Urban Resilience Thinking

for Municipalities

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Foreword
The “Grand Challenge”

This document was prepared as a contribution to the Department of Science and Technology’s (DST’s) Grand Challenge on Global Change and as a complement to flagship initiatives such as the *South African Risk and Vulnerability Atlas* project (Archer, et al., 2010). The Global Change Grand Challenge is aimed at “supporting knowledge generation and technological innovation that will enable South Africa, Africa, and the world, to respond to global environmental change, including climate change” (Archer, et al., 2010, p. ii).

While the Grand Challenge highlights the importance of science in supporting South Africa’s response to global change, it extends beyond a purely biophysical focus to acknowledge the importance of the social sciences. There is a clear understanding that the most compelling responses to global change will come through the combined efforts of the natural and social sciences. The DST therefore supports a number of research programmes across South Africa that draw on a wide range of scientific and academic fields in responding to specific challenges of global change across rural and urban –South Africa.

One of the key thematic areas supported through the Grand Challenge is “urban resilience”. This is not at the expense of work on rural areas, as there are also a number of research programmes targeting rural South Africa, but it is recognition of both the *threats* posed by poorly managed urban areas and of the *opportunities* that towns and cities offer for greater resilience and sustainability.

The programmes include “Think Tank on Resilient Urban Systems in Transition”[1] at the University of Pretoria (UP) and “Resilient Cities: Towards a Green Growth Path”[2] at the Human Sciences Research Council (HSRC).

The three-year funded programme at the University of the Witwatersrand (Wits) was titled “Urban Resilience Assessment for Sustainable Urban Development” and was developed with the specific intention of giving support to local government in South Africa. This was done with the recognition that municipalities have a potentially vital role in proactively managing processes of change.

The programme is a partnership between Wits and the Gauteng City–Region Observatory (GCRO).[3] It is also trans-disciplinary, with a working group that includes researchers in a number of fields including urban planning, architecture, law and environmental science.[4] Research in the programme is divided into five major thrusts, being:

1. Resilience and urban governance
2. Resilience in urban form and fabric
3. Resilience in urban infrastructures
4. Resilience of natural assets and ecological systems
5. Green economies for resilience

In its work, the programme has established an active partnership with the City of Johannesburg, and collaborates with the West Rand District Municipality. Through the GCRO the programme is also linked to the work of Gauteng Province. The research programmes in other universities and research institutes have established similar relationships with their respective municipalities and provincial governments.

The programme has benefitted significantly from its evolving partnership with the Agence Française de Développement (the French Agency for Development - AFD) and the Institute for Urban Morphology and Complex Systems in Paris. Municipal officials and academics from France have engaged closely with counterparts in South Africa, allowing for a constructive transfer of ideas. These collaborations will expand into the next phase of the research.

NOTES

1 http://trustsa.weebly.com/

2 Resilient Cities: Towards a Green Growth Path
http://www.hsrc.ac.za/en/media-briefs/economic-performance-and-development/building-a-new-green-growth-path

3 The GCRO is itself a formal partnership between government (Gauteng Province and municipalities) and universities (Wits and the University of Johannesburg).

4 The Working Group includes Professor Philip Harrison (Lead Investigator), Dylan Weakley (Programme Co-ordinator), Professor Alison Todes, Professor Daniel Irurah, Professor Tracy-Lynne Humby, Graeme Gotz (Research Director at the GCRO), Christina Culwick, Kerry Bobbins and Dr Costanza La Mantia. Doctoral and Masters students have also contributed to the programme and their work is acknowledged through the report.

Introduction

Urban resilience is the "new kid on the block". Over the past few years the concept has rapidly gained a central place in spatial and urban planning policy in South Africa.[1] The *State of South Africa's Cities Report, 2011,* prepared by the South African Cities Network (SACN, 2011a), for example, was written under the broad theme of resilient cities, while the SACN's (2011b) *State of Cities Finance Report, 2011,* applied ideas of resilience to the financial fortunes of cities.[2]

The City of Johannesburg (2011) made urban resilience one of the key themes in its new Growth and Development Strategy, *Jo'burg 2040*. It refers to social resilience, environmental resilience, economic resilience and more. EThekwini municipality successfully bid to the Rockefeller Foundation for recognition of Durban as one of an initial 33 participants world-wide in a resilient cities programme.[3] The City of Cape Town uses ideas of urban resilience in a number of policies and plans including, for example, the *Low Carbon Central City Strategy,*[4] while both *Tshwane 2055* (City of Tshwane, 2013) and *Ekurhuleni 2025* (City of Ekuruleni, 2013) make clear reference to resilience. The concept is also used in the strategies and plans of a growing number of South Africa's smaller municipalities, including in their Integrated Development Plans.[5]

The idea of resilience arguably adds a new and compelling dimension to policy and planning, but there is also a danger that, as its use multiplies, it will become an increasingly fuzzy, catch-all term that we pay homage to as a form of lip-service. The specific purpose of this document is to assist municipalities in South Africa in applying ideas of urban resilience in a thoughtful, intelligent and critical, way. It is not designed as a "manual" or "tool box", but rather as a tool to promote urban resilience thinking.

Working definitions

It may be useful to begin with some form of working definition, although it is important to remember that there is no single "truth" about urban resilience. Definitions are created, and change over time, reflecting evolving understanding or shifting orientation.

The *City Resilience Framework*, prepared by The Rockefeller Foundation and ARUP for city governments, offers a straightforward definition:

> City resilience describes the capacity of cities to function so that people living and working in cities – especially the poor and vulnerable – survive and thrive no matter what shocks and stresses they encounter (Rockerfeller Foundation & ARUP, 2014, p. 3)

Tshwane Metropolitan Municipality offers an even simpler definition in their long-term strategy, which refers to a resilient city as one "that can withstand shocks, roll with the punches, and come out stronger" (City of Tshwane, 2013, p. 1).

It may be helpful to start with these clear, uncomplicated definitions. As we move through this document and develop our understanding of resilience theory, we may wish to add a little more complexity. There are many scholars from the academy who have offered definitions, with less or more value for urban practitioners such as municipal officials who confront the intricacies of applying ideas within real-life contexts. We have combined two of these attempts to produce the definition below:

> Resilience refers to the capability of individuals, social groups, or social-ecological systems including towns and cities not only to live with changes, disturbances, adversities or disasters but also to adapt, innovate and transform into new more desirable configurations.[6]

Where does it come from?

One of the reasons why ideas of urban resilience may seem a little slippery is that they come from diverse sources. The various conceptual threads have become gradually entangled, but urban resilience is still used by different individuals with slightly varying meanings.

a resilient individual is able to withstand and adapt to stress and adversity

We know, for example, that psychologists have spoken of resilience for many years. They tell us that a resilient individual is able to withstand and adapt to stress and adversity, and has the coping skills to bounce back after or through a negative experience. Social psychologists have applied the idea of resilience to groups in society. In South Africa, for example, there is now a large literature on how youth in townships cope with their vulnerability to multiple threats including crime and violence, loss of employment and HIV/AIDS. The *Pathways to Resilience Project,*[7] for example, actively assists South Africa's youth in dealing with, and overcoming, adversity. South Africa's Good Governance Learning Network (GGLN), an alliance of agencies in civil society, has applied ideas of resilience to communities in a key publication, *Community Resilience and Vulnerability in South Africa* (GGLN, 2014).

Economists have written of the resilience of national and regional economies. They explore why some territories bounce back from shocks and others do not. Literature on urban economic resilience emerged from the 1970s as cities in the North and Europe lost their industries to newly developing manufacturing economies in East Asia. The 2007–2008 financial crisis has stirred new interest in ideas of economic resilience. The Brookings Institution and the London School of Economics (LSE) (2010), for example, published a report in 2010 which reveals major differences between cities across the world in the bounce-back from this global shock. One of the initiatives of the Obama administration in the United States (US), for example, was to set up an Office for Economic Resilience which has as its goal "[helping] communities and regions build diverse, prosperous, resilient economies by enhancing quality of place; advancing effective job creation strategies; reducing housing, transportation, and energy consumption costs; promoting clean energy solutions; and creating economic opportunities for all" (U.S. HUD, 2014, p. 1).

Much of the literature on urban resilience, however, arises from a concern with environmental risk and vulnerability. There is a vast literature on this subject. At first this literature focused almost exclusively on natural disasters such as earthquakes, floods and health epidemics. Gradually it expanded to incorporate social vulnerability into the concept of disaster, and to include incremental disasters such as climate change (UNISDR, 2013). The growing literature on disaster, risk and vulnerability also incorporates the concept of resilience. The most authoritative body in the field, the Intergovernmental

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Panel on Climate Change (IPCC), has drawn widely on the notion of resilience. The Fifth Report of the Panel released in 2014 provides a framework of "climate-resilient pathways" (see the Box at the end of the section).[8]

There is now a large literature on climate change resilience, and also specifically on urban climate change resilience. There are also many programmes internationally that offer support to national and sub-national governments, including municipalities, in building climate change resilience. In 2010, Local Governments for Sustainability (ICLEI) launched the *Annual Global Forum on Urban Resilience and Adaptation,*[9] to be hosted each year in Bonn, Germany. The forum connects local government leaders with experts in the field in an on-going discussion on adaptation to climate change. In 2013, the Rockefeller Foundation, for example, launched a *Resilient Cities Initiative*[10] with a focus on climate change, to give support to 100 city governments as they develop strategies for climate resilience.

While ideas of urban resilience have evolved fitfully, there have been attempts to give urban resilience a coherent theoretical framing. The most influential attempt by far is the work of the Canadian ecologist, C.S. Holling (1973). He brought together ecology and systems theory in developing the concept of resilience within socio-ecological systems. Ecologists had long shown how natural species persist by adapting to, maintaining, modifying or changing their habitats. Ecologists have also shown that species do not exist in isolation but are interconnected within structured hierarchies[11] known as "panarchies" (explained further in the following chapter). There is a constant state of change, with small changes at any one scale reverberating with changes across a panarchy. Systems theory, which had been applied widely to fields including cybernetics and engineering, was also about self-regulation and adaptation through correcting feedbacks.

Beginning in the early 1970s, Holling (1973) argued that the ability of an ecological system to self-regulate or adapt depended on its underlying resilience. In later work he related the behaviour of ecological systems to socio-natural systems such as cities (Holling, Gunderson, & Peterson, 2001). In

the process he elaborated key concepts such as “adaptive management” and the “adaptive cycle”, as well as the use of “panarchy” to explain the complex interrelationships within human-dominated systems that cross geographic scales. Holling’s theory of resilience shows how multiple, complex systems, both natural and human-created, are tied together in cycles of growth, adaptation and restructuring.

The work of C.S. Holling remains the touchstone for much of the theorising around urban resilience, including in the work of the influential Stockholm Resilience Centre in Sweden.[12] It has also strongly influenced thinking on resilience in South Africa, and will be explored in more detail in the next section of the report.

South African connections

In South Africa, ideas of urban resilience have been taken up in various ways. As already shown, they are now widely used in policy documents and plans. This use is influenced by scholarly writing in South Africa.

There have been significant recent contributions on resilience from the South African academy. Professor Mark Swilling and colleagues at the Sustainability Institute at the University of Stellenbosch, for example, have written extensively on urban sustainability, referring also to resilience challenges.[13] Professor Ivan Turok and his colleagues at the HSRC have written widely on the resilience of South Africa’s cities, linking ideas of economic resilience with ideas of socio-ecological resilience.[14] Professor Chrisna du Plessis and her colleagues at the University of Pretoria have applied ideas of complex, adaptive socio-ecological systems to urban study in South Africa, offering an “ecological worldview” for exploring change.[15] Debra Roberts from eThekwini municipality has published widely on climate change resilience,[16] while the African for Centre Cities (ACC) at the University of Cape Town has collaborated with the Climate and Development Knowledge Network (CDKN) in India on a report on climate resilience in Africa[17].

There is other work and there will be more, providing an increasingly rich resource of local material on which to draw.

Thinking intelligently, thinking critically

We must remember that there is no single “truth” about urban resilience. It would be unfortunate if urban resilience became a new orthodoxy, displacing other helpful and important concepts. We believe that the idea of urban resilience is a very useful way of thinking about the ability of cities, and the many actors and structures that make up cities, to respond to the ever-present reality of change. It adds a further dimension, for example, to the weighty concept of “urban sustainability”, but in itself resilience can only address a limited spectrum of what we must think about in relation to our urban environment.

We have purposefully avoided calling this work a “manual” or a “tool box” or something similar. If the concept of urban resilience were reduced to a checklist, for example, then it would surely lose one of its main messages – that case-specific and changing approaches are needed in response to the different ways in which urban environments change. Urban resilience must provoke thoughtful responses and actions from municipalities, responses that relate to the specific circumstances of each municipality.

Applying the idea of resilience to “cities” in particular, or “urban” areas more generally, can be tricky. A city is a very complex agglomeration of things, material and intangible. We need to think carefully and critically about what we mean by resilience in relation to this. When we talk of urban resilience, for example, we need to clarify whether we are talking about the resilience of the whole agglomeration of things, or about the resilience of some component of this agglomeration such as the natural environment, or the resilience of the people who inhabit the cities.

In the following section of the report, we address some of these conceptual issues. At this stage it is useful to understand the distinction between "resilience *in* cities" and "resilience *of* cities" (Ernstson, et al., 2010). If we are concerned about the resilience of individuals or social groups within the city, we are concerned about resilience *in* cities. If, however, we are concerned with the growth and longevity of cities *per se,* we are concerned with the resilience *of* cities. There is a relationship between the two concepts but they are not the same.

Psychologists and social psychologists have provided a strong indication of what makes individuals and groups of individuals resilient. Urban theorists are gradually coming to understand what might make the agglomerations we call towns or cities resilient. Urban areas survive and develop through multiple processes including economic exchange, human migration, the functioning of natural systems, and the flow of resources such as energy and water through infrastructure networks.

Most cities in the world are fairly resilient. That is why they have evolved from being small settlements to large agglomerations. However, cities have varying degrees of resilience. They recover at different rates from calamities including natural disasters or economic shocks, and adapt more or less successfully to incremental shifts such as climate change. It is important to understand what accounts for these differences in resilience between places, and how we might advance the resilience of any particular place.

Resilience theory does offer some valuable insights as it explores ways to respond better to change. However, we must understand also that there are criticisms of resilience theory. These do not necessarily detract from the value of the theory, but do require us to apply resilience theory with care. These criticisms are referred to in more detail in the next section of the report.

Resilience theory does offer some valuable insights as it explores ways to respond better to change.

This report

In this report we offer municipalities and their officials a set of perspectives on urban resilience that are alert to the possibilities and limitations of resilience theory, and call on municipalities to use ideas of urban resilience in a considered, critical way.

Our specific concern in this report is to provoke municipalities to take up and apply ideas of urban resilience in an informed way. Our intention is to stimulate "resilience thinking" (Walker & Salt, 2006) rather than to offer a simple "guide for practice". Our focus is on the municipalities which have the responsibility of governing urban areas in South Africa, although there is much that could also be applied in rural contexts.

There are also other agents in government and civil society that could draw meaningfully from the discussion, but we have deliberately targeted municipal government, recognising the particular role that municipalities have in building resilience from the ground up. Our message to municipalities is that the task of building resilience requires them to build strong relationships across all scales of government, and across the created divides of government and civil society.

The work was prepared through partnerships with local and provincial government in Gauteng, and so draws mainly from casework from this context, and especially from Johannesburg. However, we offer it as a resource to all municipalities in South Africa, urging them always to apply ideas with careful consideration of their own contexts.

Resilience requires us to think in an integrated way rather than in terms of sectors or any particular scale of government. It is difficult to structure a report that holds this complexity but also applies to real-world issues. In the next section we present the theory of resilience. In later sections we structure the discussions around the themes of adaptive governance, resilient urban form, infrastructure for resilience, ecological resilience and green economies for resilience. Throughout the report we emphasise the connections between the themes.

Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

The IPCC is the international body tasked with the scientific assessment of climate change. It was set up in 1988 with the United Nations Environmental Programme (UNEP) as one of its key sponsors, and it continued to provide vital scientific support to governmental policy making and the negotiations under the United Nations Framework Convention on Climate Change (UNFCC).

The ICPCC assessment reports provide a high-level review of the state-of-knowledge around climate change. They involve the direct input of hundreds of top-level scientists from around the world, with comment and review by thousands of others. In short, the assessment reports are the most authoritative documents on the subject of global climate change.

The Fifth Assessment Report of the IPCC, approved on 1 November 2014, provides the latest update. The report deals primarily with "risk and the management of an uncertain future" (IPCC, 2014a, p. 3). It offers a considered assessment of the probability of hazardous events arising from climate change, and of the consequence of these events.

The report refers in some detail to observed changes such as the warming atmosphere and ocean, and sea-level rise. It relates this in large measure to anthropogenic (human) activities, and especially to greenhouse gas (GHG) emissions which are now at their highest levels in history. The report maintains that "it is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together" (IPCC, 2014a, p. 12).

The report indicates *high confidence* that hydrological systems are altering and that many natural species have shifted their geographic range, activities, and interactions with other species. There is also: *high confidence* that there has been an overall negative influence on crop yields; *medium confidence* that human mortality has increased because of the effects; *very high confidence* that extreme weather events are related to climate change; *high confidence* that extreme sea-levels have increased; and *high confidence* that direct and insured losses have increased substantially because of weather related events. There are some areas however where evidence is still uncertain and where levels of confidence remain low.

The report recognizes that there are differential risks between places. Although the natural effects of climate change may be shared, levels of vulnerability differ because of economic, institutional, social, cultural and other factors. Furthermore, climate change generally exacerbates other stressors, especially for people living in poverty.

The report acknowledges that through history people have coped with climate variability and that currently adaptation is becoming embedded in some planning processes. Attention is also being given to mitigation but this is inadequate as greenhouse gas emission levels continue to rise.

There has been significant recent advancement in the modelling of climate variability, and the broad consensus is now that global mean temperature increase by 2035 will be in the range of 0.3 °C to 0.7 °C. For most scenarios, by the end of the 21st Century temperature rises are *likely* to exceed 1.5 °C, with *medium confidence* that they will exceed 2 °C. Some regions, however, will warm considerably faster than this. The report provides

detailed projections for what this will mean for sea level, extreme weather events, and precipitation. The bottom line is that "climate change will amplify existing risks and create new risks for natural and human systems" (IPCC, 2014a, p. 24).

There is *high confidence* that extreme weather events and more systemic change will lead to: risk of severe ill-health and disrupted livelihoods; breakdown of infrastructure networks and critical services; food and water insecurity and loss of rural livelihoods and income; and, loss of ecosystems, biodiversity, and ecosystem goods, functions, and services. A large fraction of natural species face the risk of extinction during and beyond the 21st Century. There is at least *medium risk* that "from a poverty perspective, climate change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing poverty traps and create new ones, the latter particularly in urban areas and emerging hotspots of hunger" (IPCC, 2014a, p. 28). Other problems around which there is broad agreement on likelihood include: flooding, increased ill health, displacement of people, and increased social conflict.

There is a strong possibility that changes will be irreversible and that over the longer run, beyond the twenty-first century, the effects of climate change could be extreme including, for example, the near total loss of the ice cap and a seven metre rise is sea-level.

Urgent attention to mitigation remains critical. The report states that "limiting warming with a likely chance to less than 2 °C relative to pre-industrial levels would require substantial cuts in anthropogenic GHG emissions by mid [twenty first] century through large-scale changes in energy systems and possibly land use" (IPCC, 2014a, p. 39). The report also argues that adaptation measures may reduce the risks of climate change although the adaptation limits may be exceeded if we are unable to contain increase to the 2 °C.

Arguments around adaptation and building adaptive capacity bring the Fifth Assessment Report into close alignment with ideas of resilience. Resilience does feature strongly in the report, and specific guidance is provided on ways in which it may be strengthened. There are key interventions in technological, institutional and social systems that may support improved resilience or adaptive capacity, and municipalities are encouraged to engage in detail with these proposals (see, for example, Table 4.2 in the synthesis report). For municipalities there are implications in terms of the provision of infrastructure, early warning systems, maintaining wetlands and green space, managing risk areas such as flood plains, ecological restoration, information systems, regulations, financial incentives, and more.

Municipalities are referred to the Synthesis Report but also the reports of the three working groups and especially the report of Working Group III on Mitigation (IPCC, 2014b). Chapter 12 of this report deals with "Human Settlement, Infrastructure and Spatial Planning" but there are other chapters dealing with critical issues for municipalities such as transport, buildings and energy systems. These Chapters and wider reports provide an important resource for municipalities in addressing the risks of climate change by building adaptive capacity.

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NOTES

1 The profile of “urban resilience” in current thought is new but we must acknowledge earlier uses of the term in South Africa, including by Professor David Dewar et al. (1977)
2 See http://www.100resilientcities.org/cities/entry/durbans-resilience-challenge
3 http://www.capetownpartnership.co.za/wp-content/uploads/2014/02/Cape-Town-Low-Carbon-Central-City-Strategy-20140217.pdf
4 Municipalities which refer to resilience in their plans, especially, IDPs now include Matzikama, Stellenbosch, Newcastle, KwaDukuza and The Msunduzi.
5 This is a combination of definitions from Obrist, Pheiffer, & Henley (2010) and Folke (2006), presented in Weakley (2013, p. 49).
6 http://resilienceresearch.org/research/projects/pathways-to-resilience
7 http://mitigation2014.org/
8 http://resilient-cities.iclei.org/resilient-cities-hub-site/about-the-global-forum/
9 http://www.100resilientcities.org/
10 The hierarchy ranges through a vast spectrum of scales – genes, cells, tissues, organs, organisms, species, populations, communities, ecosystems, biomes, biosphere.
11 http://www.stockholmresilience.org/
12 See for example: (Swilling & Annecke, 2012), (Schaffler & Swilling, 2013),(Peter & Swilling, 2014)
13 See For example: (Turok, 2014)
14 For example: (Du Plessis, 2008),(Peres & Du Plessis, 2013)
15 For example: (Roberts, 2010)
16 For Example: (Taylor & Peter, 2014)

1 Resilience Thinking

1.1 Introduction

In an excellent book published in 2006, Brian Walker and David Salt introduce the term "resilience thinking" (Walker & Salt, 2006). They offer a way of understanding resilience as an approach or attitude rather than as a new doctrine or even as a new theory. Resilience thinking responds to the perpetual challenges of *complexity, uncertainty* and *change* in the environments in which we live and work.

For Walker and Salt, there are three key elements to resilience thinking. First, we must understand that we live in socio-ecological systems in which human life and nature are never separated. Second is an awareness that these systems are extremely complex. Third is a willingness to improve the adaptive capacities of such systems through collaborative, flexible and learning-based approaches.

Following from Walker and Salt, the most important lesson for municipalities is that they should deliberately and continually foster a way of thinking, and therefore of action, that supports proactive adaptation to change. This does not mean adaptation for its own sake, but adaptation that expands the ability of complex systems to deliver on agreed goals such as social equity, growth, job-producing economies and environmental sustainability.

If resilience thinking becomes a normal part of the way in which municipal government works, and if adaptation rather than bureaucratic rigidity becomes the behavioural norm, then municipalities will become agents of positive change rather than the inert structures they are often perceived to be.

The following section provides general guiding principles for making resilience thinking practical within municipalities. These principles are not intended to be prescriptive, but may assist in clarifying what resilience thinking involves in various contexts. They are mainly common sense and do not require a sophisticated theoretical background. In most respects they apply as much to individuals and households as they do to town or city governments. For example, a resilient municipality, like a resilient individual, has a strong learning capacity and is well connected to a variety of external support systems.

The idea of resilience thinking, together with a common-sense approach to building resilience, may be enough to incorporate resilience into the policies and operations of municipalities. However, municipal officials who are interested in developing a deeper understanding of resilience may wish to read about

theories of resilience. Section 1.3 therefore goes beyond an outline of guiding principles to briefly explain the theoretical work of scholars who have followed Crawford Stanley ("C.S") Holling, who popularised ideas of socio-ecological resilience in the 1970s.

1.2 Guiding Principles

A few simple principles are outlined below that could guide municipalities in building the resilience of governance systems, and of the physical and social environments for which they are responsible. All the principles converge on the overall aim of improving adaptive capacity in response to change which may be sudden and immediately disruptive, but which is more likely to be incremental with accumulating effects.

