially if combined with car sharing, provide a modest addition to the emission savings achieved by reducing sprawl.

4 Cities as transformable systems

At a time of increasingly clear signals about the risks of unmanageable levels of global warming, urban policy makers face a critical choice as to whether they passively undergo disruptive change or take a proactive approach to transform interconnected transport, land use and other urban systems to reduce carbon emissions while improving health and well-being.

Because transport and land use investments so strongly shape urban ‘direction’ they are vigorously contested at multiple political levels. Change often presents some communities with prospects of real disadvantage while others with advantage. The path-dependent nature of urban development means such points of inflection are vital: from a policy viewpoint, it is important that the systemic implications of policy choices at such moments are considered and openly debated. Policy and investment can act to preserve an unsustainable status quo, or steer transport systems towards greater resilience. Urban modelling can provide insights
into the likely outcomes of infrastructure investments, but – given the numerous simplifications and assumptions involved in modelling – it is wise to remember the limitations of modelling complex urban systems (Zhao et al., 2013).

Cities resemble other evolving social-ecological systems in either undergoing planned change or eventually facing unplanned transformative disruption (Walker et al., 2004). External stresses in the form of energy price shocks particularly affected low-density US cities in 2006-7, leading to a sudden collapse of housing prices in suburban areas as petrol prices rose sharply (Cortright, 2008). Many sprawling cities are now having to anticipate a rising carbon price, which will require a difficult transformation of transport and land use (Dodson and Sipe, 2008).

Policy change that is integrated, planned and consistent, such as integrated spatial planning with a long-term perspective, is the ‘holy grail’—elusive but vital for urban resilience (Grazi and van den Bergh, 2008; Sovacool and Brown, 2010; Williams, 2010, p.130). For example, while changes in walking and cycling mode shares tend to be slow, they can occur with coordinated governance and the patience to see through a sustained transition. In London, the allocation of much of the 2003 cordon toll revenue to bus system improvement reinforced investment in walking and cycling. Public transport by 2008 accounted for 90 per cent of travel into Central London during the morning peak, and cycling numbers approximately doubled between 2000 and 2008 (Transport for London, 2010 p.273). Reducing traffic congestion with measures such as pricing may be unpopular and relies on highly sophisticated institutions (Glaeser, 2011a). However, the gains achievable from reduced congestion are important for productivity, as well as cutting emissions, and productivity may be further enhanced by the cobenefits for health from the shift to active travel.

A transformation of urban transport systems also relies on some preconditions around land use governance which do not apply everywhere. Land use planning in northern Europe is regionally coordinated and generally restricts low-density, car-
oriented sprawl (Schmidt and Buehler, 2007), and transit-oriented development is assisted by public institutions having powers to aggregate and develop land. But in many other cities, regional coordination is limited and constraints on low-density suburban development are weak. For example, in New Zealand cities, where ‘resource management’ legislation remains permissive rather than strategic, and where there is significant support for continued urban expansion (Rudman, 2011), there is limited capability to resist suburban shopping developments that dilute the role of city centres as the main specialised retail hubs, and metropolitan urban limits on sprawl are being eroded (Arbury, 2005; Witten et al., 2011; Zhao et al., 2011). Without regional governance with strong powers for strategic land use management, some metropolitan areas may continue to sprawl, creating high infrastructure costs (Floater et al., 2014), loss of high quality soils and biodiversity, tensions with the need for climate change mitigation, and worsening population health problems.

Recognising the interactions among urban systems requires challenging conventional assumptions and considering more nuanced and integrated approaches. The myth that urban expansion provides cheap housing has been shown to be particularly empty when the full social costs of car mobility are considered. And other conventionally prominent relationships (such as the growth of VKT with income) have started to shift, in line with a coevolutionary systems view of cities, taking into account changes in technology and social practices.

However a comprehensively integrated systems view of cities is difficult to enact in policy. European cities show the importance of linking together diverse measures, from promotion of compact, mixed-use development to higher vehicle and petrol taxes which raise the cost of car ownership and use, thus promoting active modes. Complementary policies include car parking constraints, and comprehensive traffic calming (including road diets and lower speed limits), which ‘reduce the overall convenience and attractiveness of car use’ (Pucher et al., 2010). A similar conclusion about recognising system synergies is reached by Calthorpe in
the US context, examining the conditions for sustainable, carbon-reducing urban change. He argues for combining smart land use policies with ‘conservation’, and a range of new technologies, externality pricing, and major public investments (Calthorpe, 2011 p.106).