The Capacity to Learn

Nothing is more important for improving adaptive capacity than enhancing learning capacity. We do this by improving our abilities to acquire, absorb, retain and use knowledge. To improve learning capacity we need to:

- have the ability to identify and acquire the knowledge;
- promote a culture of experimentation that rewards innovation;
- collaborate in building knowledge through learning networks (with other municipalities and government agencies, universities and other research institutions, the private sector, non-governmental agencies, and more);
- promote a culture of information sharing with open access to information that facilitates communication and collaboration between entities;
- systematically increase the skills of employees by supporting multiple learning opportunities;
- create a culture which appreciates learning as a core value;
- develop the technologies that support learning capacity.

In short, municipalities need a culture of learning, a learning infrastructure and the skills to maximise learning opportunities. One of the constraints to achieving this is the bureaucratic mindset, which rewards stability and conformity more than learning and innovation. Officials are often hesitant to apply new knowledge in experimental ways, because mistakes may be made, and systems often punish such mistakes. The learning process involves trying, learning from doing, and trying again. Mistakes will be made, but these should be welcomed if they produce new learning which feeds back into the system. The concept of *safe failure* is important here. Some aspects of urban governance require extreme caution because failure due to experimentation will have dire consequences. However, there are many aspects of governance where incremental experimentation will lead to long-term improvement, even if there are slip-ups in the short term.

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Redundancy (or Spare/Duplicate Capacity)

The term "redundancy" is used in everyday speech to mean either an unnecessary repetition or the termination of employment when a job becomes unnecessary. In engineering, however, the term refers to the duplication of the critical components of a system to ensure greater reliability, especially in the case of malfunctions.

Redundancy in this latter sense may also be referred to as spare or duplicate capacity. As complex systems of governance are continually confronted with unpredictable change, pre-emptive planning – although desirable – is not always possible. There is a need to *respond* to change as and when it happens, which may require a rapid deployment of additional resources. In the banking sector, for example, there is an urgent need for the duplication of critical systems. The destruction of the World Trade Centre in New York on 11 September 2001 provides an excellent example of how redundant technologies and information storage allowed firms in the finance service sector headquartered in the World Trade Centre to survive what could have been a terminal crisis.

Municipalities, too, must allow for redundancy. For example, there must be flexibility in the human resources system, with staff having the skills to take on different jobs as needed. The overall institutional architecture must also enable redundancy. A centralised command structure is extremely vulnerable to failure, or even collapse, if there is a breakdown at the top. A more decentralised system, with a number of at least partially autonomous governance units at different scales, is far less vulnerable to sudden change, although it does require mechanisms for co-ordination.

Beyond governance, redundancy must be built into all aspects of the urban system. The economy requires redundancy. For example, it is very risky for a key sector of production to have only one supplier of a critical resource, or to be narrowly dependent on a market with only one or a few buyers. Infrastructure, too, requires redundancy. The need for redundancy in information technology (IT) infrastructure is the most obvious. Will the systems of a municipality survive, and data be secured, if there is fire or sabotage or some other major malfunction? Municipalities must work towards fully redundant IT and related systems.

We also need alternative pathways for energy supply, water supply, waste disposal and transport flows. A redundant power supply requires that alternative sources of supply and distribution be in place in the event of a drastic failure in any single system component, or even in the case of a minor interruption. An Uninterruptable Power Supply (UPS) is the objective of a number of cities internationally, and involves the introduction of technologies for the storage of power supply. Some cities internationally have now introduced redundancy into their planning for water supply. Redundant pipe connections and strategically placed valves allow for temporary connections that bypass areas of damage, with water storage also helping to deal with temporary losses (Arup, RPA & Siemens, 2013). Transport infrastructure can also be built with redundancy in mind. A neighbourhood which is connected to the wider city by only one access point may be isolated if that road is blocked through accident, flooding or civil unrest. Developing a variety of transport options also improves redundancy. If the rail network does not work, for example, redundancy will provide other options for commuters.

We also need alternative pathways for energy supply, water supply, waste disposal and transport flows.

Diversity

Diversity is related to the idea of redundancy but is worth highlighting as a principle in its own right, as resilience requires a good measure of both. While redundancy involves having several components which are able to perform the same function, diversity is about a variety of components performing different functions, or performing the same functions differently. In general, the more diverse a system is, the less the risk, and the greater the opportunity for new lines of growth and development.

Diversity has many dimensions. Resilience theory had its initial roots in the science of ecology. Ecologists have argued that “response diversity” is critical for ecosystem renewal (Elmqvist, et al., 2003). By this they mean that the greater the variation of responses to change among species of a particular community, the greater the chance of successful adaptation and survival. Some writers, including Paul Leslie and J. Terrence McCabe (2013), have made the connection between ecology and social-ecological systems (SES’s) such as cities. They argue that these systems would be extremely vulnerable if all actors responded the same way to challenges, opportunities and risks. What makes

for resilience is "heterogeneity in human decision and action" (Leslie & McCabe, 2013, p. 114). They go on to say that:

> The range, prevalence and spatial and temporal distributions of different responses may be crucial to the resilience or transformation of a social-ecological system, and thus have a bearing on human vulnerability and well-being in the face of environmental, socio-economic and political change (Leslie & McCabe, 2013, p. 114).

It does not require theory of this sort to understand that within human society, diversity allows for multiple ways of thinking and doing, spreads the risk, and increases the chance of finding successful adaptations to change. Social diversity does not ensure greater resilience on its own, but the creative use of diversity for adaptation surely does. In some societies, diversity is feared and suppressed, but successful societies (and successful cities) are generally those where diversity is embraced and actively harnessed for the good of all.

… diversity allows for multiple ways of thinking and doing, spreads the risk, and increases the chance of finding successful adaptations to change.

Resilience also requires diversity in the economy. For a business, resilience through diversity may mean having multiple sources of competitive advantage and different markets, so that it can survive the collapse of any one market. For an economy as a whole, resilience may mean having a diversity of firms and sectors rather than dependence on a single one. Whether national, regional or local, an economy may grow rapidly on the back of a single industry or sector, but unless it diversifies and broadens its base it will remain at high risk. Most area-based mining economies, for example, have gone through boom and bust cycles, but a few of them – including the City of Johannesburg – have used mining as the initial stimulus but have gone on to diversify and achieve long-term sustainable growth. The same applies to economies based on a manufacturing industry such as iron and steel, or on a segment of agriculture.

Self-Sufficiency and Connectedness

One of the "productive tensions" in resilience thinking is the need to increase both self-sufficiency *and* connectedness. A good way to understand this is through an analogy with personal resilience. A resilient individual has a degree of emotional and material self-sufficiency, but also has a network of relationships with family, friends and colleagues to assist when life becomes tough or when tragedy strikes. Resilience is not achieved through being either socially isolated or overly dependent.

A municipality must also have both an element of self-sufficiency and strong connectedness. Simonsen et al. (2014, p. 6) write that "well-connected systems can overcome and recover from disturbances more quickly, but overly connected systems may lead to the rapid spread of disturbances across the entire system so that all components of the system are impacted". The balance must be managed in relation to all elements of urban functioning, including governance, the economy, spatial arrangements and infrastructure.

In terms of governance, a municipality should not be overly influenced by another sphere of government, or by any other agency, including large corporations. Its primary line of accountability should be to its electorate. South Africa's Constitution does in fact provide for a degree of autonomy for municipalities, although in practice this is less clear-cut. The internal arrangements of a municipality are also important. A level of decentralisation to different units and sub-units – also known as *modularity* – reduces risk within the system and prevents negative change from flowing too quickly from one component to another.

At the same time, however, a municipality requires strong supportive relationships with other spheres of government, with neighbouring municipalities, and with agencies in civil society and the private sector. The reality is that local development requires integrated action across institutional boundaries, and municipalities on their own cannot fulfil all the adaptation requirements in a complex and changing world. Internally, mechanisms are required to ensure integrated planning, operational co-ordination

and mutual assistance across the units and sub-units of municipal government. As we will show, resilience theory clearly points towards the importance of co-ordinated action across the scales of government.

A further aspect of governance is the flow of ideas and of innovation. Municipalities must support local innovation, but most also participate in extended learning networks that may extend globally.

A level of self-sufficiency in the economy does reduce risk, but there is also strong historical evidence that economic isolation, or autarky, leads to eventual stagnation and decline. The most successful national, regional and local economies are those which are open to global trade, investment and human migration, and are continually energised by external interactions. The precise balance between economic openness and self-sufficiency at local level must be debated in context. Not all municipalities, for example, can serve as a global gateway, with many municipalities better placed to perform a role within local, regional or national economies. Whether the connections are local or global, investment in transport infrastructure plays a major role in enhancing connectedness.

Towns and cities need to reduce external dependencies by optimising their use of resources within systems and networks of infrastructure. Efforts towards water conservation, energy efficiency, local energy production, waste recycling and urban agriculture are essential to improving resilience. The reality, of course, is that large urban areas can never be fully self-sufficient, and the challenge is to manage resource dependencies in a way that reduces risk. Food security is a good example. Food security will be achieved when all residents have access to secure supplies of affordable, nutritious food. Absolute self-sufficiency may be impossible, and perhaps not even desirable, as local production of certain foods is not always economically feasible or the most sensible use of available land. However, there is a strong argument to *optimise self-reliance* by improving local production (within and around urban areas), and wherever possible to reduce the length of food supply chains to lessen vulnerability to supply disruptions.

Efforts towards water conservation, energy efficiency, local energy production, waste recycling and urban agriculture are essential to improving resilience.

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Energy supply is another example of how resilience can be achieved. With their massive demands for power, it is extremely unlikely that large cities will become self-sufficient in electricity and fuel. However, there are ways to lessen vulnerability. Significant progress has been made by a number of cities in improving efficiencies in the use of energy through interventions in the transport, building and industrial sectors. Some cities are also making progress towards local energy production by using every possible opportunity to harness local, renewable sources of energy. Some cities are also starting to produce their own low-carbon or zero-carbon fuels.

The overall lesson is that resilience comes from local knowledge, skills and action, and from a degree of *modularity* that prevents negative change from flowing too quickly from one component of a system to another. However, it also comes from connections with external agents that allow for innovation, collaboration, mutual learning and assistance.

1.3 Digging Deeper: Learning from Theory

The ideas and principles outlined above are supported by a theory of socio-ecological resilience. While it is not necessary to grasp the theory to use the ideas of resilience in a practical, common-sense way, a theoretical understanding will add depth and value to the ways in which municipalities use the term in their policies and plans.

Before outlining the key theoretical idea of towns and cities as "complex, adaptive socio-ecological systems", we will attempt to clarify the use of resilience as a concept in development thought.

Some Common Questions

Among the possible questions you may ask are:

- What is the difference between "sustainability" and "resilience"?
- Does resilience mean "bouncing back" after the disruption caused by change, and adjusting to a "new state of being"?
- Is resilience always positive?

The Relationship between Sustainability and Resilience

Since the 1970s, the idea of "sustainable development" has been widely used globally in development thinking and policy. In some ways, it has become a mantra for development policy. The most famous definition of sustainability was provided by the United Nations World Commission on Environment and Development (the so-called Brundtland Commission) in its 1987 report *Our Common Future.* It was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 39). A key contribution of the idea of sustainability is that our economy and society exist within the limited spaces and resources of the natural environment. The notion of sustainability also brings an understanding that the needs of present and future generations cannot be ensured unless a productive balance is achieved between economic, social and environmental objectives (see Figures 1.1 and 1.2).

While theories of resilience go back to the 1970s, their popularity in policy and planning circles is more recent. A common misunderstanding is that resilience replaces the idea of sustainability, or that resilience and sustainability are essentially the same.

It is true that sustainability and resilience are conceptually linked, but they are not equivalent in meaning. There is no reason why they cannot co-exist as concepts, however. One way of understanding the relationship between the two terms is to consider sustainability as an essential *goal* for development, and resilience as a way of thinking and acting that would lead us towards achieving sustainability. Walker and Salt (2006, p. 37) write that "resilience is the key to sustainability". A system

is sustainable, even in the face of unpredictable change, when it has achieved a high level of resilience or adaptive capacity.

Bouncing Back or a New State of Being?

The question could be rephrased in this way: Does resilience mean the ability to change or the ability to stay the same? There is some difference of opinion in the scholarly literature on this matter.

FIGURE 1.1: Nested Sustainability[2]

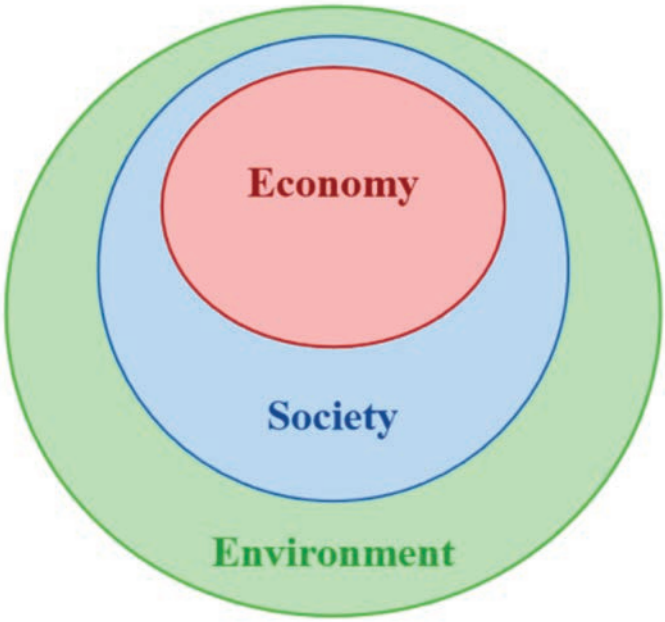
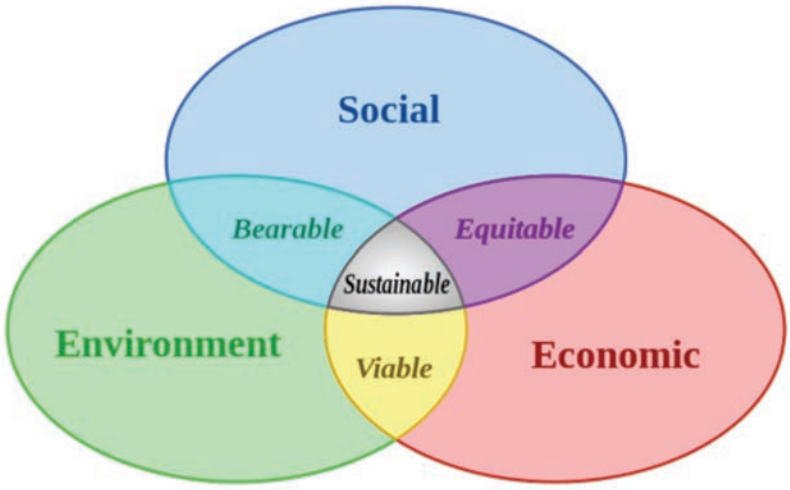


FIGURE 1.2: The Spheres of Sustainable Development[3]

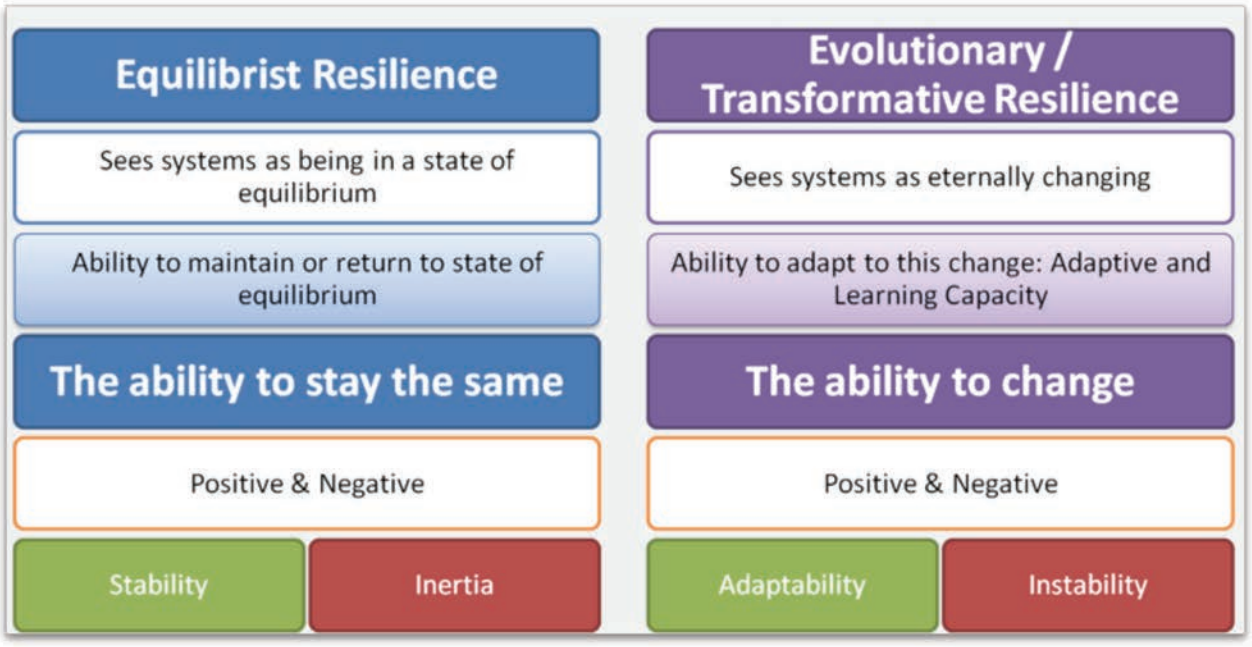


There are theorists who have emphasised what we may call “equilibrist resilience” (Simmie & Martin, 2010). They believe that systems are in a state of stable balance or equilibrium, and that when they are disturbed they must find a new equilibrium. In some cases, the system may return to the pre-existing equilibrium, but in other cases it may evolve into a new state of equilibrium. From this point of view, the resilience of a system depends on the speed with which it restores equilibrium, or the ability to resist being knocked off its state of equilibrium in the first place.

The challenge for complex systems such as cities is that change is constant and so a state of steady equilibrium is hardly attainable. Some theorists respond to this reality by referring to multiple points of possible equilibrium (Holling, 1973). Increasingly, however, there is recognition that, because of the constancy of change, systems never achieve a point of stability but are always adapting. With this understanding, resilience means the capacity for continual adaptation to never-ending disturbance. There is no complete or end-state to the adaptive process, not even for a short period of time. This understanding is referred to as “evolutionary resilience” and sometimes as “transformative resilience” (Gotham & Campanella, 2010; Holling, Gunderson, & Ludwig, 2001).

Figure 1.4 compares “equilibrist resilience” with “evolutionary/transformative resilience”. While it is clear that ideas of equilibrist resilience are inadequate for explaining change in complex systems, they should not be entirely rejected. There are sub-systems that may require a state of equilibrium to function (for example, an infrastructure network), and human life requires a degree of stability in some areas at the same time as there is constancy of change in others. While change is constant and often positive if properly embraced, too much change (for example, continual institutional restructuring) may lead to damaging instability. Figure 1.3 thus suggests that there are positive and negative aspects in relation to both equilibrist and evolutionary/transformative resilience, and that desired resilience may be subtle combination of the two.

FIGURE 1.3: Equilibrist and Evolutionary Resilience (Weakley, 2013, p. 54)



Is resilience always positive?

The term resilience is generally used in a positive sense as a desired state of adaptive capability. We must add a cautionary note, however, as there are times when system resilience may be negative.

As Heider et al. (2014, p. 1) explain, "many situations have been identified in which social-ecological systems persist and exhibit short-term resilience, inhibiting efforts to adapt or transform". For example, in the face of global climate change, resilience requires a shift away from the use of carbon-based energy. However, short-term economic or energy security requirements may reinforce the use of carbon-based energy. In terms of spatial form, long-term resilience may be best ensured by more compact and integrated forms of development, but in the short term cities may sprawl in response to the profit-taking imperatives of property developers.

… in the long term an economically and socially equal world and greater tolerance for diversity will support the sustainability of human society.

Similarly, in the long term an economically and socially equal world and greater tolerance for diversity will support the sustainability of human society. However, in the short term economic structures and political systems which perpetuate exclusivity or inequality may serve objectives such as economic growth or system maintenance. In South Africa, for example, the apartheid system proved fairly resilient, with its effects on our cities and society still clearly visible today.

As Davoudi (2012) advises we do need to ask the question of resilience: for what end? Resilience may be a powerful state-of-being for an individual, an institution or a complex system such as a city, but is this resilience supporting endeavours to create just and sustainable futures?

Starting with ecological resilience

As explained in the introductory section of this report, the idea of resilience is informed by different threads of thinking. However, there is a specific theory of resilience that comes from the study of ecology.

C.S Holling introduced the term resilience into ecology in 1973. He used it to explain the capacity of ecological systems – such as lakes, forests and coral reefs – to renew themselves in the context of disturbance. In explaining how a system self-renews, Holling used two key concepts – the "adaptive cycle" and the "panarchy" – which are explained below.

The adaptive cycle

Holling (1973) developed the notion of an adaptive cycle. He identified four phases of the cycle: (1) exploitation; (2) conservation; (3) release or creative destruction; and (4) reorganisation (Figure 1.4). In the first phase following a disruption, there is a rapid colonisation of a disturbed site by one or more species best able to exploit the change. This rapid change is followed by a period of slower change (conservation), as material and energy are accumulated. The system may seem stable but it is "brittle" and a small disturbance could result in a moment of "release" in which change may suddenly cascade through the system, leading to a process of reorganisation or productive change. There are different possible trajectories of changes, and relatively small influences may direct a system onto one path or another.

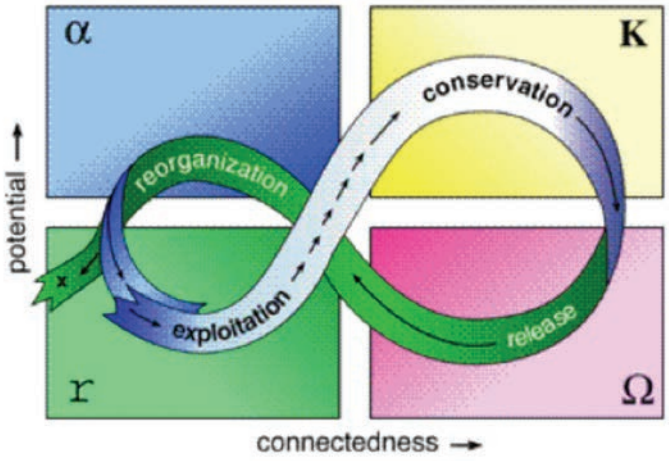
The resilience of the system has to do with the capacity for reorganisation, and may be measured in terms of the time it takes for a system to be restored to a new state of equilibrium (Gunderson, 2000).

In Holling's conception, disturbance is not necessarily negative as it may unleash the forces of "creative destruction" and lead to new and possibly better states of being. However, Holling does warn that an adaptive cycle may become maladaptive if resilience potential is destroyed (for example, if the diversity and connections required for adaptation are removed). This leads to severe system degradation or what is termed a "rigidity trap" (Holling C. S., 2001).

Panarchy

The idea of panarchy is a central concept in resilience theory, and has been used to represent dynamic interactions across scales. In ecology, a panarchy is an overlapping hierarchical structure ranging

FIGURE 1.4: The Adaptive Cycle (Holling C. S., 2001, p. 394)

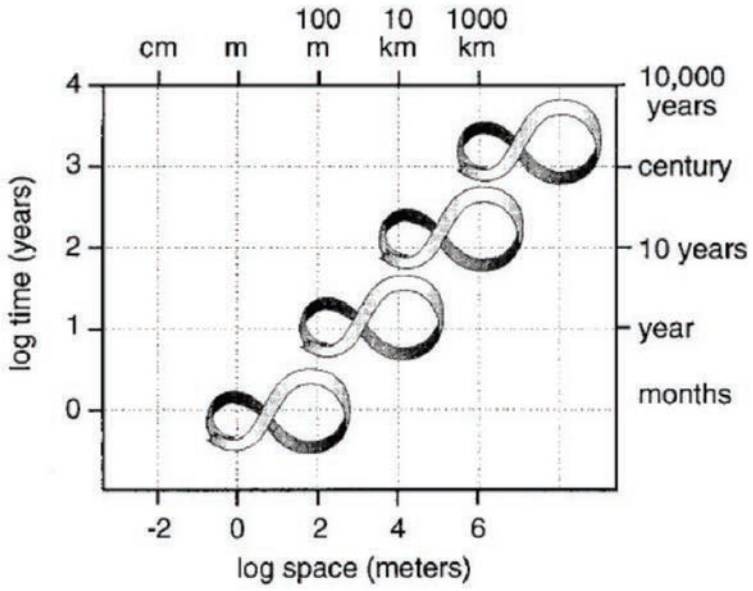


from a single-cell organism to an entire biosphere. It is not a traditionally defined hierarchy as there is no form of authoritative control from one level to the next, but rather a complex set of interconnections and influences.[4]

The complexity emerges because the adaptive cycles at each level of the hierarchy operate at different speeds, in periods that may span days or epochs lasting billions of years. The large components of the hierarchy tend to transform more slowly than the smaller components which have shorter adaptive cycles, and this provides continuity and memory for the system as a whole. The panarchy thus has an intricate mix of change and continuity.

Dramatic, far-reaching change may come if tipping points are reached in the wider levels of the system, while a collapse (referred to in the theory as "a revolt") at one level may trigger a crisis in another. Holling (2001, p. 399) acknowledges that "extremely large events can overwhelm the sustaining properties of panarchies, destroying levels, and triggering destructive cascades down the successive levels of a panarchy".

FIGURE 1.5: Panarchy (Holling C. S., 2001, p. 397)



Applying the theory to social-ecological systems

Although Holling began with a study of ecology, he went on to argue that the patterns and processes he identified in natural systems could be applied to socio-ecological systems, and that the human adaptive cycle follows the same broad trajectory as that of other species. However, Holling (2001) does identify three features that distinguish human systems from others. First, there is human foresight and intentionality, which may spare human systems from catastrophic change. Second, there is the human ability to communicate ideas and experiences over time and place, which permits informed and co-ordinated action, and allows us to preserve accumulated experience. Third, technology massively amplifies the scale of influence of human action (for better and worse). It is for these reasons that human systems are more unpredictable and complex than natural systems, but also more amenable to active management.

The additional complexity is the integration of human and natural systems. Holling argues that because nature and humanity are co-evolving, their adaptations must be discussed within a single conceptual framework. He describes the combination of social and ecological systems in terms of a mega panarchy:

> Panarchy is the term we use to describe a concept that explains the evolving nature of complex adaptive systems. Panarchy is the hierarchical structure in which systems of nature (for example, forests, grasslands, lakes, rivers and seas) and humans (for example, structures of governance, settlements and cultures), as well as combined human-nature systems (for example, agencies that control natural resource use) and social-ecological systems (for instance, co-evolved systems of management) are interlinked in never-ending adaptive cycles of growth, accumulation, restructuring, and renewal. These transformational cycles take place in nested sets at scales ranging from a leaf to the biosphere, at periods from days to a geologic epoch and from the scale of a family to a socio political region at periods from years to centuries (Holling C. S., 2001, p. 392).

As with ecological panarchy, this socio-ecological panarchy exhibits a combination of change and continuity, with the built-in resilience coming from the partial separateness of the different levels. However, Holling and others also warn of the potential for major disruption across the levels (Folke, Hahn, Olsson, & Norberg, 2005; Abel, Cumming, & Anderies, 2006; Gunderson & Holling, 2002a). Despite the human capability for foresight and intentionality, a long view of human history reveals a number of calamitous events. Holling states that these are not always sudden events, but can be slow changes that allow stress to accumulate: “Organizations and institutions often fail to cope with these slow changes either because the changes are invisible to them, either or because they are so complex and highly contested that no action can be agreed on” (Holling C. S., 2001, p. 399). Climate change is an obvious example of a possible creeping disaster.

Cities as “complex, adaptive [political] socio-ecological systems”

Following the introduction of resilience theory to systems that include human life, a number of scholars have identified cities as examples of complex, adaptive socio-ecological systems. A city may be regarded as a panarchy of sorts, with a nested set of neighbourhoods, suburbs, urban nodes and metropolitan regions. It may also be regarded as a level within a mega-settlement panarchy that extends from small villages to a global urban network.[5] As with other forms of panarchy, there are complex cross-scale relationships with an intricate mixture of change and continuity.

The city as a socio-ecological system, or as a panarchy, is “complex” rather than “complicated”. A machine such as a computer or the engine of a motor vehicle is complicated. An ordinary person may not understand how they work but IT specialists, system engineers or motor mechanics can fully comprehend them. They can isolate the component parts, and predict the resultant outputs when inputs are added. They know how a change to one part of the system will affect the way in which the entire system will operate.

A socio-ecological system, on the other hand, is complex. The operation of the system is non-linear and mainly unpredictable. The human element adds considerably to the unpredictability, as individuals and collections of individuals act in a tangled mix of rational and irrational ways (Walker & Salt, 2006). There is a nesting of scales and components, but they cannot be separated in the way that a component of a machine can.

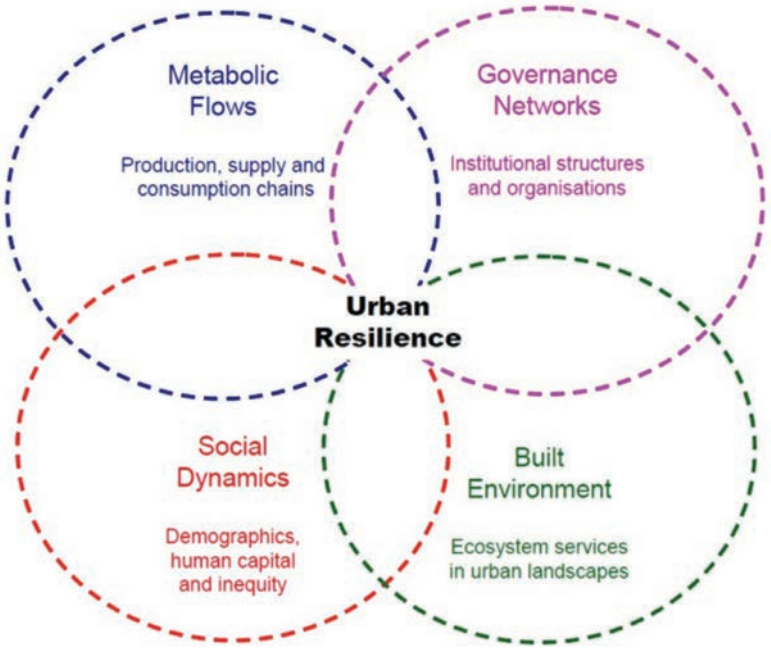
The interactions across scales are often extremely difficult to comprehend. In general, the larger systems change more slowly and show more continuity, while smaller systems may change very quickly. An example might be the almost overnight development of an informal settlement in a city that is growing incrementally. The change in the smaller system may add some disturbance to the larger system but the effects will be quickly absorbed.

Even within the same level of an urban panarchy, the knock-on effects of change in one local system on change elsewhere may not be initially apparent. For example, paved roads might be installed in a particular neighbourhood, which adds to the quality of life of its residents. However, the increased water run-off that results might cause erosion and flooding in a downstream neighbourhood.

There are also enormously complex interactions between different (non-scalar) components of a socio-ecological system including governance networks, economic systems, resource flows, social dynamics and the structure of the built environment (Figure 1.6). There is a mix of gradual, incremental change and sudden disturbance, with climate change as an example of the former and an unanticipated collapse of a stock exchange the latter. The agents of change may be relatively minor, such as a thunderstorm or the closure of a firm; or they may be far-reaching and major, such as a change of government or a global economic depression.

It is because of their complexity that cities can never be fully understood, controlled, planned or predicted. Instead of the traditional paradigm of planning for a predictable future, resilience theorists call for "diversifying preparedness in anticipation and acceptance of the unknown" (Weakley, 2013, p. 47). While it is difficult to predict change, including the effects of development decisions and actions, accumulated experience does gradually allow for an increased general understanding of these trends.

FIGURE 1.6: Four interconnected research themes for prioritising urban resilience research (Resilience Aliance, 2007, p. 10)



Limits to the theory

Davoudi (2012) advises that as notions of resilience are popularised they might lose their force and clarity and become yet another buzzword to justify all sorts of practices. This is a danger and does require us to think carefully about precisely what we mean when we use the term in our policies and plans. Resilience cannot mean everything. More than this, as indicated previously, resilience may not always be positive and may serve unjust ends.

There are some cautionary notes about the theoretical construct outlined above. We must be aware of how ideas of resilience have been translated from ecology to the human world. Davoudi (2012) reminds us that, in the human context, the adaptive cycles of nature do not work in any deterministic or inevitable way. Human foresight and intelligence, and the application of technology, can significantly alter the nature and speed of adaptation. Holling, of course, did recognise this, but in the work of some theorists the translation is overly simplistic.

… in the human world resilience for some may mean a lack of resilience for others and so we must give attention to question of justice and fairness, and to the distribution of benefits and rewards.

Davoudi (2012, p. 306) also points out that resilience theory tends to be "almost power blind and a-political". She suggests that this is a consequence of the ecological origins of the idea, as ecologists working with the natural world tend to look neutrally at the consequences of disturbance and change, and not the human world of intrigue and power relations. Davoudi reminds us that in the human world resilience for some may mean a lack of resilience for others and so we must give attention to question of justice and fairness, and to the distribution of benefits and rewards.

Fortunately, there are scholars who draw on theories of resilience who do pay attention to these issues. Ernstson et al. (2010, p. 531), for example, recognise how "ecological processes in the city are … modified and entangled in social and therefore political processes (most obviously through competing land uses)". They refer to cities as "complex, adaptive *political* socio-ecological systems" [our emphasis] (Ernstson, et al., 2010, p. 531). In the South African literature, Turok (2014, p. 5) writes that "resilience is not a neutral attribute of a social system, affecting all groups the same way. It is necessary to discuss 'for whom' it applies and not assume homogeneous interests".

In the GGLN publication, *Community Resilience and Vulnerability in South Africa,* an additional key point is raised. We are reminded that many people in South Africa live in an *existing state* of "generalized precariousness". Severe stress and risks are part of everyday life and there is no normality to return to. Our theory should respond to the conditions which have led to this present situation as well as to the need to adapt to current and future change (GGLN, 2014).

Davoudi (2012) offers a sympathetic critique of resilience theory. She argues that resilience theory provides a useful framework for understanding "the complex interplays between persistence, adaptability and transformability" and "has the potential to become a bridging concept between the natural and social sciences". However, she concludes by saying that "in applying an ecologically rooted concept to the social setting, we need to tread carefully and ensure that in trying to understand society through the lens of ecology we do not lose the insights from critical social science" (Davoudi, 2012, p. 306).

1.4 Conclusion

Ideas of resilience do not offer a simple panacea for municipal governments. They provide a way of thinking and require intelligent application. They are rooted in an understanding that change and disturbance are inevitable, and often unpredictable, and so building adaptive capacity is critical. Fortunately, there are useful principles to assist in doing so. We know, for example, that the learning capacity of our institutions, together with diversity, redundancy, self-sufficiency and connectedness are key ingredients. What this means practically in the context of each municipality must be worked out locally.

We also have the benefit of a theory of resilience which has its roots in ecological study but which has been applied to socio-ecological systems, including cities. This theory points towards an understanding of the interactions across scales; the position of cities within wider systems; the interdependencies between natural, technical and social networks; and the importance of learning and innovation. The theory shows that large cities have a high degree of resilience, as adaptive cycles in a nested hierarchy (from neighbourhoods upwards) allows for change and continuity to co-exist. However, there is also a sobering warning that the slow changes which may go largely unnoticed could take a city to an irreversible tipping point.

We must also take account of an important critique of resilience theories which points to the role of power and politics in shaping the way in which resilience is produced. We are reminded that resilience theory is partial and must be informed by theories from the social sciences that offer critical insights into the ways in which human society works.

There is of course much substantive detail that is missing from this broad description of resilience thinking, resilience principles and resilience theory. In the chapters that follow we fill in some of the gaps in relation to the key components of urban functioning.

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NOTES

1 “Nested sustainability-v2” by K. Tucker - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Nested_sustainability-v2.svg#mediaviewer/File:Nested_sustainability-v2.svg.

2 “Sustainable development” by original: Johann Dréo (talk · contribs) translation: Pro bug catcher (talk · contribs) - Own work Inspired from Developpement durable.jpg. Translated from Developpementdurable.svg. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Sustainable_development.svg#mediaviewer/File:Sustainable_development.svg.

3 Holling has tried to avoid the term “hierarchy”, referring rather to systems that are nested within each other.

4 For the use of resilience and panarchy in relation to urban settlements, see Churchill (2003)

2 Governance for Resilience

2.1 Introduction

In recent times much has been said about the shortcomings of government administration in South Africa. Chapter Thirteen of the National Development Plan (NDP), for example, provides a sobering account of what is required for "building a capable and developmental state" (NPC, 2012: 407). There is an international literature that points more broadly to governance failure as a major contribution to many challenges that currently confront us – from the failure to ensure the provision of basic human needs to our struggles to respond adequately to the looming prospects of climate change. The literature shows that systems of governance are too often still constrained by rigid hierarchies, institutional self-interest, corruption, short-term thinking and planning horizons, sector divides and fragmentation, over-regulation, poor engagement between governmental and non-governmental actors, and low learning and innovation capacities (Pahl-Wostl, 2009).

In many instances it is not deficiencies in the resource base which is the source of our problems but rather failures in governance (Pahl-Wostl, 2009). The effects are felt from the neighbourhood to the global level. Within a neighbourhood, a lack of collaborative engagement by local actors may leave a children's park badly maintained. At the city-scale, a shortage of water may have more to do with a breakdown in administration than a drought. Nationally, a power deficit may be traced to poor planning and regulatory deficiencies rather than a shortage of natural resources. At the global level, we may be losing the battle to contain climate change because of the failure of multi-lateral institutions to broker an agreement between squabbling nation states. To ensure long-term resilience we must find ways to build systems of governance that can both absorb change and use change proactively to move towards higher levels of long-term sustainability.

A resilience perspective places "adaptability" at the heart of successful governance. Notions of governance are now well established. While "government" refers generally to the agents charged with governing and to the structures within which they operate, "governance" refers more broadly to the enormously variant arrangements, processes and relationships through which social co-ordination and collective action takes place (Jessop, 1998; Folke et al., 2005). The specific idea of "adaptive governance" is more recent, having been introduced into the literature on resilience around 2004 (see,

for example, Anderies, Janssen and Ostrom, 2004; Walker et al., 2004; Folke et al., 2005). The related idea of "adaptive management" goes back a little further, as there were studies in the 1990s which challenged traditional approaches to resource management which failed to recognise the human element and the extent of environmental change (Walters, 1997).

If resilience is about capacities to respond meaningfully to change, then systems of governance and management must clearly be adaptive. However, change is a vast, embracing category. It includes many shades of the negative and the positive, and ranges from the sudden, unexpected shock to slow, incremental, almost imperceptible processes. The idea of adaptive governance is therefore not a simple one. At times adaptation may require the ability to absorb or bounce back from a major shock, but it often involves the capacity to adapt over time to a changing environment, and to use change constructively for positive transformation. Resilience in governance and management thus requires a mix of persistence, adaptability and transformability. In most cases resilience in governance requires the balancing of persistence and change, being decisive yet flexible, stable yet adaptive.

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The main contribution of this chapter of the booklet is to offer a cognitive frame – that is, a way of thinking – about governance that draws on resilience theory. It begins by showing how resilience theory can assist us to understand process of change and adaptation. It briefly introduces the two key concepts – adaptive governance and adaptive management. It then brings these concepts together in a single framework and offers municipal officials practical guidance in the form of a set of broad principles for adaptive governance and management. It also provides illustrative case studies drawn from the Johannesburg context.

The task of local officials is to think practically of what these concepts and principles may mean within the particular context of their municipality. Resilience thinking is a significant challenge to the conventional approaches to governance common in South Africa's municipalities, which

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mainly involve a focus on the internal organisation of bureaucracies, the exercise of hierarchical authority, compliance with legislative and policy frameworks, and skills development within individual components of government. A resilience approach, as we will see, focuses on such factors as the multiple scales of governance, links and interactions across these scales, networks of learning and innovation, the relationships between formal and informal processes, and the role of elements such as leadership, values and degrees of trust.

We move now to the two concepts of adaptive governance and adaptive management, and provide a brief account of their theoretical or conceptual roots.

2.2 Explaining the concepts

The concepts of adaptive governance and adaptive management are related but are not the same. Governance is a wide-ranging term that refers to the full network of actors, relationships and processes across scales that help co-ordinate or influence action in society. Management refers more specifically to processes of monitoring, analysis, supervision, organisation and resource deployment that are necessary to achieve agreed goals. The idea of adaptive governance comes directly from the application of ecological theory to the context of complex socio-ecological systems (SES). Ideas of adaptive management, on the other hand, developed from attempts to apply resilience theory to the management of natural resources such as watersheds, forests, coastal ecosystems and fisheries; that tended to be concerned with the use of management processes to keep the use of natural resources within bounds (Pahl-Wostl, 2009).

2.3 Adaptive governance

As we know from Chapter 1 of the booklet, the key framing concepts in the underlying theory are “the adaptive cycle” and “panarchy”. These concepts allow us to think about the complexity of change and adaptation in a way that is very different from the conventional approach.

We know that a socio-ecological system is strongly influenced by human intention, organisation and power relations, and so will not necessarily follow the process of adaptation observed in an ecological system. However, there are insights that may be carried over from ecology. As with ecological systems, our governance arrangements may be caught in a “rigidity trap”. They may seem stable and able to control change, but this very stability may ultimately be the greatest threat to long-term adaptive capacity. Governance systems that lack accountability, are inwardly focused, have authoritarian leadership, and are structured in tight hierarchies are often extremely brittle. They lack the elasticity that allows for long-term adaptation. If a point is reached where the pressures of change exceed the ability of the system to contain change, even a minor pressure may trigger a downward and degenerative cycle. The real strength of a governance system comes from such factors as learning capacity, accountability, responsiveness, relational strengths, and multi-layered and multi-modal organisation.

The notion of panarchy provides us with a way to think of governance as a multiplicity of adaptive cycles operating at different scales and at different speeds, with an intricate set of connections between them (Holling, Carpenter, Brock, & Gunderson, 2002). The resilience of the system as a whole is related to the individual cycles, but comes largely from the fact that that there are these different cycles which are connected to, but also partially insulated from, each other. The overall resilience of a *governance* panarchy is shaped by:

- the rate and nature of adaptation of each scale of governance, and
- the nature of formal and informal interactions within and across the scales.

Elements which influence these two factors include:

- leadership,
- levels of trust,
- social and institutional norms,
- capacities within and across scales, and
- institutional learning

In this conception, adaptation cannot be understood only in terms of organisational change within a stand-alone institution. It has to be understood in terms of a broader system where many processes of adaptive change evolve at the same time. A governance system may be viewed as panarchy in itself, but ultimately it forms part of the integrated panarchy in a socio-ecological system where nature, governance, space, economy and society do not exist as separate domains. We cannot pretend to grasp this complexity, but thinking of change in this way is helpful. It directs us towards "trigger points" where we are best able to influence the nature and direction of change. We know, for example, that it is the relational elements of a system – the connections across scales, between actors, and across cycles – that are crucial in supporting overall resilience. And yet, we also know that it is the relational issues that often receive the least attention within our institutional processes.

We also know that governance is not limited to formal systems but embraces a variety of informal processes.

We also know that governance is not limited to formal systems but embraces a variety of informal processes. Yet our attention and knowledge is largely directed to the formal aspects. We have formal legal structures, regulative frameworks and professional codes. But we also have a variety of normative, cognitive and cultural codes which shape practices, which in turn shape idea around what is or is not permitted, what is or is not thinkable, and what is or is not judged to be wrong. In our interventions to support governance we may give a lot of attention to the reform of formal systems, but we may have little understanding of the ways in which informal codes and practices shape outcomes in our towns and cities.

As we develop our understanding of the complexity of governance we need to expand our conception beyond the cycles of adaptation across the scales of government, to include cycles of change that operate across our artificially conceived boundaries between the public and private spheres. We must ask, for example, how the adaptive cycles within all levels of government relate to behavioural changes among households at the neighbourhood level. Take, for example, policy and behavioural changes at neighbourhood, city and national levels. In some cases change happens more quickly at the national level, and this gradually influences a slower pace of change at a lower level. But often people's behaviours at neighbourhood level change more rapidly than systems of government at city or national level because they are affected by daily pressures. These "spontaneous" changes become new system dynamics, which in turn produce behavioural changes in the system at large, often affecting policy-making. In the field of energy efficiency, for example, how much of the change is resulting from national actions such as new legislation and publicity campaigns, and how much from household response to factors such as rising energy costs? In reality, there are influences from above and from below but the interactions of these streams of influence, and their relative contribution, requires careful consideration.

This understanding of change reveals the enormous complexity of governance and raises the legitimate question of whether change can ever be "governed". In the following section we ask the question of what governing for resilience actually means, and how it might happen.

South Africa's Constitution provides a strong framework for adaptive governance. It avoids an overly hierarchical structure, distributing power across three spheres of government and separating legislative, executive and judicial responsibilities. The notion of co-operative governance (between spheres) expresses a key principle of adaptive governance, as does the idea of participatory governance. In

South Africa's complex governance system, we have a form of panarchy with co-evolving spheres and porous boundaries between government and society.

The real experience of government in post-apartheid South Africa, however, reveals the considerable challenges involved in achieving the constitutional ideals of adaptive governance. The formal mechanisms governing relationships between the spheres of government are provided for in the Intergovernmental Relations Framework Act, 2005. However, in practice, insufficient attention has been paid to developing the network of formal and informal relationships across the spheres, and finding mechanisms which allow the panarchy to work on a day-to-day basis. The capacities for handling the complex nature of governance have lagged behind the challenges. More seriously, the attention given to participatory processes has not translated into active governance partnerships. While many South African residents are active in the public space, the form of interaction between social actors is often destructive.

The South African experience reveals both the importance and limitations of formal (constitutional and legal) arrangements. They may be enabling, but they do not translate automatically into forms of adaptive governance unless attention is paid to a range of "softer" issues such as norms, relationships and leadership.

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2.4 Adaptive Management (and Adaptive Co-management)

Recently cities all over the world have seized upon ideas of adaptive management to deal with complex problems such as reducing greenhouse gas (GHG) emissions, managing sewer overflow, maintaining urban waterways, and alleviating traffic congestion.

The traditional management approach assumes a system operating around a stable equilibrium, and focuses management interventions on one or a few variables. Adaptive management, on the other hand, proceeds from an assumption of radical uncertainty and from an understanding that social dynamics and relationships are as important as the traditional variables. For example, in the traditional management approach, a national or municipal roads agency dealing with storm-water in an informal settlement might construct a number of culverts along major transport routes. The design and placement of the culverts could be influenced by the slope of the land and the amount of rainfall in

that vicinity. However, this approach might not take account of the real waste management strategies of people living in informal settlements, where there are infrequent or no waste management services. In dealing with this deficiency, community members might drop a small bag of solid waste at the place where they wait for taxis to transport them to work in the morning. The nearby culverts quickly become blocked, increasing the risk of flooding from only a small amount of water. In order to ensure the effective and efficient functioning of such basic urban infrastructure, the management approach that recognises the complex interactions among a diverse array of physical and social forces – including the waste management strategies of individuals within the informal settlement – is likely to be more successful.

Adaptive management is also an advancement on traditional systems of management in seeking to apply scientific knowledge to the design, implementation and evaluation of management strategies. Although adaptive management is more than "learning by doing", it is underpinned by a desire to undertake the management of a socio-ecological system in a way that progressively improves the understanding of the complex, changing variables that make up the system. It is therefore as much a social as it is a scientific process, and requires the creation of new and flexible institutions and institutional strategies by present and future stakeholders (Resilience Alliance, n.d.). In this process, traditional institutional divides may need to be breached. Box 2.1 looks at the merger of the Infrastructure and Environment Departments in the City of Johannesburg which was an experiment with breaching these divides. Beyond the internal workings of government, new institutional linkages may need to be forged with a range of other actors including private sector and community agencies, as well as academic institutions.