Integration offers major governance challenges, as organisations and agencies with diverse interests have to be persuaded of the merits of linked policies. For example, implementing a zero carbon city agenda would require the cooperation of finance, transportation, land use planning, and other departments within one city council. Integration can be especially challenging when it also requires aligning public and private interests – as, for example, in rethinking city transport systems. In such situations, evolutionary policy learning may help, through encouraging diverse innovations, and learning what measures work via policy experiments that reflect on systemic behaviour (Chapman, 2004).

5 Conclusions

This paper has argued that adopting a framework that views the city as a complex system that coevolves with changing institutions, technologies, infrastructure and natural systems, can generate important insights for urban health and sustainability. A systems framework underlines interconnections and co-benefits, providing a basis for more integrated approaches to urban policy making and planning. While there are increasing calls for sound urban management for economically productive and sustainable city growth (Floater et al., 2014), going further, to a better understanding of the connected long-term challenges of urban governance, requires a coevolutionary systems view.

Further analysis and case studies of urban systems are important in order to build knowledge of how these systems interact and coevolve in a variety of cities. For example, we need better understanding of how urban transport and land use
can interact in limiting sprawl by creating a virtuous circle of well-designed intensification, more efficient transport, lower carbon emissions and higher quality of life (Crawford and French, 2008; International Council for Science; Regional Office for Asia and the Pacific, 2011; Proust et al., 2012; Rode et al., 2014).

Our second conclusion, about policy, follows from the first: each time an urban policy proposal is put forward, it should be appraised in terms of critical interrelated outcomes – health and well-being outcomes, and climate change mitigation in particular. These are critical aspects of resilience and sustainability, and studying how policy can influence them is vital. Because of the political complexity of shaping integrated urban policy, there is also a strong need for horizontal alliance building, with an emphasis on thoughtfully appraising the cobenefits of policies during policy formulation, and evaluating long-term interactions with underlying evolutionary drivers of urban systems.

Questions arise as to whether the policy and planning institutions in many countries are able to cope with and ‘manage’ the complexity of urban systems with appropriately integrated policies, especially where local government receives minimal fiscal and political support from central government (Bulkeley and Kern, 2006). Hull’s study of UK local authorities and vertical links to central government, analysing impediments to joined-up planning for transport and land use sustainability, concluded that strategic sustainability issues can ‘fall through the “cracks”’ (Hull, 2008 p.101). Despite this risk, cities have in many instances developed governance capacity over time to be strategic and address important adverse side-effects such as congestion, noise and air pollution. Strong public institutions, in dialogue with a well-educated urban constituency, can articulate the case for governance in the wider, longer-term public interest, resisting narrow sectional interests. For example, urban property development is typically carefully regulated in the developed world – in terms of design of public spaces, building height, shading, view-shafts, and even architectural form – in the public interest (Brook, 2013). Better integrated cities evolve in this way and it is evident that these
constraints yield benefit over time, as the merits and competitive advantages of compact, coherent and aesthetic urban centres become clear.

Our final conclusion relates to timing. If critical environmental issues such as climate change are to be addressed effectively within the next decade or two, it is essential that cities not wait for detailed and complete assessment of urban policies before adopting far-reaching policies for sustainability. The speed with which climate change is now becoming manifest indicates that this evolving driver of city form and function will have to receive dramatically increased attention in future, not only in terms of adaptation but also in terms of reducing emissions fast enough to avoid unmanageable climate change later this century. All cities have an obligation to contribute to mitigating climate change, and effective action requires escaping conventional thinking (Anderson and Bows, 2012), and boldly taking opportunities (Rutland and Aylett, 2008). Growing cities can learn from the maladaptive paths taken by others, and avoid over-investing in carbon-intensive, car-oriented transport and land use configurations. The potentially transformative paths taken by cities such as Copenhagen, Curitiba, Portland and Wellington (Gössling and Choi, 2015; The Economist Intelligence Unit, 2013) offer hope that this pressing issue can be addressed in a way that also promotes the health and well-being of citizens.

In short, urban system governance can be seen as an opportunity to plan, design, develop and transform cities and towns in ways that realise a mix of outcomes, but especially health, well-being and climate change mitigation. Immediate needs must be considered, but policies also need to anticipate the longer-term coevolution of urban systems. It is desirable that governance actors – such as transport and spatial planning agencies – make use of systems thinking to develop a more integrated view of outcomes, and understand the dynamic interactions between urban systems as they attempt to advance those outcomes. Better urban governance is a huge global challenge, but reflection on system
interactions and behaviour has the potential to contribute significantly to improved outcomes.

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Acknowledgements

Funding from the Ministry of Business, Innovation and Employment through the Resilient Urban Futures programme grant to the New Zealand Centre for Sustainable Cities is acknowledged.