Within the resilience literature, a distinction is made between passive and active adaptive management. Passive adaptive management (often referred to as the adaptive management cycle) involves increased monitoring of key indicators, and feeding data into a planning-implementation-evaluation loop that allows for policies to be adjusted in the light of what has been learned. The cycle begins with planning, target-setting, prioritisation and decision-making, and proceeds to implementation and on-the-ground works. Monitoring, investigations and research determine the extent to which implementation conforms to plans, targets and priorities. Results are then evaluated and reported to a range of stakeholders with the aim of informing the next cycle of co-ordinated and collaborative planning.

To what extent has South African legislation incorporated passive adaptive management in regulatory regimes that are binding upon local governments? The national framework for the management of air quality, for instance, positions compliance monitoring as an integral component of the environmental governance cycle. Compliance monitoring informs enforcement but also influences problem identification, prioritisation and strategy development (Republic of South Africa, 2007). By establishing the South African Air Quality Information System (SAAQIS), the framework provides a common platform for monitoring to influence policy-making and strategy development, and for national, provincial and local spheres of government to co-ordinate their air quality management interventions. In a similar fashion, the manner of setting and monitoring key performance indicators for the development priorities and objectives of integrated development plans under the Local Government: Municipal Systems Act 32 of 2000, together with the requirement of annual review of such plans, could be seen as a form of passive adaptive management. On its own, however, monitoring of indicators is not sufficient to constitute passive adaptive management. Monitoring should instead be leading to increased understanding of the relationships among the complex, interacting set of variables involved in the delivery of any social good.

Active adaptive management, on the other hand, involves a conscious effort to tailor management interventions so as to test scientific hypotheses. Instead of a single design or operational plan for implementation, monitoring and adjustment, active adaptive management uses multiple designs or operational criteria to test competing hypotheses. Thus several possible management alternatives are tested at the same time in order to determine which of them produces the best results. For example, in the Comprehensive Everglades Restoration Project in the United States, reservoir test cells were

BOX 2.1: The Complexities of Adaptation: Planning in South Africa as a Case-in-point

The primary mechanism the Constitution uses to share powers among the three spheres of government is the lists of functional areas in Schedules 4 and 5. The complex mixture of exclusive and overlapping powers listed in these schedules gives effect to the Constitution's notion of co-operative governance, which captures the idea of the different spheres of government (and the different divisions in each sphere) functioning in co-operative and not competitive relationships with one another. The complexity of the power-sharing in the Constitution is aptly captured by the various ways in which "planning" features in the lists: "Municipal planning", listed in Part B of Schedule 4, is a functional area over which national and provincial spheres of government exercise concurrent legislative and executive competence, and in respect of which municipalities have executive authority and the power to make and administer by-laws. "Regional planning and development" and "Urban and rural development", situated in Part A of Schedule 4, are constituted as functional areas of concurrent national and provincial legislative and executive competence. "Provincial planning" in Part A of Schedule 5 is a functional area of exclusive provincial competence. These constitutional mandates have allowed for the development of laws that spell out the powers and obligations of agencies within each sphere of government and their relationships with agencies in other spheres. These have included the (now defunct) Development Facilitation Act (DFA) of 1995 and, more recently, the (not yet in force) Spatial Planning and Land Use Management Act of 2013.

The confusion and litigation that emerged during the early 2000s regarding the meaning of "municipal planning" and the scope of local authorities' powers over municipal planning is illustrative of the limits of tools of governance, which can create conditions for disorder and lack of social co-ordination at one scale, just as much as they attempt to resolve problems at another scale. The Development Facilitation Act, for instance, was conceived as a stop-gap, providing a parallel land-use management regulatory system for the approval of much-needed reconstruction and development projects while the transformation of the local government sphere was being achieved and a longer-term vision for urban and planning regulatory reform was being worked out (Berrisford, 2011). The structures and processes created by the DFA, however, became problematic when they began to be used to subvert the existing local land use management procedures and when attempts at co-ordination failed. Ultimately local authorities had to resort to the courts for clarity. Following decisions in City of Johannesburg v Gauteng Development Tribunal and Minister of Local Government, Environmental Affairs and Development Planning, Western Cape v Habitat Council local authorities have been able to exert near exclusive control over municipal planning. This points to how even high-level governance frames may shift and change. They are in themselves adaptive – whether through dispute resolution or other modalities of change. Governance structures may adapt in different ways and at different scales.This adaption and experimentation should be on-going to continually address limitations of process and structures.

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BOX 2.2: Bruma Lake Project

A good example of how a flexible, adaptive governance system can help overcome complex socio-environmental issues – by improving coherence and co-ordination among different Institutional entities – is the Bruma Lake Project in Johannesburg.

Bruma Lake was an artificially constructed waterfront that suffered from a number of environmental problems. The impoundment was constructed in-stream, to intercept the natural watercourse, but the concrete channels that lead water into Bruma caused an increase in water flow. This, together with a lack of vegetation resulted in the erosion of riverbanks and deteriorated water quality in the lake. Bruma Lake has been subject to pollution and siltation for many years, resulting in complaints from residents and users of the surrounding shopping area. For a long time the lake was neglected. The City wanted to address the issue but it was not clear how to proceed, neither in technical terms nor in delegating responsibility for the project.

In 2011 the City of Johannesburg made an important adjustment to its governance structure, merging two formerly separate departments – Infrastructure and Environment (see box 2.3). The new Environment and Infrastructure Services Department had an extended scope and important co-ordination functions. With the new setting, the newly formed Department took the lead at Bruma Lake. A flagship project was developed where the dam would be closed and drained. Afterwards there would be a re-naturalization process to turn the area in an ecological park. The rehabilitation project foresees an improvement in water flow; increased natural aeration; natural water filtration by plants along vegetated banks; improved access for removing debris; reduced sediment build up; restoration of the ecological linkages between upstream and downstream areas; and restored habitat opportunities for birdlife.

The project, supported by key stakeholders around the lake, is part of the integrated efforts of the City to address upstream sources of water quality problems through the reinstatement of natural wetland bio-filters, improving sewer and storm-water infrastructure, by-law enforcement, litter management, river clean ups and inner city upgrading projects. The City approved R60 million over two financial years for the engineering works followed by landscaping of the modified site into a park and vegetated channel, with the project starting in 2014.

While previous frameworks merely allowed the City to temporarily clean the dam, under the new strategic framework and related operational setting there has been the chance to make (relatively) long-term plans to improve the dam.

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constructed in various locations to test competing hypotheses relating to subsurface seepage and embankment durability (U.S. Army Corps of Engineers & South Florida Water Management District, 2011).

Active adaptive management is frequently revealed in partnerships between government and research and academic institutions, and may generate important new scientific knowledge. For example, in order to establish a climate action plan, the city of Santa Cruz in California followed the conventional route of quantifying its greenhouse gas emissions in a series of GHG emissions inventories. This has enabled the city to track net carbon dioxide (CO_2) emissions, identify key emissions sectors, prioritise reduction strategies and track progress in emissions reduction over time. Following the establishment of a Climate Action Compact with the County of Santa Cruz and the University of California, the city is also working with academics on how to measure the real-time production of urban greenhouse gas emissions by transportation, air-conditioning and industry, as well as the absorption of such emissions by trees, greenways, gardens, parks and agricultural zones. This information will enable policy-makers to know how much CO_2 people are actually generating before some of it becomes absorbed by plant life. Armed with this information, city planners might be better informed about the relative advantages of investing in an urban light rail system over improving the city's green infrastructure. The scientific gains of the project to date have included: the adaptation of existing scientific instruments to sense carbonyl sulfide; an innovative method for measuring carbon-absorbing photosynthetic activity (by tracking carbonyl sulfide); methodologies for deploying sensor networks across the CO_2 dome produced by the city; and data assimilation models for the processing of sensor results so as to calculate how much CO_2 is being emitted (CITRIS, 2014).

The term adaptive co-management is used to denote a distinct approach that combines adaptive and collaborative aspects in resource management. The social learning that takes place in both passive and active adaptive management is horizontal in nature, centring on the managers, their relationships, requirements and capacities. Co-management, on the other hand, focuses on vertical relationships between managers, other state entities, and resource users and communities. Adaptive co-management attempts to forge both horizontal and vertical links for shared learning-by-doing between various actors over a medium- to long-term timescale. It tends to be multi-scale in scope, and is concerned with enhancing the capacity of all actors who have a stake in sustainably managing the resource at hand (Plummer et al., 2012). Plummer et al. (2012) list some of the enduring themes discussed in the adaptive co-management literature include:

- the influence of learning on adaptive co-management and its interaction with variables such as leadership, incentives and trust;
- the knowledge (information, skills, expertise, experiences and world views) that individuals and organisations bring to adaptive co-management, their types and combination, as well as knowledge communication and control;
- the structural and functional connections constituting the networks among entities;
- the manner in which entities involved in adaptive co-management are able to share power; and
- the formal and informal links between and among organisations.

Adaptive co-management is not equivalent to enabling public participation in regulatory decision-making. In South Africa public participation is mandatory in the development of an integrated development plan and in many of the prescribed processes for obtaining various environmental licences. Two common forms of stakeholder engagement do not meet the criteria for adaptive co-management: The first is processes that are "cobbled together" to allow participation by more or less diverse parties. The second is "naked deal-making" among a select group of local parties (Karkkainen, 2002). Many participatory processes in South Africa either fall within these categories or do not involve the genuine openness to learning and on-going redefinition of self-interest by all parties involved that is required in successful adaptive co-management (Karkkainen, 2002).

BOX 2.3: The Merger of the Infrastructure and Environmental Departments in the City of Johannesburg

This chapter of the booklet shows how multi-dimensional governance is essential for resilience. It requires attention to formal and informal processes and relationships and to actions and interactions that cross scales and cross the boundaries between government and other stakeholders in society. Adaptive governance cannot ever be reduced to institutional organisation within government. However, there is a place for institutional reform, and it is useful to consider different instances where institutional reform has taken place.

Johannesburg is an interesting case-in-point. It has a history of institutional experimentation. The creation of city-owned corporate entities (for example, Joburg Water, Pikitup, City Power, Johannesburg Road Agency) was an example of experimentation in the early 2000s. The jury is still out as to whether or not this form of reorganisation has added to the resilience of the city. In some cases services may have been delivered more efficiently, but the system has added some challenges of institutional co-ordination.

Here, however, we report on a more recent and limited experiment with institutional form that attempts to bring the delivery of infrastructure in line with the City's commitment to environmental sustainability. With the advent of the 2011 Growth and Development Strategy (GDS) known as Jo'burg 2040, concerns with resource efficiency and sustainability were elevated to the level of key priority for the city government. One of the key challenges was to re-orient the activities of major infrastructure agencies towards sustainability objectives. This was difficult as these corporate entities were concerned with the financial bottom-line and were hardly incentivised to support demand management in the use of resources such as energy and power.

The question of how to re-incentivise entities delivering infrastructure remains, but some progress has been made in the reform of institutional structures to bring infrastructure delivery into a closer policy and environmental relationship with sustainability and environmental management functions. An infrastructure department was set up in the City in 2006 to provide policy oversight and guidance to a number of the corporate entities. At the same time an environmental department was established to guide the city in its response to a range of environmental concerns including climate change. In 2011, the infrastructure and environmental departments were merged in an unusual institutional manoeuvre which highlighted the critical link between these two sectors. At the time of writing, it was difficult to assess the effectiveness of the reform as it has taken time for the operational functions of the new department to merge in actual practice but it is an experiment worth following. The challenge will be to follow the institutional change with adequate attention to the range of other factors necessary for adaptive governance which are discussed in this booklet.

The City of Johannesburg has also attempted to cluster its departments around the key priorities of the GDS. This follows similar experiments in national and provincial governments. The role of the clusters was to bring different departments together to facilitate discussion and co-ordination in decision-making, service, and project management and delivery in the context of the GDS' strategic goals of resource sustainability, liveability and resilience.

This is a significant step towards alignment of strategic goals and operational structures but may require on-going adaptation as it raises new questions of co-ordination (i.e.

between clusters) and of the required capacity to make the clusters work. It is arguably only a beginning as this internal reorganisation needs to be carried through into effective multi-scalar governance and into new relationships with actors outside government.

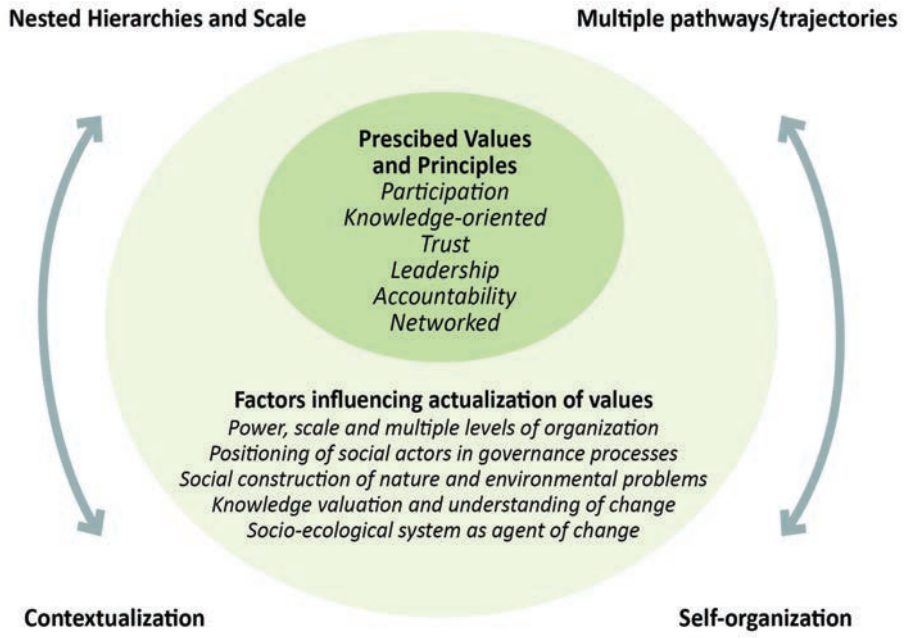
2.5 Bringing together adaptive governance and adaptive (co)management

Although there are some differences in focus between the concepts, the application of one does not preclude the other, and we encourage municipal officials to engage with both (Gunderson & Holling, 2002). It is possible to draw the concepts together into a single combined Framework for a Resilience-based Urban Governance (Gamestani and Benson, 2013). In the framework illustrated in Figure 1, multiple characteristics contributing to governance for resilience are presented which draw from the insights of writers using both concepts.

2.6 Making governance for resilience real: some guiding principles

How do we make adaptive governance and management real? This is an enormous topic given the relationship of governance to both government and non-governmental sectors, and the interaction across these barriers. Since this report is geared towards municipalities, we focus on the extent to which the institutions of government can effectively adapt their governance approaches, systems and structures. How can institutions, which are fundamentally administrative bodies, keep "working", delivering services, maintaining the machine that lets our cities operate on a daily basis, while learning to be flexible and adaptive? How can an institution be more decisive in moving towards sustainable and resilient development patterns, without being undemocratic?

FIGURE 1: Conceptual framework to examine forms of adaptive management and adaptive governance



(Graphic re-elaboration from Armitage, 2006)

Numerous worldwide case studies have found that many successful practices of adaptive management and flexible governance are characterised by a certain "messiness" or "unplanned incrementalism" (Brunner et al., 2005). However, they also point at a series of critical factors that shape the extent to which adaptive governance is realisable as an ideal (Allan and Curtis, 2005; Armitage, 2006). This suggests that we can intentionally improve the adaptive capabilities of governance systems.

These factors are outlined below in the form of proposed actions for strengthening adaptability.

i. Move from the "logic of governing" to a focus on interacting with change.

The "logic of governing" is primarily about the exercise of authority and power. "Adaptive governance" may also involve power and authority but not in a straightforward way, as power is more diffuse and is often shared across institutional barriers. In terms of traditional logic this may mean that government is weak, but in terms of resilience thinking this suggests greater strength as the system is less dependent on single actors and there is less risk of major failure (Armitage, 2006). A preoccupation with governing undermines the flexibility of systems as the focus is on control rather than on adaptability, including both the capacity to reorganise the system in response to a sudden shock and the capacity to adapt on an on-going basis to the contingencies necessitated by change.

ii. Support multi-nodal but integrated systems of governance (polycentric governance).

One of the "productive tensions" in resilience thinking relates to both the need for multiple centres of activity to reduce risk and increase opportunities for innovation *and* for strong linkages across these diffuse centres to ensure synergy and co-ordination. In resilience thinking we need "structurally adaptable" governance systems which combine traditional and new (even informal) institutional relationships in a way that allows new approaches to evolve. The idea of "polycentric governance" is based on recognition that in modern, complex society there are multiple centres of power with degrees of independence from each other, but also with multiple links to each other. These may include the bureaucracies of government, special governmental agencies, organisations of civil societies, the firms and organisations within the private sector, the media, and so forth. A view of governance that is overly focused on the hierarchies of government will fail to appreciate the ways in which the system really works, and may end in frustration as the action of government alone flounders in this complexity. A resilience perspective involves both acknowledging and embracing polycentric government. At the same time, however, it also involves a commitment to developing greater coherence in the system by developing formal and informal linkages and mechanisms of co-ordination between the multiple actors.

iii. Embrace the multi-scalar nature of governance.

It is almost impossible to address the complex problems of the current age within any single scale of governance (neighbourhood, city, city-region, province, country, global). Instead, solutions for many of our problems are to be found in collaborative action across spheres of government. While there may be a limited number of issues that could be addressed within a single scale of governance, most issues require actions that cross scales. While our institutions are generally structured in a way that directs attention inwardly within a single scale, resilience thinking requires us to think simultaneously across the scales. It requires an acknowledgement that institutional processes at one level influence processes at another, and within complex systems of governance flows of authority may be both top-down and bottom-up.

iv. Focus on relational aspects (and especially on building trust).

Traditionally the focus has been on the functioning of each component of a governance system but a resilience perspective, which directs attention to multi-nodal and multi-scalar forms of governance, requires a strong focus on the relational elements of governance. Instead of encouraging competition between the various components, and the emergence of embedded

institutional self-interest, the focus should be on building mutually supportive inter-linkages. There are formal mechanisms of linkage such as the service delivery agreement and the governance contract, but there are also multiple forms of informal connections which may be even more important. Many studies show that trust is the key ingredient which facilitates information-sharing, reduces system risk, and makes the formal mechanisms of interaction actually work. Quite simply, building successful relationships is essential for the functioning of complex socio-economic systems. However, in practice, governance reform or development is overwhelmingly associated with changes to formal structures.

v. Build learning institutions and networks.

There are multiple "lock-ins" in our governance systems. These are established ways of doing things that persist despite their inferior performance within changing contexts. The lock-ins may derive from legislation or regulation, but are often the result of an internal logic or tradition. Adaptive governance requires a willingness to assess and reform (even radically reconstitute) practices on an on-going basis and an openness to new ways of thinking and doing. There are many factors which support or impede the development of learning institutions. They include access to and sharing of information, appropriate use of technology, the connections between government and teaching/research institutions, and the ethos promoted by leadership. With our context of pervasive change we need deep and collaborative learning. The literature usefully distinguishes between three levels of learning in governance networks (see Pahl-Wostl, 2009, for a summary):

a) *Single-loop learning* – or the refinement of behaviour without a change of assumptions or fundamental routine (e.g. an improvement to climate change adaptation policies)

b) *Double-loop-learning* – a change in the frame of reference and a rethinking of assumptions (e.g. a shift from increasing the capacity of the existing system to using natural retention when dealing with storm water)

c) *Triple-loop-learning* – a transformation of the structural contexts which shape the frame of reference (e.g. the overhaul of regulatory frameworks, dominant practices and even value systems in response to a perceived threat such as climate change).

The process may begin with single loop learning but move on to double and triple loop learning. For example, effective double loop learning may have its limits, requiring and prompting triple loop learning. Moving towards triple loop learning requires the formation of strong learning networks. Within single loop learning, actors may remain within their individual institutions or communities of practice. With a transition to double loop learning, they may search for advice from outside the institution or community, but triple loop learning generally requires changes in the configuration of network boundaries and connections. New actor groups are formed with significant shifts in roles and power relations.

vi. Build mutual accountability in governance.

Accountability may be defined as "a relationship in which one party, the holder of accountability, has the right to seek information about, to investigate and to scrutinise the actions of another party, the giver of accountability" (Mulgan, 2002). As governance systems become increasingly complex – multi-nodal and multi-layered – a difficult questions of accountability arises. While there may be mechanisms of accountability within components of the governance system, it may become increasingly difficult to ensure overall accountability. A complicating factor is that there are many directions of accountability. And yet, accountability is the critical check in a complex, evolving system. We need to strengthen accountability within each component of the system – for example, to the electorate, shareholders or residents. However, within the complex system there needs to be mutual accountability across agencies and actors. The institutions and systems which ensure formal accountability need to be protected; mechanisms such as compacts, contracts and partnerships should be developed in a way that builds multi-directional accountability across the

system; and normative commitments and levels of trust should be developed that build an innate sense of co-ownership and shared accountability.

vii. Promote adaptive leadership.

The success of all the above is largely dependent on the effectiveness of leadership across complex governance systems, as it is leadership that motivates or inspires people to change. In conventional approaches, leadership is often conflated with hierarchical supervision, regarded as one-directional (i.e. leaders with followers), depicted as a personal attribute, and seen as something apart from the environment within which it happens. The idea of adaptive leadership challenges these assumptions. Du Rue (2011) argues that leadership is in fact a complex, adaptive process. All members of a group may have "leader" and "follower" attributes, and in adaptive systems the pattern of leading and following within a group may change depending on the demands of the context. A fluid pattern of leadership and following allows a system to adapt more effectively over time. Stable patterns of leadership may emerge given specific attributes of individuals which may be partly defined by formal authority structures, but the systems should have the flexibility to allow variability and recognise the potential leadership role of all.

2.7 Conclusion

It is impossible to deal substantively with every element that shapes the resilience of an urban system. However, if we focus on improving the adaptive capacity of our governance systems we are significantly increasing the chances of current and future decision-making and action that will support urban resilience. There is now a wide literature that provides valuable guidance on how to improve adaptive capacities. It draws on concepts and theories that are still developing through debate, learning-by-doing and case-study. Municipal officials are encouraged to read this material. What is most important, however, is to develop a way of thinking that embraces change and actively supports arrangements and processes of governance that adapt proactively to this change. There is no definitive answer as to how this can be done, but we can conclude with certainty that the key element in all of this is the capacity for on-going learning.

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3 Resilience in Urban Form and Fabric

3.1 Introduction

This section explores aspects of the relationship between resilience and urban form and fabric. We first discuss resilient urban form in general, focusing on the contrasting ideas of adaptability and stability in the face of change, and how spatial planning has attempted to use strategic planning to respond to a constantly changing environment. We then discuss some of the physical planning principles that spatial planners and urban designers suggest will result in more resilient urban environments, questioning how new some of these ideas might be. Both sustainability and resilience thinking emphasise compact cities and the shift towards public transport. Some South African cities such as Johannesburg are attempting to improve public transport through the introduction of Bus Rapid Transit (BRT). We examine how the early introduction of BRT is affecting an area around a station, and whether it is helping the shift towards greater resilience.

The major part of this chapter focuses on density and its relationship to resilience, a major theme of our research. We discuss this relationship and the concepts that have been put forward to think about it, focusing on the idea of "resilient densities". We then draw from our research on Johannesburg to understand this more fully. South African urban spatial policies generally promote the idea of densification and, as we show, densification is happening in our cities but not necessarily in the ways planned for in city policies. We show that higher densities do appear to be associated with greater use of public transport, as theory would suggest. However, densification is occurring in very different ways in various parts of cities. We examine cases in four areas, and look at both advantages and challenges associated with processes of change in each area. This suggests that densification is a complex process that is context-specific, and it requires contextually appropriate policy responses. Too often, it is used in a broad and ambiguous way. Densification, if it is to make our cities more sustainable and resilient, needs to be more than just an increase in people or buildings per square kilometre. It needs to be accompanied by, for example, a diversification of land uses, increased access to both social and physical infrastructure, better links to public transport, and integration with public and green spaces.

The final part of this section briefly introduces "micro-scale" responses at the level of green buildings, and how households and businesses, driven by market pressures, new technology and planning policy, are moving towards more sustainable practices with regard to the use and design of buildings and associated infrastructure.

Brian Boshoff 2014

3.2 Resilient Urban Form: Responsiveness and Adaptiveness

The notion of urban form and fabric includes the physical components and layout of towns and cities, and should be considered across different spatial scales. This includes everything from individual buildings to neighbourhoods, streets and street networks, public and open space, to the entire city. As cities are systems, the resilience of the components and the connectedness between different parts of the city affects the resilience of the entire system. This connectedness does not only refer to the physical urban structures, but includes the society that lives in and uses the city as well as the natural environment in which it exists. These factors cannot be considered in isolation from one another.

Urban form can be resilient in both senses of the concept, as outlined in chapter 2 of this report. Over time and through change, urban form can maintain structure and stability, and at the same time morph and adapt to accommodate different needs and circumstances. Change and adaption of urban form can be through physical change and growth (such as changes to road networks, city expansion, replacing low-density with high-density buildings, or the introduction of new public space), or it can change in the way it *functions*. For example, while a neighbourhood's buildings, road network and public space may remain fairly unchanged over time, the income and demographics of groups who live there may diversify and certain land uses may change. "Soft" changes can thus change how "hard" urban form performs. For example, changing land use regulations or introducing police patrols could transform the way in which a neighbourhood performs without changing its form physically.

Urban form is in a process of continuous change that is the result of a constant stream of exchanges and processes of restructuring. This includes: shifts in the way space, land and buildings are used; changes of the people who inhabit the city; the fluxes and movements of people and goods; and how all of these are shaped by economic, social and cultural dimensions, formal and informal forces, and more. Transformation can sometimes be aimless, sometimes ad hoc and sometimes consciously

planned towards immediate or distant goals. At times, informal, organic behaviours and mechanisms overcome rigid plans, radically transforming urban spaces at an unexpected pace. However, the spatial structure and character of the built environment are in many ways related to the needs and aspirations of an ever-changing society, living in and modifying its space over various historic periods during which different modes of development are prevalent.

Resilience thinking highlights the capacity of a system to deal with change while continuing to develop and thrive. This is achieved through responding to unexpected change, and (where possible) through anticipating change and restructuring for slow, positive evolution. Society is key in the process of structural change; human beings are active agents, driving change at the physical and non-physical levels.

Planning to avoid change, therefore, seems not just useless, but harmful (Ernstson, et al., 2010, p. 531). Rather, embracing change, adaptation and flexibility in our cities is the key. This requires a deep conceptual shift, re-centring the planning profession on a paradigm of unpredictability and abandoning the logic of "control" in favour of a more strategic dimension. This has already been seen to an extent in the shift from "master planning" to new forms of strategic spatial planning specifically aimed at taking on this challenge, as Box 3.1 shows.

Observing and decrypting spontaneous changes is also important. In order to be able to trigger and drive change, it is necessary to read the current system's behaviours and to decipher their spontaneous dynamics of change. This reading is fundamental in determining how to interact with change dynamics, by promoting positive streams of change and addressing or managing negative ones.

Embracing change and fluidity leads to a more positive perspective on informality, one which sees "incrementality" and self-organising dynamics as strengths, and where acupunctural interventions could interact with progressive systems of spatial change and social empowerment. Box 3.2 on the Kya Sands informal settlement in Johannesburg shows the advantages offered by the settlement from a resilience perspective, but also the challenges that need to be addressed by appropriate planning and development.

3.3 Resilient Urban Form: Principles and Approaches

BOX 3.1: Resilience and Strategic Spatial Planning

Strategic spatial planning can be described as a mode of planning that works with multiple possible futures – the idea that change is inevitable and plans should accommodate flexibility, exploration and experimentation (Albrechts, 2006; Balducci, Boelens, Hilleir, Nyseth, & Wilkinson, 2011; Healey, 2009). The approach attempts to integrate a variety of actors providing a means for achieving long term goals while incorporating short term actions. There are some similarities between resilience thinking and strategic spatial planning. Each approach attempts to work with a dynamic world while acknowledging that cities are spaces of change and disturbance which cannot always be controlled or anticipated. The more recent emergence of evolutionary (or socio-ecological) resilience does indeed resonate with the principles behind strategic spatial planning. It is argued that both put an emphasis on the "fluidity, reflexivity, contingency, connectivity, multiplicity and polyvocality" of urban systems (Davoudi & Strange, 2009, p. 37). The socio-ecological view of resilience proposed by Walker & Salt (2006) sees the key to becoming more resilient as first being able to embrace change, a notion also held by strategic spatial planners (Balducci, Boelens, Hilleir, Nyseth, & Wilkinson, 2011).

BOX 3.2: Kya Sands – A Resilient Informal Settlement?

It may be argued that informality and informal settlements represent a strong form of urban resilience since people have adapted to the limited work and housing opportunities in South African cities by building their own houses and generating their own incomes. Weakley's (2013) research in Kya Sands found that while the residents of the settlement are vulnerable to a number of hazards, and that living conditions are far from ideal, the settlement provides some valuable services to its inhabitants, and to the city as a whole.

The first of these is actually affordable housing, which is either free, around R200 a month when rented, or around R2000 to purchase a stand. Second is access to jobs. As informal settlements are based on (informal) markets, where possible they locate close to work opportunities. Kya Sands lies directly adjacent to two industrial areas – Kya Sand and Hoogland – which provide many work opportunities; it is also near to a number of formal residential areas such as Bloubosrand and Northriding, where many people work as domestic workers or security guards. Third is access to city services such as schooling and healthcare, which is limited in residents' rural or foreign places of origin.

Benefits of informality and informal settlements also exist for the wider city. For example, it may be argued that they take some pressure off government in providing housing and jobs in the short term. As they are also so affordable and even sometimes free to live in, they provide surrounding areas with affordable labour. This is partly because, in well-located informal settlements like Kya Sands, people can walk to work and hence have limited or no transport costs.

At the same time, residents do report that crime, fire, lack of city services (most notably electricity and sewage systems) and poor living conditions are major problems with living in the settlement. However, if informal settlements are relocated, the benefits that people enjoy in the area would be eliminated, even if physical conditions were better in the new area.

Hence it is important, when intervening in informal settlements, to address the negative aspects that they represent to their inhabitants and the city at large, but in doing this to promote the resilience shown in the settlements and by the people living there. In Kya Sands, this suggests the need for an in-situ upgrade, as the living conditions are clearly sub-standard, but the settlement is well located in relation to jobs and wider city benefits.

Dylan Weakley 2012

Conceiving cities as socio-ecological systems implies understanding them in a complex, holistic way. It allows us to consider the many interactions among physical and non-physical aspects which shape systemic behaviours and the capacity of a city to adapt, evolve and thrive. The structural order of a complex system is always the result of a process, forcing us to think in terms of relationships and patterns. In every complex system, including cities, these processes operate in both directions: the urban form and spatial structure of cities influences where and how people live in the city, the way economic activity occurs, and the resources used (such as energy and water), but these elements also shape the spatial organisation of cities.

Planning and designing for resilience aims to address the increasing environmental, social and economic stresses associated with the impacts of climate change, resource scarcity and other unexpected future shocks, including economic ones.

Planning and designing for resilience aims to address the increasing environmental, social and economic stresses associated with the impacts of climate change, resource scarcity and other unexpected future shocks, including economic ones. As a consequence, in a resilient city, the physical, social, ecological and economic health of its citizens is directly connected to the way in which urban structures deal with the relationship between spatial forms and processes, balancing redundancy and durability, persistence and change. In many cases, however, the built environment needs to adapt in order to function better.

One of our studies explored the way writers have linked resilience to urban form and the spatial organisation of cities (Groesser, 2013). Salat et al (2011) studied numerous cities in Europe, North America and the Far East, and has developed an argument based on "the resilience of fractal urban forms". Similar to the perspective of evolutionary resilience, the argument is that the urban form of a city must adapt over time, transforming from state to state if it is to be a "resilient living city". Complexity is also crucial to the resilience of a city. The more structured and multi-connected the form of a city, the better it will absorb disturbance and modify its structure. Drawing from Christopher Alexander's *A City is not a Tree* (1965), Salat and Bourdic (2012a) state that, like the veins on a leaf, a resilient city has street networks that are connected in a "semi-lattice" structure. Here, as in a panarchy, roads should be connected across all levels, instead of in a hierarchical way where roads only connect to levels immediately above or below them in the hierarchical pyramid. In a tree, for example, cutting a branch would also cut off all smaller branches and twigs along that branch from the main system of the tree. However, if the branches were interconnected as are the veins in a leaf, cutting one artery would not exclude all smaller arteries from the wider system due to their connection across scales and levels.

Newman (2011) argues that a resilient city is one that is carbon neutral, has a well-distributed infrastructure, utilises renewable energy, contains a biophillic landscape, is place-based and eco-efficient, and uses sustainable transport. He also argues in his book *Resilient Cities: Responding to Peak Oil and Climate Change* (2009) that compaction is the key to making cities more adaptable to the increase in fuel prices and to mitigating climate change. ResilientCity.org (2014) proposes a number of principles for resilient urban planning and design in what, they argue, means a shift away from traditional ideas of single-use zoning and privatised transportation. These include: density, diversity and mix; pedestrians first; transit-supportive, place-making, complete communities; integrated natural systems; integrated technical and industrial systems; local sources; engaged communities; redundant and durable-life safety and critical infrastructure systems; and resilient operations. However, not all of these ideas are new to planning. Some are similar to or the same as principles and approaches that emerged with the critique of modernist planning, such as new urbanism. In the South African context, several of these ideas have long been promoted by academics such as Dewar and Uytenbogaardt (1991; 1995) and have been influential in policy for many years. This may be why some ideas seem similar to those often contained in municipal policy documents, as the following box on the Johannesburg's Spatial Development Framework shows.

One of the key elements of a more resilient urban form is a shift towards public transport and away from reliance on the car. This would enable a reduction in the use of energy, making the city less

BOX 3.3: Urban Form and Resilience: City of Johannesburg's Spatial Development Framework

In Johannesburg, many of the spatial principles associated with resilience thinking are already imprinted in the City of Johannesburg's approach to future spatial development, even if it is not recognised by the spatial planners (Groesser, 2013). Perhaps the reason for this is that spatial planners in the City have not yet developed their own understanding of what resilience looks like in space. Nevertheless, the Spatial Development Framework itself has built on new urbanist ideas (such as compaction, mixed-use, transit-oriented development) for a number of years. This begs the question: is resilience planning really a paradigm shift (especially in spatial planning), or merely a new concept to describe the same principles that planning policy has been promoting for years?

BOX 3.4: The Impact of BRT at a neighbourhood level: Diepkloof, Soweto

BRT has become a leading public transport investment strategy in South Africa. Two broad objectives of the investment include improving the service quality of public transport as well as providing a catalyst to drive spatial transformation. It is widely understood that public transport stations can generate significant land development investment due to the accessibility benefits they present. In the case of Diepkloof, the station had been in place for about two years at the time of the study. Researchers found that:

- BRT users said that the system had a positive impact on their travel and lifestyle.
- The introduction of the system reduced the local taxi activity in the area.
- Although there has been relatively significant development activity in Diepkloof over the past decade, the impact of the BRT on building intensification is less clear.
- There is a limited indication that the BRT has benefited businesses located in close proximity to the station.
- A major private-sector development, the Diepkloof Square shopping complex, which was built on municipal land in 2012 about 1 km from the station, shares no clear connection to the BRT investment but has had a number of significant impacts on the area:
    - an overall reduction in population density (the land previously accommodated a densely populated informal settlement);
    - improved access to a range of goods and services which previously were not available in the area;
    - negative impact on small local retail businesses in informal shops and market stalls south of the shopping centre.

These findings highlight the current institutional division between the development of land use and transport, and the lack of co-ordination between the two initiatives. While the mall has some benefits for residents, it is not strongly oriented to public transport. Seeking to combine the benefits offered by both the BRT and the shopping mall through improved integration would arguably support the growth of a more sustainable and resilient urban landscape. Furthermore, the access and mobility benefits presented by the BRT system provide a compelling case for densification around the station to ensure that more people are able to access the system.

vulnerable to declining oil resources and rising prices, and would improve everyone's accessibility to the benefits of the city. In theory, improved public transport systems should make possible dense, mixed-use development close to stations, thus increasing convenience and improving access to services and facilities. Several South African cities, including Johannesburg, have invested in Bus Rapid Transit systems as a way to improve public transport in the city. Our research investigated how the introduction of the BRT affected neighbourhood development in Diepkloof, Soweto. Box 3.4 provides a summary of the findings; it shows that while the BRT did have some positive effects, more co-ordinated efforts with other initiatives in the area could have enabled a stronger movement towards sustainability and a more resilient city.

3.4 Density and Resilience

For many years, increasing density has been seen as key to urban sustainability. While density is an important dimension of resilient cities, a resilience perspective helps to unpack the complexities of density and enables us to develop a more nuanced policy approach, moving beyond quantitative calculations of built or population densities, to looking also at qualitative dimensions. Increasing people or buildings per square kilometre will not result in greater resilience on its own, and has to be accompanied by a number of other changes.

There are many links between a more dense system and resilience ideas. A dense urban system is consistent with the resilience principles of redundancy, diversity and vibrancy, among others. Resilient cities would be characterised by diversity, density and mix of uses/users, building types and public spaces. Dense mixed-use neighbourhoods allow for the effective functioning of all types of business, social and cultural activities, and at the same time require relatively low inputs of energy for transportation (of goods, services and people). In a resilient city, every neighbourhood would be able to provide the needs of daily living within walking distance, underlining that resilience requires us to maximise the active use of space and land, and to reduce the carbon footprint of urban development (for instance by enabling people to walk or cycle, instead of using a car). Our research on Johannesburg shows that there is a clear link between the use of public transport and density, even in higher income areas, as Box 3.5 shows.

Resilient cities would be characterised by diversity, density and mix of uses/ users, building types and public spaces.

Still, there are risks associated with higher density linked to the amplified effects of negative behaviours; hence the concept needs to be seen in a complex way.

We cannot just think about urban density in terms of quantitative measures such as the number of inhabitants per square meter, or the measures of physical elements like buildings, streets, public space and infrastructures. We need to understand the context and the qualitative dimensions too (see Figure 3.2). We have to recognise that the way that people live in, use and move in the city is highly influenced by social and cultural beliefs, economic status and habits, specific social dynamics and so on. In turn, this influences the way in which the built environment is perceived, used and transformed by people. Social elements therefore impact strongly on uses of space/activities/amenities and vice versa.

We need to incorporate the complexity of everyday living into the "hard" dimension of density (i.e. the quantitative calculations of spatial elements), so the "soft" dimension becomes fundamental (i.e., aesthetic or symbolic qualities of the physical environment, people's behaviours, needs and perceptions, social networks and dynamics, patterns of usage, and so on).

The picture surrounding density is therefore fuzzy. However, resilience theory helps us to understand that in reframing density, we first need to talk about "densities" rather than just "density". By enlarging scope and definition of the concept, resilience theory helps us to include (and impact on) quality of life, liveability, perceived equity and sustainability, and other non-physical but crucial factors that are needed to raise decision-makers' awareness of the wider impact of density on the design of

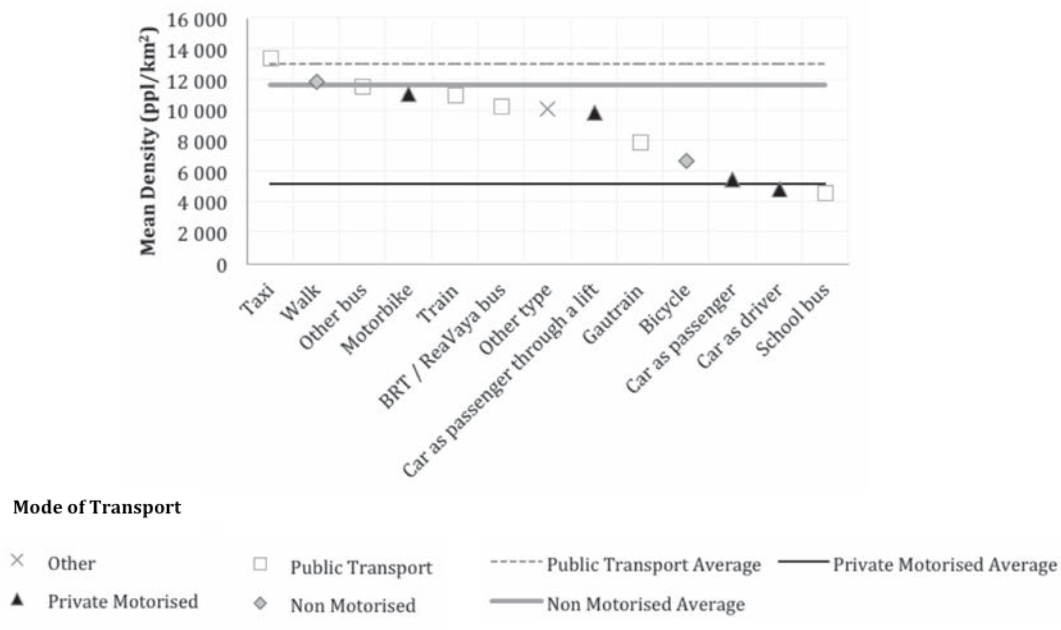
BOX 3.5: Urban Density and Public Transport Use in Johannesburg

One of the reported benefits of increased density is making public transport more viable. Weakley (Forthcoming) uses transport and density data for Johannesburg to show that this relationship does exist. Results show that people living in lower-density areas are more likely to use private, motorised transport while higher-density urban dwellers are more likely to use public transport, walk or cycle. Further, while household income correlates to the use of different modes of transport (with higher-income households more likely to use cars, and lower-income households to use public transport), across all income categories in the data, those who use public transport live in higher densities than those who do not. This shows that even within the highest income category in the census, those who use public transport live, on average, in higher densities than those who do not.

The data highlights two main reasons for this correlation. The first is cost, with households who use public transport spending on average R679 on transport a month, while those who do not spend on average R1042 a month. Added to this is the fact that household income and density are inversely proportional. This means that, on average, higher-density urban dwellers earn less than those living in lower-density areas. A second reason relates to the walking time to public transport. Here density and walking time are also indirectly proportionate: the average walking time to the nearest public transport is shorter in high-density areas, and vice versa.

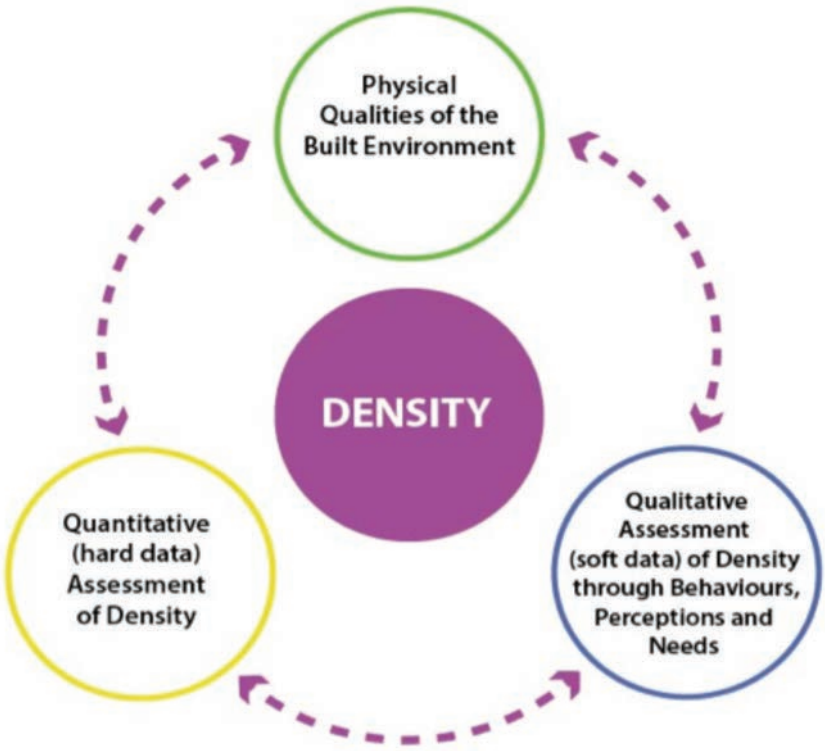
High density urban areas seem to provide a good market for public transport (see Figure 3.1). This is so because public transport is generally cheaper than the use of private cars. In the South African context this is important; data from the study shows higher densities generally mean lower incomes. A second and probably more prevalent factor is the simple fact that if public transport infrastructure is installed in a high-density area more people will have walking access to it than if it were installed in a lower-density area. This means that there is a bigger market in higher-density areas, which in turn means that public transport investments are more likely to be successful there.

FIGURE 3.1: Main Mode of Transport by Mean Residential Density in the City of Johannesburg



urban environments. As we show below, a simple increase in density as measured by quantitative methods does not in its own right lead to greater resilience. Rather, the way this occurs and whether it is appropriately managed is important. Therefore, urban density must be defined and managed in relation to a series of general principles to enhance systemic resilience. However, while the principles are general, the management of density (meaning both the way to conceptualise and address density) must be case-specific.

FIGURE 3.2: Conceptual Diagram of the Aspects of 'Resilient Densities'



3.5 Resilience, Density and South African Cities

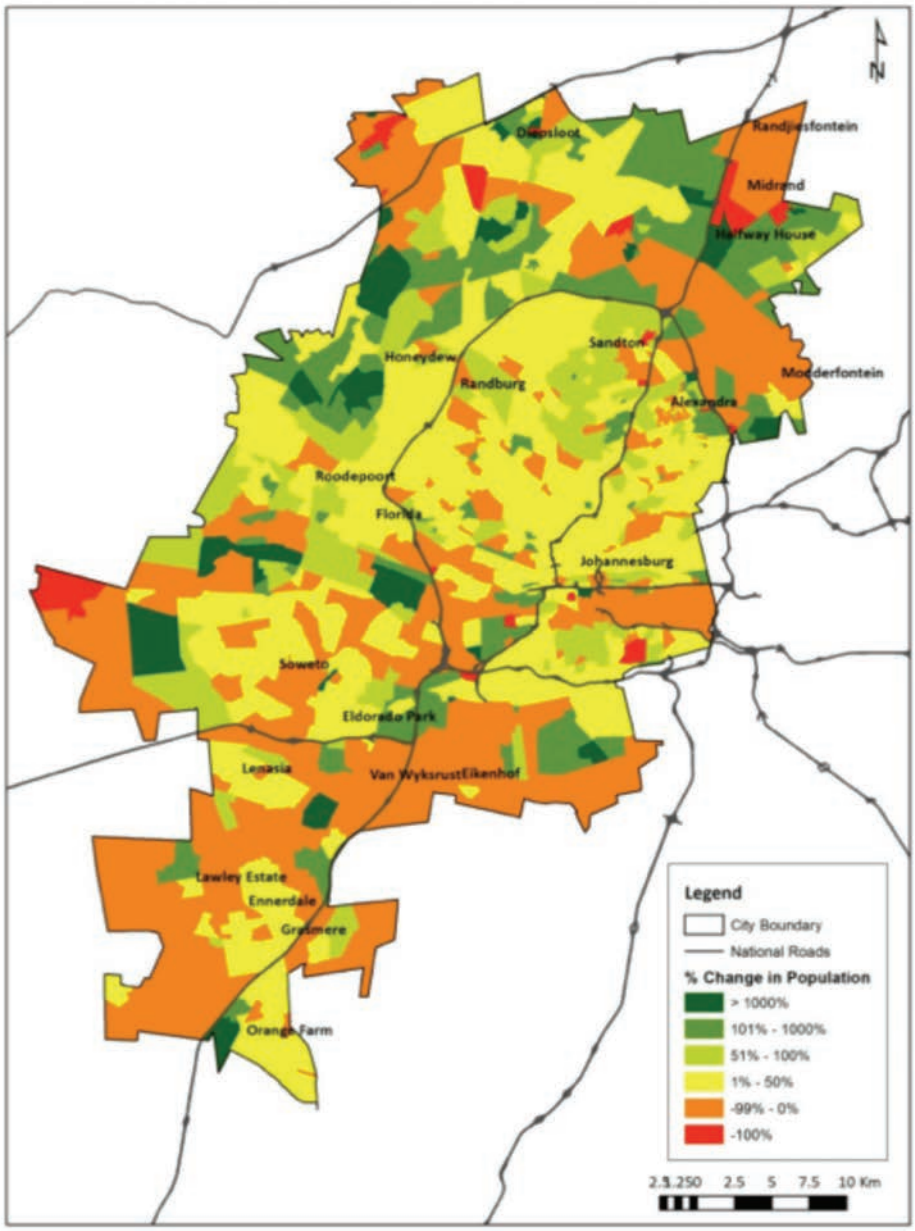
South African cities have been heavily shaped by apartheid spatial policies, which sprawled and fragmented the cities' fabric. In the post-apartheid era, sprawl and low-quality, mono-functional environments have been extended through state-driven RDP housing developments on the outskirts of cities where land is cheaper (Charlton & Kihato, 2006). At the same time, the private property market has continued to develop sprawling townhouse complexes and new economic nodes in other parts of the urban periphery, often contrary to formal policy (Todes, 2006). New forms of spatial inequality and division have emerged. Although post-apartheid policies talk about compaction, integration, and a more sustainable and equitable urban environment, these policies have had limited impact in the desired direction. Spatial plans frequently advocate densification – especially residential densification, often tied to transit-oriented development policies, as in the case of Johannesburg.

The relationship between planned and "real" densities, however, is complex. While the city of Johannesburg was planning for densification around new public transportation corridors, densification was happening spontaneously in other parts of the city and in very different ways. Backyard units emerged in former townships and RDP housing projects; townhouses replaced detached houses in other areas; occupancy levels rose in flats and houses in inner city areas; and growth on the outskirts

of the city in the form of both swathes of townhouse complexes and RDP housing projects was denser than in old suburban areas. Figure 3.3 shows the changing density in Johannesburg. In the map, green areas show those of highest densification, with orange and red showing those areas in which densities have declined.

The city of Johannesburg has indeed become denser, but not always due to direct government intervention and not always with positive effects on its functioning, its sustainability or the quality of life of its inhabitants. Rather, some of those spontaneous dynamics caused negative feedback since the municipality had not been ready to deal with rising densities in those areas. For instance, in the absence of planning for increased densities, infrastructure and services became overloaded in some of these areas, resulting in problems such as traffic congestion and waste in streets. In higher-income areas where densification took the form of townhouse complexes, density levels were still too low to facilitate a move towards public transport, with the result that densification has exacerbated traffic congestion.

FIGURE 3.3: **Density Change in the city of Johannesburg**



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Box 3.6 provides a summary of our four case studies, and points to the very different and diverse outcomes of densification. There are both positive and negative dimensions of densification in the four areas, as well as varying needs for management of and response to these processes.

The influence of these kinds of spontaneous dynamics in an area is substantial, as it is often associated with new patterns of occupation and usage. All this clarifies even more how complex it is to engage with a substantial and structural change in urban density.

As we have stated above, densification is a complex, multi-layered notion. Residential densification should be seen in a developmental way, and should contribute to improved environmental quality involving a diverse and mixed built environment, promoting social mixing and producing chances for social empowerment by enhancing economic vibrancy.

A density strategy should provide the means to shift the growth trajectory of a city towards a more efficient, equitable, environmentally sound and therefore sustainable direction.

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A density strategy should provide the means to shift the growth trajectory of a city towards a more efficient, equitable, environmentally sound and therefore sustainable direction. It needs to be developed at a range of scales, from the site-specific and neighbourhood scales to the urban and city scale, where wider actions and interventions support those at more local scales. We need to look for opportunities to create better spaces in the existing urban fabric, but also look for patterns of change occurring spontaneously in various areas and across the urban system. Beyond simply density, a variety of patterns of change are occurring at the level of the micro-urban fabric, as the following section shows.

BOX 3.6: Densification Case Studies from Johannesburg

Hillbrow

Area	Population		Density (people/ km2)		Percentage Increase
km2	2001	2011	2001	2011	2001-2011
1.08	62 240	74 131	57 443	68 418	19.11%

- Densification Typology: Interior densification
  - Densification through multiple people and families sharing rooms and flats with little change to exterior built form.
- Qualitative Findings
  - Positive
    - Increased diversity of land uses. Where formal services are limited, they are provided for informally.
    - Good walkability. Most functions are in walking distance.
    - Good sense of identity and social networks.
  - Negative
    - Living conditions sometimes cramped and not up to official standards.
    - Infrastructure struggling due to aging and below-capacity networks.
    - Formal social services are limited, but these are subsidised by informal ones.

Houghton Estate

Area	Population		Density (people/km2)		Percentage Increase
km2	2001	2011	2001	2011	2001-2011
6.94	6 641	7 866	957	1 134	18.45%

- Densification Typology: Townhouse infill
  - Densification through large single stands being sub-divided and developed into townhouse units.
- Qualitative Findings
  - Positive
    - Diversification of income (although still generally high income), racial and religious groups.
  - Negative
    - Increased traffic.
    - Little diversification of land use, still mainly residential.
    - While residents' incomes have diversified somewhat, it remains an upper income and fairly exclusive area.
    - Car-oriented neighbourhood.

Bram Fischerville

Area	Population		Density (people/ km2)		Percentage Increase
km2	2001	2011	2001	2011	2001-2011
13.2	19 827	91 403	1 504	6 933	361.00%

- Densification Typology: Backyarding
  - RDP settlement that has seen infill, mainly in the form of informal backyard houses and extensions.
- Qualitative Findings
  - Positive
    - Community has evolved from a sterile, homogeneous RDP settlement into a diverse, mixed use one, with much of this development being informal.
    - Densification has resulted in economic gains for owners, and affordable access to the city for tenants.
  - Negative
    - As buildings are informal, there is limited building regulation and thus living conditions are sometimes sub-standard.
    - Public space, environment quality and connectivity can be improved; this could be addressed by municipal intervention.
    - Infrastructure is under strain.
    - Well-connected but not in regard to jobs.

Northriding and Bellairs Park

Area	Population		Density (people/km2)		Percentage Increase
km2	2001	2011	2001	2011	2001-2011
2.93	1 638	9 034	559	3 081	451.64%

- Densification Typology: New townhouse development
  - Previously smallholdings that have been subdivided and transformed into large, gated townhouse complexes.
  - Qualitative Findings
    - Positive
      - Houses are elatively affordable and have relatively high rent, so there is a good return on investment.
      - People report that they have good access to shops.
    - Negative
      - Little community cohesion.
      - Extremely heavy traffic (due to the smallholding roads not having been upgraded with development).
      - Limited access to public space.
      - Suburb not walkable, car-oriented.
      - No integration between land uses. Suburbs consist of townhouse complexes and malls.

3.6 Micro-scale Responses and Market-mediated Transitions to Greener Urban Areas and Buildings

Analytical concepts such as the ecological footprint and urban materials flow can be used to study the decoupling of urban systems from current excessive resource and environmental impact. The critical resource indicators for ecological footprint (EF), urban materials flow analysis (EMFA) and decoupling studies are land, energy, water, waste, food and materials. Decoupling strategies also focus on demand-side management interventions such as densification, improved energy efficiency, renewable energy for distributed generation, and the three Rs (reduce, reuse and recycle). Behaviour change is key in driving through these changes.

At the micro-scale, the strategies translate into interventions which can be implemented at the building-scale together with the associated behavioural change. Escalation in cost of optimally located land (in terms of purchase and municipal rates), construction materials, electricity and gas as well as water has started to insert market-related influence on people's choice and behaviour in relation to critical decisions such as location of homes or office space, the size of the built area versus open spaces (including landscaped yards with service requirements).

Through such market-mediated behaviour change, there has been voluntary scaling down of spatial consumption in key urban areas which is characterised by the following:

- Households opt for smaller and more compact homes (within the 100m^2 range). This translates to reduction in both the land-take as well as materials consumed in construction and maintenance/ servicing of such properties.
- Businesses and organisations opt for flexible/reduced workspace per worker (including ICT-mediated work patterns) which has similar spatial/resource implications as the household responses above.
- There has been a prioritisation of voluntary and mandatory adoption of green building practices, with energy and water efficiency as well as renewable energy as the key interventions. The voluntary green buildings rating tool of the Green Building Council of South Africa (GBCSA) and the mandatory Energy Efficiency Regulations for new buildings (SANS10400-XA) are some of the examples in practice so far. Mandatory water efficiency regulations are expected within the next two years.
- This has now gone to the extent where municipalities such as Cape Town allow for grid-interactive connections for properties through which surplus power from roof-top photovoltaics or other technologies can be fed to grid at an agreed tariff to the property owner. Mandatory water efficiency regulations are expected within the next two years.
- There is increasing adoption of extended life of buildings (such as conversion and upgrades of inner-city buildings rather than demolitions), as well as reusing and recycling construction materials into new building components.
- Measures in urban agriculture at various scales are also starting to emerge in response to food insecurity and as a measure of trying to close the water-waste-water resource loop.

Although such market-mediated micro-scale interventions are crucial in urban decoupling pathways for sustainability transitions, they also highlight the significant risk of exclusionary green urbanism. In that scenario, households and businesses who can afford to do so buffer themselves with green technologies while the poor continue to be subjected to unreliable, low-quality services as the related infrastructure weakens and deteriorates.

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NOTES

1 Using data from the Gauteng City Region Observatory's Quality of Life Survey data, 2011 (GCRO, 2011)

2 Using the census 2011 sub-place layer (Quantec, 2013)

4 Enhancing urban resilience through green infrastructure[1]

4.1 Rethinking Urban Ecological systems

The concept of green infrastructure has emerged internationally as a way of understanding how green assets and ecological systems function as part of the infrastructural fabric that supports and sustains society. Green infrastructure refers to the interconnected set of natural and man-made ecological systems, green spaces and other landscape features. It includes green assets – networks of planted and indigenous trees, wetlands, parks, green open spaces, original grassland and woodlands – as well as building and street-level design interventions, incorporating vegetation such as green roofs (Schaffler, et al., 2013).

> "For many decision makers the environment remains a luxury good, deserving of attention and budget resources only once more pressing needs with regards to housing and basic services have been satisfied, or in order to prevent or respond to a natural catastrophe. It is a view that fails to acknowledge the important linkages between human well-being, development and the health of the natural environment (Cooke et al, 2010), but which remains prevalent due to the systematic discounting of environmental value and the perceived lags between environmental investments and human benefit." (Cartwright & Oeloffse, 2014:14)

The functioning of green assets has assumed an infrastructural role through the idea that ecosystem services can serve similar purposes to traditional grey infrastructure. The rationale behind this approach is that green assets and green infrastructure deliver ecosystem services which can provide more sustainable infrastructure alternatives for cities in the future (The URBES project, 2013a). Ecosystem services are defined as the benefits supplied to humans by nature (Bolund & Hunhammar, 1999). Urban ecosystem services can range from air purification, water flow regulation, erosion reduction and disaster risk mitigation (The URBES project, 2013a). Other services provided by green infrastructure include the provision of recreational and cultural space and green space, for urban food production.

Cities have become a central nexus in the relationship between people and nature as they have become sites for both the demand and use of ecosystem services (Elmqvist, 2014). Ecosystem services typically found in cities include food, water, construction material and waste assimilation, and the source of many environmental impacts.The close relationship that exists between human and natural systems implies that cities can neither become sustainable nor resilient until they have acknowledged their dependence

on ecosystems (Elmqvist, 2014), and the value of their green assets. It is therefore necessary to start considering the importance of managing green infrastructure in urban contexts (Elmqvist, 2014) and its benefits for city-level planning and management. This is through its profound impacts on land use, human welfare, social equity and sustainability in urban contexts (Ahern, 2011).

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4.2 Green Infrastructure for urban resilience

Multi-functionality of ecosystem services

Walker et al. (2004) define urban resilience as the capacity of a system to absorb disturbance and to reorganise while undergoing change, to retain similar function, structure, identity and feedbacks. Creating urban resilience is a complex and multi-dimensional challenge for urban sustainability planning and design (Ahern, 2011; The URBES project, 2013b). This is because it requires a proactive and deliberate response to urban challenges or risks (Folke, 2006; Pelling, 2003). Ahern (2011) outlines key design principles for building urban resilience and addressing resilience challenges faced by cities. These principles present a way forward for considering the uptake of resilience programmes on the ground. The principles include multi-functionality, redundancy and modularisation, biological and social diversity, multi-scale networks and connectivity, and adaptive planning and design (Ahern, 2011).

A key challenge for addressing the resilience of cities is that many urban problems are locally generated (Bolund & Hunhammar, 1999). The best way to deal with these problems is through local-based solutions that can offset the impacts in situ (Bolund & Hunhammar, 1999). An alternative solution for addressing key resilience challenges faced by cities is through the uptake of an ecosystems approach and through the implementation of green infrastructure. This allows for urban-based problems to be addressed in situ, and allows for the uptake of all the design principles defined by Ahern (2011).

> "Green infrastructure provides a space for habitat and biodiversity, which in turn provide services to the urban environment that are not available through traditional grey infrastructure… the provision of services is therefore an important aspect of green infrastructure" (Dunsmore, 2014:2).

Bolund and Hunhammar (1999) define a handful of urban green assets and the multi-functional services that they provide in the urban context. The multi-functional characteristics provided by ecosystems and their services are critical in understanding how green assets and infrastructure can create more resilient cities. Focusing on trees (including street trees) as one example of urban green assets that provide ecosystem services, Bolund and Hunhammar (1999) state that they provide air filtering, micro-climate regulation, noise reduction, rainwater drainage (urban forest) and create recreational and cultural values (see Table 4.1 for other examples).

In contrast to many grey assets, which are typically geared towards a single purpose, natural systems perform a range of functions.

In contrast to many grey assets, which are typically geared towards a single purpose, natural systems perform a range of functions. Utility networks in conventional infrastructure tend to remain dormant due to their mono-functional design, unless their specific service is required; this means that they draw on vast resources to perform a single function (Belanger, 2009; Egyedi & Spirco, 2011). Ecological systems, on the other hand, are naturally multi-functional, simultaneously providing a suite of services such as flood alleviation, cooling heat islands, carbon capture, water filtration, local food production and the provision of spaces for people and nature to reconnect (Roe & Mell, 2012).

TABLE 4.1: Urban ecosystems generating direct services

	Street tree	Lawns/ parks	Urban forest	Cultivated land	Wetland	Lakes/ sea
Air filtering	X	X	X	X		
Micro-climate regulation	X	X	X	X	X	X
Noise reduction	X	X	X	X		
Rainwater drainage		X	X	X	X	
Sewerage treatment					X	
Recreational/cultural values	X	X	X	X	X	X

Source: (Bolund & Hunhammar, 1999)

Based on Ahern's (2011) resilience principles, when a function or service is provided by a central entity of urban infrastructure it is more vulnerable and likely to fail. When the same function is provided by a distributed or decentralised system it becomes more resistant to disturbance. Green infrastructure allows for redundancy and modularisation – that is, spreading risks across geographical areas, time and multiple systems. This is a result of the social, physical and economic diversity of green infrastructure that forms part of an effective strategy for supporting urban resilience (Ahern, 2011).

In urban environments, the connectivity of built systems is generally robust and often over-designed. However this is not necessarily the case for natural systems (Ahern, 2011). The fragmentation of natural systems can lead to the vulnerability of urban landscape elements, creating significant impacts on ecological processes. Connected natural systems networks are thus critical for building resilience capacity as this maintains functional connectivity despite disturbances to the network.

Planning for resilience in cities using a green infrastructure approach

Developing urban resilience through green infrastructure planning involves understanding the functionality of ecosystems and how they can be used to benefit society. The importance of ecosystem valuation is emphasised in developing a business case for planning and investing in green infrastructure (De Wit et al., 2009).

From a strategic planning perspective, green infrastructure offers a unique opportunity for adaptive planning and design through natural resource management (Ahern, 2011). The multiple services provided by ecological assets can maximise the delivery of services and address critical infrastructure backlogs. This shift in thinking involves incorporating the multifunctional services that could be provided by one ecological asset in planning. This includes examining the interactions between different ecological assets, and evaluating how they interact with grey infrastructure. Box 4.1. Briefly discusses the consideration of cemeteries as green infrastructure, outlining the many environmental services they can provide for cities.

BOX 4.1: Cemeteries as Green Infrastructure

Cemeteries can be viewed as elements of green infrastructure, and can be planned and designed so that they provide both social and ecological services. Those that have reached full capacity and are either not well-maintained or have been abandoned can be rejuvenated by including green infrastructure elements within them. Being planned as part of the green infrastructure network automatically strengthens their ability to deliver ecosystem services that contribute to the resilience of urban spaces. This goes beyond viewing them as spaces that only provide the unique function of burial and the spiritual and social aspects associated with it. For instance, cemeteries can provide ecosystem services such as water retention, reducing urban heat-island, flood and soil erosion control and preserving biodiversity. In this way, they can help conserve, protect and restore natural resources so as to influence adequate land-use and development practices and contributes to increased urban resilience.

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The premise of green infrastructure planning is that if ecosystem services are valued and systematically planned alongside the services produced by conventional infrastructure, they can contribute to society's everyday functioning and build urban resilience at the same time. (The URBES Project, 2013c). This rationale encourages the extension and maintenance of existing green networks, and the implementation of green-grey engineered solutions. A combined green-grey approach is a specialist form of engineering infrastructure that replaces conventional elements for green assets, using a green infrastructure approach (Pitman & Ely, n.d.).

Natural and engineered green infrastructure solutions can create unprecedented opportunities for building resilient cities for the future. These green alternatives are explored through two examples that address storm-water challenges – a natural approach, and an engineered approach. An example of a natural green infrastructure option would be to design and develop a park using sustainable design principles so that it provides both recreation and flood attenuation services. In this way, a park can provide both recreational and storm-water management services (Sustainable Cities Institute, 2012).

An engineered green infrastructure approach could use vegetated swales, storm-water planters, rain gardens, vegetated curb extensions, and green gutters and roofs, which act as combined grey-green infrastructure to attenuate storm-water (Figure 4.1). Through pairing the correct green asset design with the grey infrastructure in localised areas, the lifecycle costs associated with implementation and maintenance of the overall solution can be reduced over the long term. In addition to the ecosystem services that are provided, the maintenance of these networks can provide place-based jobs that can absorb unskilled workers into the workforce and thus enhance livelihoods. At the same time, green assets developed to extend grey networks can assist with water purification or storm-water attenuation. Additional benefits include increased infiltration, which can reduce short-term drought impacts, as well as erosion control and shade, which can prolong the lifespan of existing grey infrastructure.

FIGURE 4.1: Green infrastructure has been used to alleviate the effects of storm-water on grey infrastructure. These images indicate methods of incorporating grey and green infrastructure to meet storm-water challenges. (Source: Bioform et al., 2011.)

4.3 Urban resilience in city–regions

Co-ordinated green infrastructure efforts require the input and involvement of multi-level and multi-stakeholder actors to support the uptake, planning and management of green networks across administrative boundaries. Thus city–regions create an opportune governance space to begin to address green infrastructure interventions. Transitions in the planning, management and budgeting of related green infrastructure programmes, using a multi-scalar approach, can allow for maximum benefits provided by green infrastructure over the long term.

Table 4.2 highlights key examples of green infrastructure plans that address challenges, and provides an existing evidence base for the uptake of a green infrastructure approach for increased urban resilience.

The following section reflects on some aspects of green infrastructure in the Gauteng City-Region.

TABLE 4.2: Overview of green infrastructure plans and guidelines and how they have been design to address key issues in cities and city-regions around the world.

Name of Green Infrastructure Plan	City / Country	Key focus	Source
The All London Green Grid	London, United Kingdom (UK)	Greening urban environments to conserve nature, increase access to nature, adapt to the impacts of climate change and encourage healthy living.	Greater London Authority (2011)
New York City Sustainable Storm Water Management Plan	New York, United States of America (USA)	Create combined green-grey engineering to address storm-water overflow challenges in the city.	NYC (2007)
Ecological Region	Paris, Ile-de-France	Decision-making tool for the acquisition, development and management of green spaces to ensure the inclusion of biodiversity in planning and management, the provision of urban food production, and climate change adaptation.	Metropolis (2011)
Community Green: using local spaces to tackle inequality and improve health	West Midlands and Greater Manchester, UK	The significance of urban green space on human health and the well-being of different socio-economic and ethnic communities, the impact of varying urban green space quality on health and well-being, and how green space can successfully be used to target inequality.	Commission for Architecture and the Built Environment (CABE), (2010)
The value of green infrastructure: a guide to recognising its economic, environmental and social benefits	Mixed applications, USA	Mixed benefits of green infrastructure in urban contexts. Generally refers to economic, environmental and social benefits, but more specifically to the reduction of storm-water runoff, energy use, improved air quality, reduced CO2, urban heat island effect, community liveability and improved habitat.	Center for Neighbourhood Technology & American Rivers (2010)
Green City Clean Waters: The city of Philadelphia's programme for combined sewer overflow control	Philadelphia, USA	Enhance watersheds and catchment areas by managing storm-water with innovative green infrastructure to meet urban demands in a cost-effective manner.	Philadelphia Water Department (2014)
Life: building up Europe's green infrastructure. Addressing connectivity and enhancing ecosystem functions	Regional programme, Europe	Combat biodiversity loss through increasing the connectivity of green networks, strengthening the functionality of ecosystems for delivering services to mitigate and adapt to the effects of climate change, increasing resilience of natural systems, promoting integrated planning, and contributing to a greener economy.	European Commission (2010)

4.4 A green infrastructure approach for the Gauteng City–Region

The GCR attracts people because of its relative success in creating job opportunities, the greater availability of basic services such as water, housing and sanitation compared to other parts of South Africa, its proximity to urban amenities, and higher standards of living (Schaffler, et al., 2013). As a result, Gauteng's population has grown faster than that of all other provinces, at an annual rate of 2.7% between 2001 and 2011 (GCRO, 2012). These growth rates mean that Gauteng may have to meet the needs of 16 million people by 2025, and 20 million people by 2050 (Schaffler, et al., 2013). The current population densities are likely to increase from an estimated 672 to 859 people per square kilometre by 2020 (GCRO, 2012).

The need to stretch resources to meet the increased demand for shelter, water, food, energy and waste removal creates compounded challenges for the city–region.

Rapid population growth and increased population densities create challenges for Gauteng amid existing service delivery and equity concerns. The need to stretch resources to meet the increased demand for shelter, water, food, energy and waste removal creates compounded challenges for the city–region. Added to this are waste and pollution, and the fragmentation of natural and green spaces. While the provision of infrastructure meets developmental and social agendas, the use of traditional infrastructure "blankets" Gauteng's land with impervious surfaces. This once again compounds challenges related to storm-water runoff and heat-island effects, and impairs the functioning of natural systems that provide air and water filtering services and regulate natural cycles (The URBES project, 2013b).

The following priorities have been identified in the Gauteng Provincial Government's (GPG) Programme of Action (2009–2014): creating decent work, promoting quality education, prioritising health care, food security, reducing crime, building sustainable communities, and developing good governance. In an attempt to address these key priorities, the GPG aims to invest in public infrastructure, encourage the sustainable use and management of natural resources, and address inequality in the access to basic services (GPG, 2009).

Green assets of the GCR and existing green infrastructure networks

Existing green infrastructure networks of the GCR include a combination of indigenous grassland, mixed indigenous–exotic urban forest areas, as well as mix of planted vegetation found in private and public green spaces. The latter also includes agricultural lands located on the outer urban edges of the region. The networks of natural and planted green infrastructure connect across the GCR and spread over internal and external administrative boundaries. These networks create living corridors in built-up areas and urban nodes, providing a wide range of services to residents of the GCR.

Spatial datasets collected for the city–region reveal the mixed nature of the Gauteng landscape, where naturally occurring vegetation is interspersed with planted vegetation. Figure 4.2 provides some insight on the complexities of land transformation in the GCR. The following components are included in the map: dense trees, woodland and grassland ("untransformed"); man-made green space, urban trees, urban grass and cultivated land ("transformed"), and built-up areas ("urban"). Applying a green infrastructure approach in Gauteng includes the appreciation of both transformed and untransformed green features, including those located within the urban core.

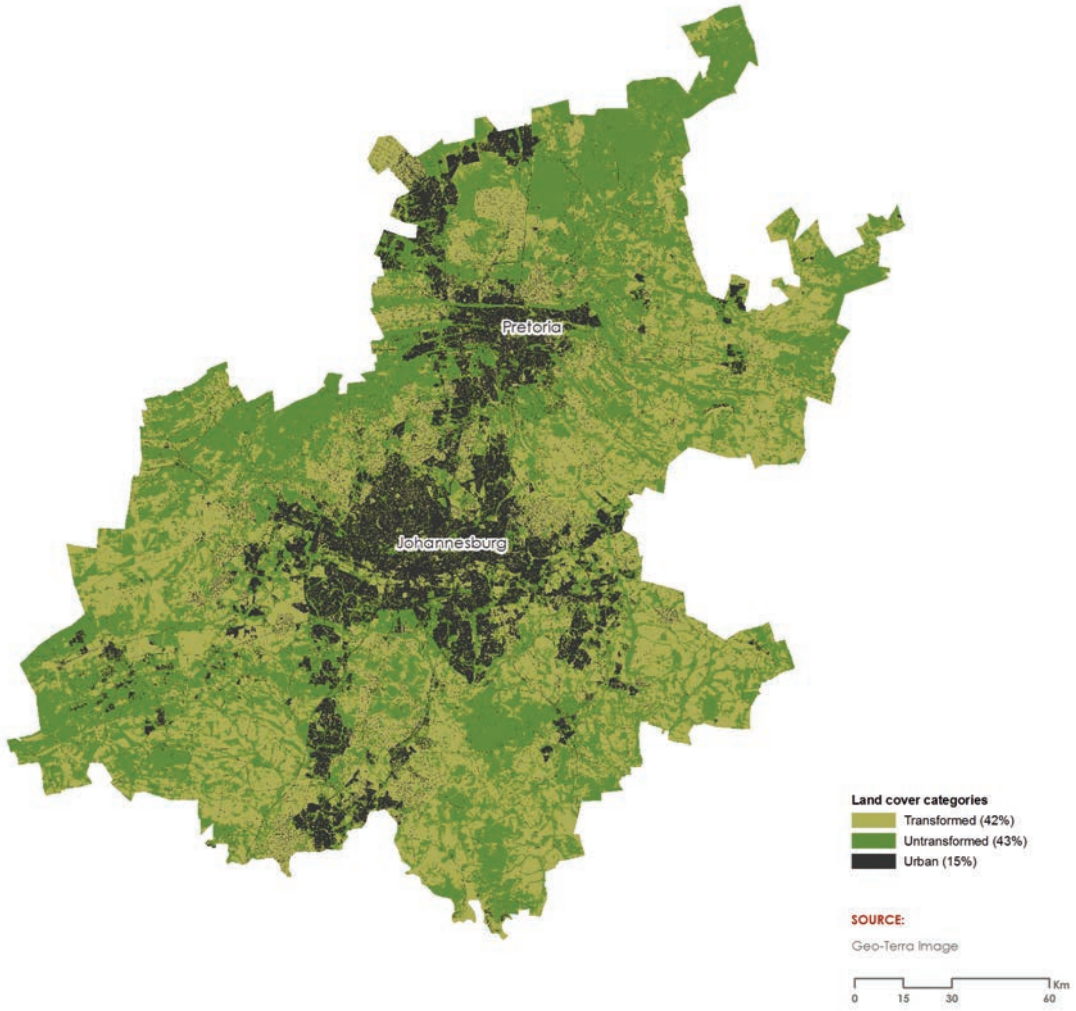
The data illustrate that while some municipalities appear to be more urbanised than others, the share of green assets per municipality is shown to be largely dominated by planted and natural grassland and commercial agriculture (Figure 4.3).

An important component of green infrastructure is the interconnectedness of the green assets in an integrated network – different forms of natural and planted vegetation, agricultural land, constructed recreation places, protected areas and hydrological networks (Figure 4.4).The idea of connectivity is important in understanding the role of planning an integrated green infrastructure network that provides necessary services and builds urban resilience.

A prominent green asset in the GCR is the large forested expanse which extends across the city–region. It is evident that tree coverage is more concentrated in the urban core than the outer edges of the province, and in overall terms, non-indigenous trees dominate the Gauteng landscape (Figure 4.5). The greatest density of trees in the province is found in the City of Johannesburg (CoJ). The forest is not uniformly distributed; there are distinct differences in coverage between north and south, and between different areas. Many of the trees in the urban forest are between 50 and 100 years old, and date back to tree-planting schemes that accompanied the mining boom in the late nineteenth century.

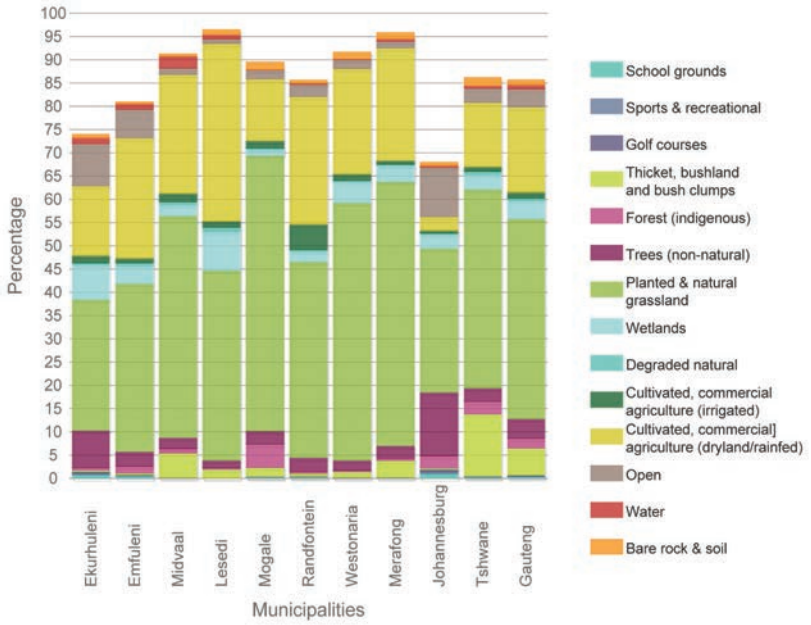
The striking socio-spatial differences in tree coverage in the CoJ are depicted in Figure 4.6, where high tree concentrations are evident in historically wealthy areas and tree coverage is sparse in informal settlements. The uneven share of green space in Gauteng has fuelled the drive to readdress the ecological disparities that were inherited from the apartheid era. Green infrastructure planning in this regard not only provides an opportunity to equalise the access to green spaces across the province, but also creates an opportunity to serve those who have been historically under-served by ecosystem services. In this way, green assets can be linked to the discourse on the rights to services and the inequality in infrastructure coverage. The obligation to improve access to green space for all individuals in Gauteng has generated strategic dialogues about relative shares of green space for a particular population group and standards for maximising access (Schaffler, et al., 2013).

FIGURE 4.2: Landscape transformation status in Gauteng



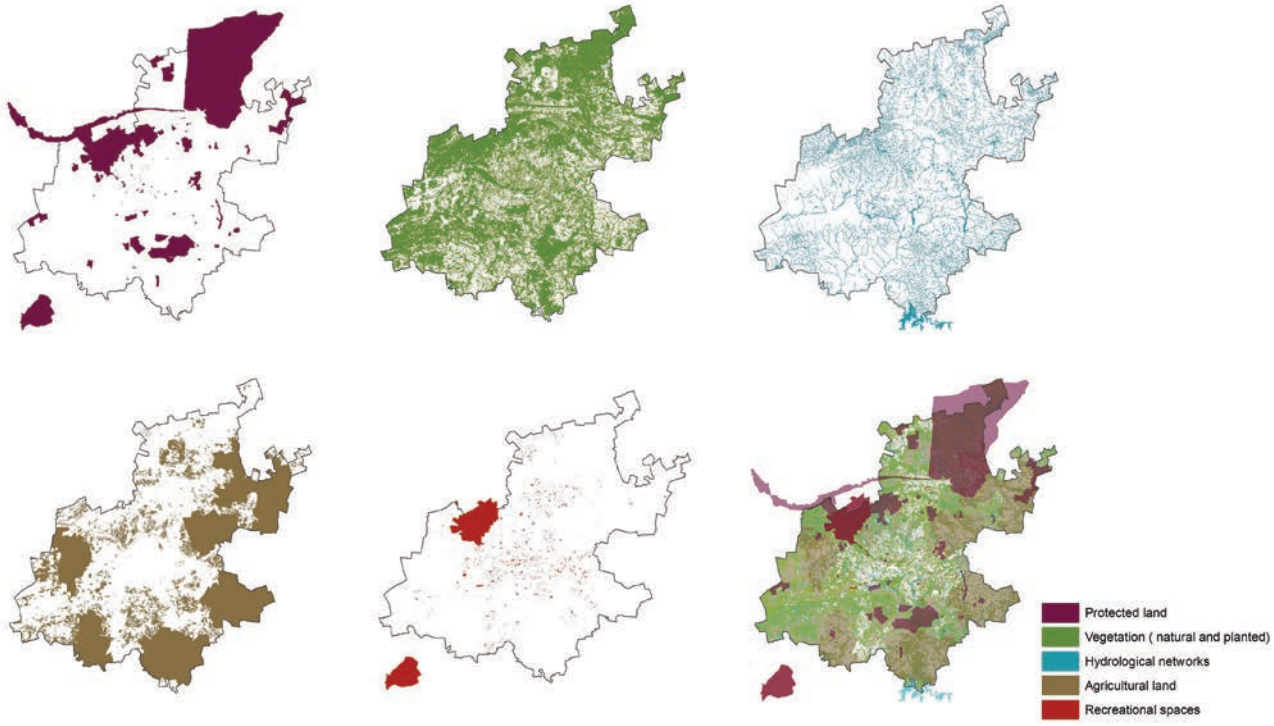
(Source: GTI 10m LandCover data, 2009)

FIGURE 4.3: Percentage of selected land-cover classes of each municipality in Gauteng



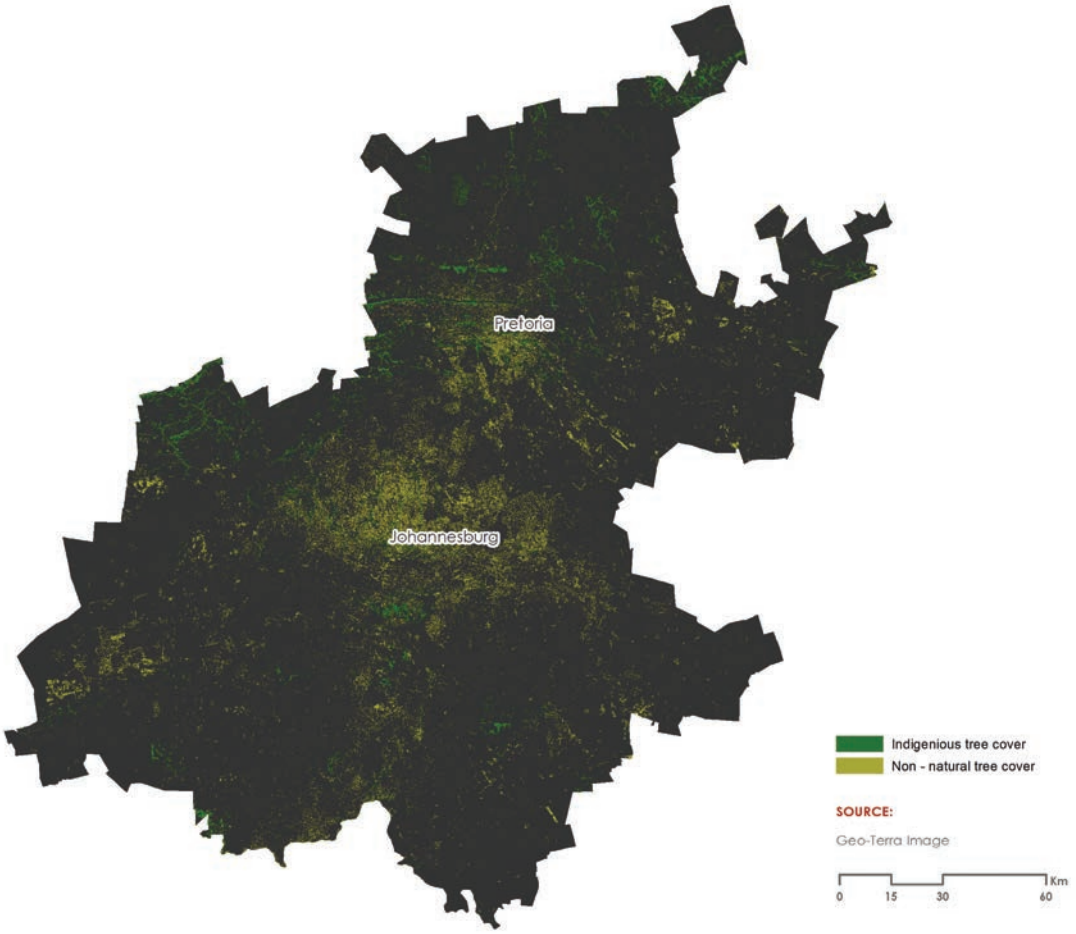
(source: GTI 2,5m urban land cover, 2012)

FIGURE 4.4: Overview of the multi-layered and connected green infrastructure networks of the GCR



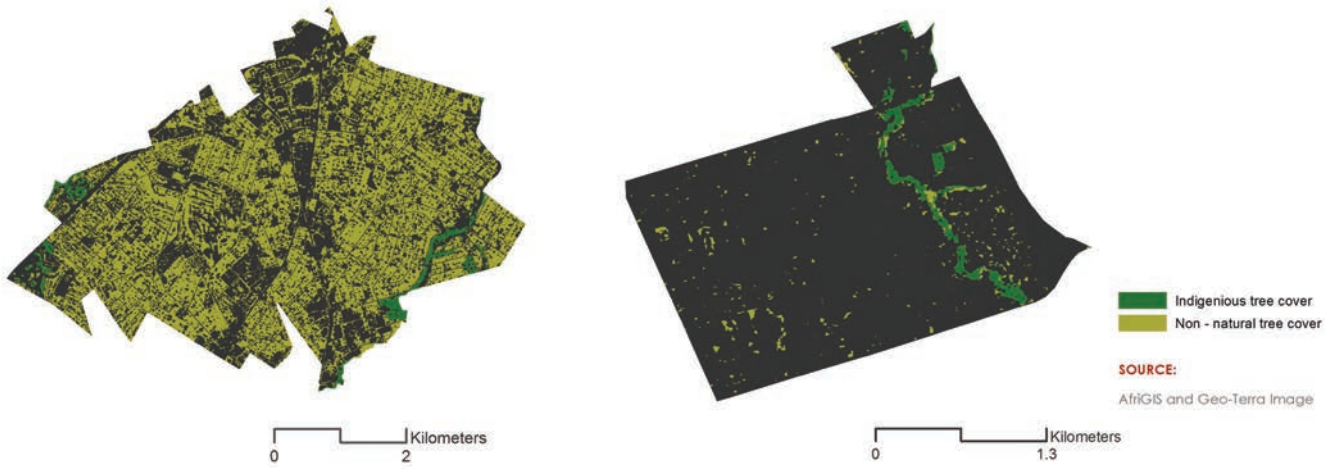
(Source: A merger of green datasets from 1) municipalities of Gauteng (City of Johannesburg, City of Tshwane, Ekurhuleni Metropolitan Municipality, West Rand District Municipality, Mogale City Local Municipality, Randfontein Local Municipality, Midvaal Local Municipality and Merafong Local Municipality); 2) Gauteng Provincial departments (Gauteng Department of Agricultural and Rural Development, Gauteng Department of Roads and Transport); 3) National departments (South African National Defence Force, South African National Biodiversity Institute, National Geo Spatial Information, Department of Environmental Affairs, Council for Scientific Research) and 4) Purchased datasets (GTI 2,5m urban land cover, 2012).

FIGURE 4.5: Indigenous and non-natural trees in Gauteng



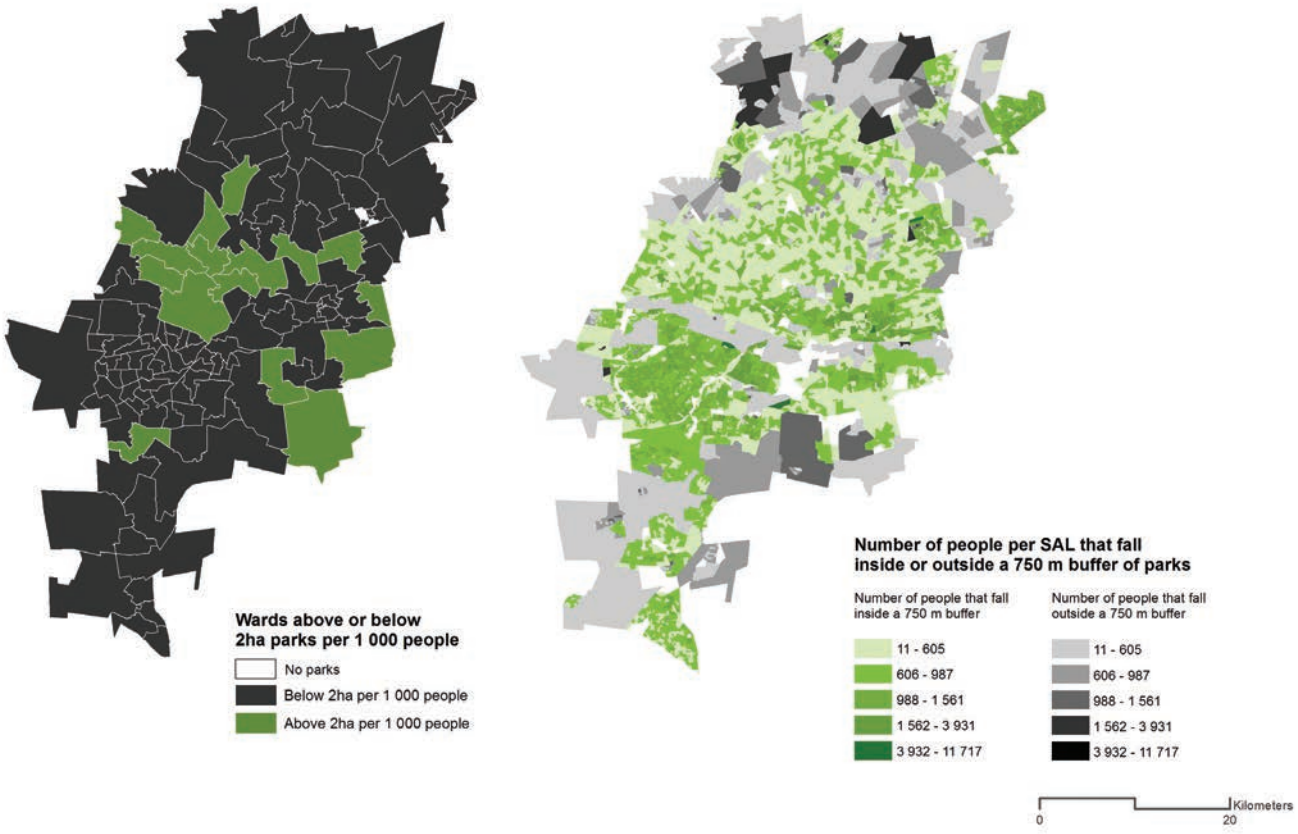
(Source: GTI 2,5m urban land cover, 2012 and AfriGIS suburbs layer)

FIGURE 4.6: Tree coverage in Bryanston (left) and Alexandra (right)



(Source: GTI 2.5m urban land cover, 2012 and AfriGIS Suburbs Layer)

FIGURE 4.7A AND B a) Wards above or below 2ha parks per 1000 individuals; b) The total population per SAL that fall within and outside a 750m buffer of parks.



(Source: Johannesburg City Parks, 2013 and StatsSA Census 2011)

Figure 4.7a represents wards in the CoJ that fall above (green) and below (black) the City's "two hectare" target of quality parks per 1000 people. It is clear from this analysis that the majority of wards in the City are below the target, and those wards that either meet or exceed the target are concentrated in historically wealthy parts of the city. It is important to note that this analysis fails to reveal that those wards below the two-hectare target are not necessarily underserved in terms of public parks. Figure 4.7b indicates an alternative measure of access – the total population per small area layer (SAL) that falls within and beyond a 750 metre buffer of a public park (i.e. an average walking time of 15 minutes). Based on this analysis, 93% of the City's population (in SALs) falls within a 750 metre buffer. There are, however, many concentrations of people without immediate access to parks. The deficit in parks is significant, as the largest gaps in access are located in the poorer southern parts of the city. There is also a clear deficit of parks in the far north, which has seen extensive urban growth in recent years. The comparison between the two means of assessing park access and provision illustrates the complexity of measuring and providing useful information for planning and policy-making.

Existing and potential green infrastructure projects of the GCR

From an engineered perspective, green assets perform better as part of a larger network of assets and can provide a range of services that contribute to the overall resilience of a system (Dunsmore, 2014). There is a range of current municipal projects that already link with the aims and objectives of a green infrastructure approach (Dunsmore, 2014). Some of these include vegetation along power-line corridors, rooftop gardens, swales for storm-water attenuation and constructing new wetlands (Dunsmore, 2014). Despite this, there is no co-ordinated approach to introducing and developing

green assets, and attention is mainly given to site-specific opportunities (Dunsmore, 2014). While international best practice provides a good base from which to implement grey-green design solutions on the ground (see Table 4.2), it is necessary to develop locally adapted standards. In Gauteng, the Highveld conditions present challenges for the direct uptake of these guidelines; more research and development is needed.

4.5 Valuing Green Infrastructure

Globally, innovative urban solutions such as green infrastructure have had to mobilise funding through alternative instruments and programmes. A range of public and private instruments exist for funding resilience projects at the local level, including local taxes, user charges, concessions for key infrastructure, commercial loans and municipal bonds (Kidney, 2014). All of these instruments rely on placing a value on green infrastructure.

A key consideration in valuation is appreciation or depreciation over time, and the associated ability to provide services, and to build or reduce resilience. The value of green assets is understood to appreciate in value over time, unlike traditional grey infrastructure which depreciates over time. In South African municipal accounting practices, time-based depreciation rates are applied to fixed infrastructure assets (SPAID, 2010). Because green infrastructure grows in value over time, and increases the ability to provide benefits and services, investing in and maintaining green infrastructure leads to compounded benefits over time.

The value of green assets is understood to appreciate in value over time, unlike traditional grey infrastructure which depreciates over time.

Green infrastructure and ecosystems can be attributed multiple values including economic, ecological, socio-cultural, health and insurance values (Table 4.3) (The URBES Project, 2013c). Despite the significant value of ecosystem services, these values are seldom recognised by urban planners and decision-makers, and the impacts of their loss are consequently invisible to these processes (The URBES Project, 2013c).

> "Most people do not know that they rely on ecosystem services, and so they need to develop an understanding of what services they use, how they access it, what habitat produces it, where in the landscape does it come from, who owns the land that produces it, and what the owners are doing to that landscape" (Mander, 2014:9).

Incorporating green infrastructure values into public planning and budgeting requires an understanding of the potential role of the monetary valuation of ecosystem goods and services. Through monetary valuation, the economic multipliers of investing in ecosystems become evident. The value derived from ecosystems in terms of the return on public investment in green infrastructure is significantly better than traditional returns. This shows the value of using public funds to sustain and invest in ecological assets (De Wit et al., 2013).

In an attempt to map the value of green networks in the CoJ, De Wit, Van Zyl and Crookes (2013) conducted a study to estimate the total economic value of green infrastructure. The benefits transfer technique was used to generate preliminary indicative values, and it relied on valuation findings from an analysis conducted for the City of Cape Town.[3]

The share of green assets in the CoJ was calculated according to value estimates (low, medium and high) in South African Rand per hectare per year (R/Ha/Yr). The study reveals that values vary according to the type and area of the green asset. Figure 4.8 indicates the medium estimate calculated in 2013 for all green asset types recorded in the City.[4] Broad-scale trends across the CoJ regions depict that open space values correspond with total area of open space (Figure 4.9). There are some exceptions, such as Region D, which has a concentration of higher value open space types compared to other regions. The high value in Region D is a result of the large number of municipal sports grounds located in this region.

There is increasing evidence that investment in green infrastructure will have cost-saving benefits for municipalities (NYC, 2007). As such, green infrastructure as a framework for planning is gaining momentum worldwide in various urban and regional strategies, plans, policies and projects (e.g. Table 4.2). Many valuation exercises are aimed at demonstrating the value of green space, to encourage the maintenance and extension of these networks for the services they provide.

Measuring and accounting for the resources consumed in cities and is also important when considering the value that the wider environment provides for urban inhabitants. This is explored through the notion of "ecological footprints" in Box 4.2.

TABLE 4.3: Overview of the multiple values that can be attributed to green infrastructure and the ecosystem services they provide (extracted from The URBES Project, 2013c).

Types of value that can be attributed to ecosystem services	Description
Economic	Direct or indirect monetary values. An example of this can include costs avoided for property damage as a result of environmental extremes.
Ecological	Environmental outputs that have value for human beings. An example of this is water filtration.
Socio-cultural	Moral, spiritual, aesthetic, ethics and values associated with biodiversity and ecosystem services. This can include emotional, affective and symbolic values.
Health	The health benefits for humans obtained from green spaces. This can include mental health.
Insurance	The contribution of ecosystems and ecosystem services to increased resilience and reduced vulnerability due to shocks, such as flooding.

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BOX 4.2: Natural assets and ecosystems beyond the city boundaries

Most cities are unable to meet the needs of their populations from within the city boundaries, but must rely on resources (food, water, energy, material goods) imported from elsewhere. While some of these resources may be obtained from the surrounding region, they are increasingly being drawn from distant areas across the globe, as supply chains become more and more globalised. This means that cities are embedded in a much larger system. The resilience of a city cannot be assessed without considering this larger system and the dependencies and feedbacks it introduces. The more dependent a city is on the natural assets and ecosystems beyond its boundaries, the more strongly its resilience will be determined by factors beyond the control of city authorities.

Ecological footprint analysis is a resource accounting tool which uses economic data to illustrate the demand made by cities (or countries or regions or households) on the natural environment. The ecological footprint for a particular human population is defined as the total area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes the population produces, wherever on earth that land and water may be located (Rees, 1995, p. 200). The human demand on natural resources is measured in relation to "biocapacity", or the overall capacity of ecosystems to produce materials useful to the economy and to absorb waste, using current management schemes and extraction technologies. When a city's demand on nature exceeds the regenerative capacity of the relevant ecosystems, "overshoot" occurs, leading to a depletion of natural assets and a build-up of waste.

The ecological footprint is useful for assessing resilience because it helps to capture the connections between the city and the larger system. Dependence on distant ecosystems is not necessarily a bad thing, but a city whose inhabitants are consuming more than their fair share of resources has compromised its long-term resilience. Recognising this, a number of cities have adopted the ecological footprint as an indicator of progress towards sustainability. These cities include San Francisco, Vancouver, Quito, Hong Kong, London, Cape Town and Johannesburg.

Calculating ecological footprints at city level is challenging due to the complexity of the interactions between cities and the larger system, as well as the lack of data. However, several new methods have been developed recently which overcome these obstacles and allow ecological footprints to be calculated for different socio-economic groups, neighbourhoods, households and even products. These methods can help city authorities to develop strategies to increase their resilience, within the context of the larger system.

4.6 Conclusion

Green Infrastructure – the interconnected set of natural and man-made ecological systems, green spaces, and other landscape features – presents an unprecedented opportunity for the uptake of alternative approaches to city planning and management in the future. The concept of green infrastructure has emerged internationally as a way of understanding how green assets and ecological systems can work as part of the infrastructural fabric that supports and sustains society and builds resilience.

FIGURE 4.8: Overview of indicative values (R/ha/yr) for open space types in the City of Johannesburg

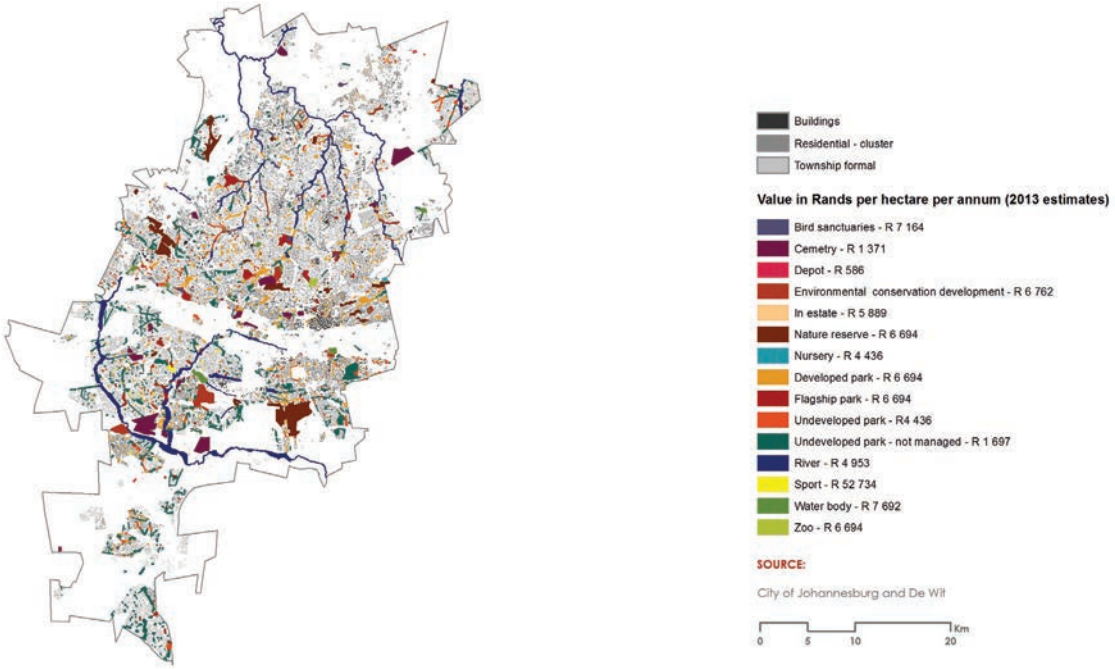
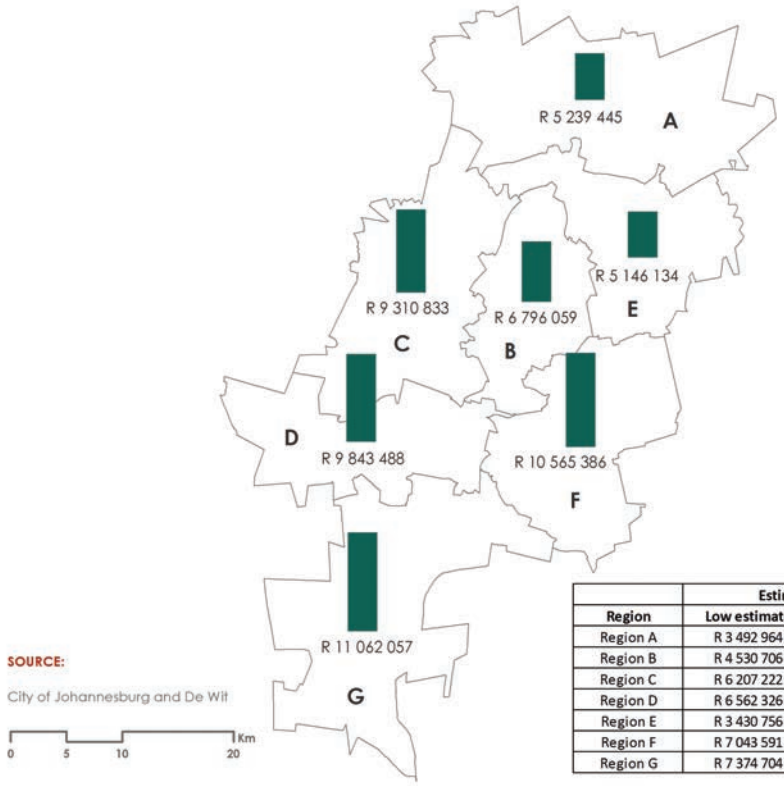


FIGURE 4.9: Overview of indicative values (R/ha/yr) for all open space types in the City of Johannesburg across low, medium and high scenarios



	Estimated value in Rands/Hectare/year		
Region	Low estimate	Medium estimate	High estimate
Region A	R 3 492 964	R 5 239 445	R 6 985 927
Region B	R 4 530 706	R 6 796 059	R 9 061 412
Region C	R 6 207 222	R 9 310 833	R 12 414 444
Region D	R 6 562 326	R 9 843 488	R 13 124 651
Region E	R 3 430 756	R 5 146 134	R 6 861 513
Region F	R 7 043 591	R 10 565 386	R 14 087 181
Region G	R 7 374 704	R 11 062 057	R 14 749 409

Green assets have assumed an infrastructural role through the idea of ecosystem services and the promotion of these to meet key challenges faced by cities and city-regions around the world. Green Infrastructure is a multi-functional alternative to traditional grey infrastructure. It appreciates in value over time, and offers cities a more sustainable option for meeting increasing service delivery demands. At the same time, it creates a more resilient urban form that can mitigate the effects of natural shocks and climate change.

Green infrastructure boasts benefits that are not always appreciated in valuation approaches and techniques. Thus, incorporating it into public planning and budgeting requires an understanding of the potential role of the monetary valuation of ecosystem goods and services. However, monetary valuation alone has proved insufficient to transform municipal planning and decision-making processes. Cities around the world are grappling with how to incorporate the true value of green assets and ecosystem services into local government accounting and decision-making. Until the value (both monetary and non-monetary) of green assets is understood and incorporated into municipal systems, the ecosystems approach that underpins the concept of green infrastructure will not be adequately included the in the planning and developmental mandates of cities.

The scope and potential for the uptake of a green infrastructure approach in the GCR is extensive. The vast wealth of green spaces, both natural and man-made, together with the green corridors, inject life into urban nodes and create a prime canvas for the implementation of alternative infrastructure for building resilience. Through maintaining and/or extending green networks in the GCR, using natural systems or combined grey-green engineered solutions, the direct benefits and cost savings can work to direct resources and funds into achieve the GPG's Programme of Action. In the context of growing demand for services and development in the GCR, planners and policy makers are under pressure to ensure development and service provision at the lowest cost to people and the environment. Green infrastructure provides a unique and multi-functional solution for short-term problems with long-term benefits.

BOX 4.3. Complex-adaptive infrastructure systems

There is growing use of the term "resilient infrastructure" but variance in the way it is understood. The most common use refers to the extent to which infrastructure is protected from disruptive events and/or is able to recover from these events. One definition of resilient infrastructure is "the infrastructure's ability to continue to provide critical services efficiently following a disruptive event" (Sandia National Laboratories, 2014, p. 1). In the United States, for example, this understanding of resilient infrastructure is commonly referred to in relation to concerns with national and "homeland security" (U.S. Department of Homeland Security, 2013).

There are arguably three key principles in relation to this understanding of infrastructural resilience:

- When one element of a network fails, the total system should be protected;
- When the total system fails, critical individual elements of the system should be protected; and
- Where failure happens, it should be a "safe-failure" (meaning that failure should not result in catastrophe as may happen when a levee breaks during a flood or the single source of water for a municipality fails).

There is growing attention to the technical capabilities required to achieve this by applying concepts of redundancy, coupling, and decoupling. Redundancy requires alternative

means of providing an infrastructural service if there is a disruption. Coupling means joining systems together so that there are more options when a disruption does occur. In some parts of the world, for example, countries are linking their energy grids to reduce the risk of failure in any one country. Decoupling, in contrast, refers to the ability to delink rapidly from a larger system to protect a critical component of infrastructure from cascading failure. So, for example, hospitals, critical communication facilities, and water treatment plants, need to be decoupled in the event of a power failure.

In terms of power supply, for example, a more complex system of distributed generation and storage will allow for higher levels of redundancy, coupling, and decoupling. Reliance however on a few large power stations, and on a simple distribution network, leaves a country or city highly vulnerable to disruption.

New York is an example of a city that has been struck by multiple disasters in recent years that have affected the power grid. There has been a tornado, blizzard, tidal surge, heat wave, and also the infamous Superstorm Sandy. The results have been damages, outages, and the temporary loss of the subway service. There is now a strong recognition that resilience of electricity infrastructure is critical, and the city has prepared a strategy for a range of investments to protect and strengthen the grid. There are investments to make infrastructure more robust (e.g. water proofing of sub-stations), to reduce peak demand and network congestion, and to develop a smart grid for greater responsiveness (e.g. smart meters which communicate reliable information on performance and use of the network) (Arup, RPA & Siemens, 2013).

The idea of infrastructural resilience as avoiding or coping with disruption is important. With greater concentration of people in urban areas, and increased dependence on large infrastructure networks, vulnerabilities have increased, and we do need to mitigate this. To some extent we can achieve this by applying the sort of technical solutions that are being introduced in New York City (recognising, of course, that many municipalities in South Africa face resource and capacity challenges and will need to find locally appropriate adaptations).

We also need to understand that dealing with disruption to infrastructure is not only a technical matter. As one commentator observed:

> "When dealing with severe weather events, the type that climate change is making more common, improved infrastructure is important. But the social ties of a neighborhood – the kind of relationships that are nurtured by trips to the corner coffee shop and chats on the sidewalk – might prove equally important when it comes to saving lives" (Goodyear, 2013, p. 1).

We do however need to go beyond this broadly "equilibrist" approach to infrastructure resilience with its emphasis on response to disruption (as important as this is). Investments in infrastructure produce assets that shape development patterns for decades, and so the long-term effects must always be considered. A key consideration is how current investment in infrastructure will support the transition to a low-carbon economy, and how it will assist in mitigating, and adapting to, climate change.

Municipalities need to invest in low-carbon infrastructure. They need to consider direct support for the production of electricity from renewables; energy storage; retrofitting of buildings for energy efficiency; use of green assets (e.g. green roofs, rainwater harvesting, urban forests and wetlands); low-carbon transport solutions including non-motorised

transport; and more. Direct investment by municipalities is important but will have a limited impact, and so attention should also be given to influencing the behaviour of firms and individual households through regulation, targeted incentives and subsidies, mobilizing private resources (e.g. green bonds), tariff structures, and so on. All i nfrastructure and related decisions must be made with direct consideration of the long-term impact and of its contribution to sustainability goals. (As a resource, see for example, ADEPT, 2011).

Fortunately, there are now many examples we can draw on for guidance. The City of Toronto, for example, has a low carbon infrastructure plan which provides a comprehensive set of interventions to change the growth path of the city (Sugar & Kennedy, 2013). These include:

- Bold interventions to reduce use of energy and emissions from buildings including: designing all post-2012 buildings to consume 60 percent less energy than standard; retrofitting all pre-2012 buildings; solar air heating and green roofs on commercial buildings; designing post-2012 buildings with borehole thermal energy storage (BTES); and, solar water heating and ground-source heat pumps in pre-2012 homes.
- Significant interventions in the transportation sector including: improved public transit infrastructure; a complete shift to electric vehicles; improved bicycle infrastructure; increased parking prices; and, taxes and tolls on private vehicles.

Advice need not only come from the global North however. Across the BRICS countries, for example, there are a range of innovative low carbon solutions. There are big investments in public transit infrastructure across almost all large BRICS cities, and also significant gains in terms of energy efficiency. There are especially innovative examples from cities such as Sao Paulo and Shanghai. In Sao Paulo, for instance, an elevated freeway is being closed to create a linear public park while in Shanghai petroleum-based fuels are being replaced with green alternatives. In Shanghai, the municipality has an ambitious programme for generating electricity through offshore wind farms and is investing heavily in intermodal transport hubs.

Although there is guidance, there are critical challenges and choices. The key emerging debate over the long-term future is whether resilience and sustainability may be best achieved through more efficient integration into "smart grids" or whether the most secure long term solution is to reduce dependence on these systems through off-grid solutions. Municipalities need to think intelligently about this, understanding that decisions do need to be made, but that the long term solutions may not be either-or. It is possible to conceive of smarter networks but also of fail-safe alternatives to these networks. Smaller cities and towns are also making progress across the BRICS countries, although with scaled down programmes.

As a conclusion, we reproduce below the advice offered by Her Majesty's Treasury to organisations concerned with carbon reduction. This is advice that could be taken up by municipalities in South Africa who are using the provision of infrastructure as one of the paths towards long term sustainability (H.M. Treasury, 2013, pp. 19-20).

Effective leadership

Vision – Provide the highest-level sponsorship, vision and commitment

Values – Embed carbon reduction as a core organisational value – make it part of the DNA

Policy – Deliver clear and consistent policies on carbon reduction

Communication and culture

Behaviour – Be clear what carbon behaviours are wanted and reward them

Communication – Share carbon knowledge effectively within your organisation, your supply chain and the wider industry

Skills – Develop carbon skills at all levels through education and training

Metrics and governance

Baselines – Know where you're starting from; establish a baseline against which to measure performance

Targets – Set stretching carbon targets and strive to beat them

Tools – Put appropriate carbon modelling tools into the hands of those that need them

Visibility – Shine a light on carbon performance

Governance – Build clear and effective carbon control into the delivery process

Innovation and standards

Innovation – Unleash new thinking across the supply chain

Standards – Enable existing standards and specifications to be challenged; set new standards for carbon best practice

Commercial solutions

Procurement – Bake carbon into commercial and contractual solutions; create a commercial environment in which innovation can thrive

Reward – Align supply chain objectives with reducing carbon; support positive carbon behaviours through long-term incentives; equitably share risk and reward

Integration – Remove blockers in the value chain

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NOTES

1 This piece is based on the Gauteng City–Region Observatory's (GCRO) multi-year Green Assets and Infrastructure project. The aim of the project is to produce a Green Infrastructure Guideline Plan for the Gauteng City–Region (GCR). The insights of this written contribution are drawn from the "State of Green Infrastructure in the GCR" Report, published by the GCRO in 2013, and commissioned work on green infrastructure across South Africa, specifically on valuation and grey-green engineering. These insights sum up the role of green infrastructure in building urban resilience, and piece together a critical reflection for the uptake of a green infrastructure approach for the GCR.

2 More information on this study can be found in Turpie et al. (2001).

3 For a more detailed overview of values calculated for the CoJ, see Appendix A.

APPENDIX A: Overview of indicative values per hectare per year for open space types in the City of Johannesburg (source Schaffler et al., 2013).

	2013 VALUE IN R/HA/YR			
	LOW ESTIMATE	MEDIUM ESTIMATE	HIGH ESTIMATE	
Values from the Cape Town Open Space Values Study				
Parks	R 3 926	R 4 462	R 4 999	
Sportsfields	R 25 173	R 35 156	R 45 139	
Natural vegetation	R 1 438	R 5 089	R 8 741	
Vacant lands	R 390	R 825	R 1 260	
Wetlands	R 3 127	R 5 166	R 7 206	
Values applied to Joburg City Parks land				Explanation of values used from Cape Town Open Space study to generate comparable low estimate for application to Johannesburg:
BIRD SANCTUARY	R 4 776	R 7 164	R 9 552	Ave between parks and natural vegetation medium value
CEMETERY	R 914	R 1 371	R 1 828	Ave between natural vegetation and vacant land low value
DEPOT	R 390	R 586	R 781	Vacant land low value
FLAGSHIP ROAD ISLAND	R 914	R 1 371	R 1 828	Ave between natural vegetation and vacant land low value
ENVIRONMENTAL CONSERVATION DEVEOPMENT	R 4 508	R 6 762	R 9 015	Ave between parks low and natural vegetation medium value
IN ESTATE	R 3 926	R 5 889	R 7 852	Parks low value
INFORMAL SETTLEMENT	R 825	R 1 238	R 1 651	Vacant land medium value
MAIN ARTERIAL	R 914	R 1 371	R 1 828	Ave between natural vegetation and vacant land low value
MAIN ROAD	R 914	R 1 371	R 1 828	Ave between natural vegetation and vacant land low value
NATURE RESERVE	R 4 462	R 6 694	R 8 925	Parks medium value
NURSERY	R 2 957	R 4 436	R 5 914	Ave between natural vegetation and vacant land medium value
PARK – DEVELOPED SMALLER PARKS	R 4 462	R 6 694	R 8 925	Parks medium value
PARK – FLAGSHIP	R 4 462	R 6 694	R 8 925	Parks medium value
PARK – AS YET UNDEVELOPED	R 2 957	R 4 436	R 5 914	Ave between natural vegetation and vacant land medium value
PARK – AS YET UNDEVELOPED (Not actively managed)	R 1 132	R 1 697	R 2 263	Ave between natural vegetation low and vacant land medium value
RIVER	R 3 302	R 4 953	R 6 604	Ave between medium wetlands and low natural veg value
ROAD ISLAND	R 2 957	R 4 436	R 5 914	Ave between natural vegetation and vacant land value
SIDEWALK	R 2 957	R 4 436	R 5 914	Ave between natural vegetation and vacant land value
SIDEWALK (Not actively maintained)	R 390	R 586	R 781	Vacant land low value
SPORT	R 35 156	R 52 734	R 70 312	Sportsfields medium value
TOWN ENTRANCE	R 2 957	R 4 436	R 5 914	Ave between natural vegetation and vacant land medium value
WATER BODY	R 5 128	R 7 692	R 10 255	Ave between wetlands and natural vegetation medium value
ZOO	R 4 462	R 6 694	R 8 925	Parks medium value

EXPLANATORY NOTES: Low estimates for values applied to Joburg City Parks land are based on values from the Cape Town Open Space study, some of which are used directly and others adjusted. An explanation is provided for how each low estimate value for Joburg was derived in this way
Medium estimates for Joburg City Parks land were derived by increasing low estimates by 50%. High estimates for Joburg City Parks land were derived by increasing Low estimates by 100%

Table 10. Indicative values per hectare per year for open space types in the City of Johannesburg

5 Economic resilience

In recent years there has been a growing use of the term resilience in relation to national, regional and local economies. This relates in part to concerns in the wake of the 2008 global economic crisis and in part to a growing understanding that long term resilience requires more sustainable resource use and less carbon dependency.

This section of the report deals with both aspects of economic resilience. First, it addresses the ability of local economies to bounce-back after an economic shock and, more importantly, to adjust to continually changing economic realities. Secondly, it addresses the transition of economies towards resource sustainability and green production for long-term resilience.[1]

5.1 Bounce-back and adjustment

5.1.1 Defining economic resilience

Briguglio *et al* (2009) define a resilient economy as one that is able to:

- Recover rapidly from the effects of adverse shocks; or,
- Withstand shocks.

This notion of resilience is strongly present in a literature which deals with both the effects of an economic recession (or shock such as the collapse of a property or stock market bubble) and the economic impact of an unexpected natural disaster such as a flood, earthquake or drought (Park, Cho, & Rose, 2011; Hallegatte, 2014).

This understanding draws exclusively on an equilibrist notion of resilience (See Chapter 1). While it is important for a local economy to recover from a major disturbance, resilience should not only be understood in relation to big and sudden events. An evolutionary or transformative notion of resilience would appreciate that the wider economy (up to the global scale) is in a constant state of change and that local economic resilience must involve the capacity for on-going successful adaptations. It must also involve adaptation to anticipated future conditions such as resource scarcity and climate change.

Simmie and Martin (2010) take the evolutionary view of economic resilience. They warn that short-term resilience (that is, the ability to withstand shock) does not necessarily indicate long-term resilience.

Indeed, it may even suggest a long-term lack of resilience. An economy that is unresponsive to change may in fact indicate functional and structural rigidity. Hassink (2010) advises that it is "lock-ins" or "path-dependencies" that are the real impediment to long-term resilience. Raco and Street (2012) warn that an equilibrist approach to resilience could support very conservative politics that direct us towards 'more of the same'. It may simply return us to a previously unacceptable state in terms of resource use or socio-economic exclusion.

A transformative approach suggests that crisis may in fact lead us towards a more desirable state. As Schumpeter (1943) famously suggested with his theory of "creative destruction", turbulence can be a driver of positive change. We do need to recover from shock but a long-term perspective on resilience may require economic re-orientation rather than a return to a pre-existing condition. Resilience is however not just about the threats and opportunities of an unexpected shock but also adaptation to an on-going state of change that supports evolution towards more inclusive and sustainable economic forms.

5.1.2 Differences in economic resilience

The difficulty here is that, as far as we are aware, there is no empirical data that provides an account of evolutionary or transformative resilience in cities. The evolutionary perspective on economic resilience is relatively new and a methodology of assessing and measuring the ability of a local economy to adapt in response to on-going change is not adequately developed.

What we do have however is a number of studies which show the bounce-back of economies from the global crisis of 2008. As discussed above, bounce-back is a measurement of equilibrist resilience rather than evolutionary or transformative resilience. While we are wary of using this data to generate conclusions on resilience, the data is helpful in making the simple point that there are significant differentials between cities in economic responsiveness and performance. It raises the vexing question of why the difference?

The *Global Metro Monitor* (Berube, et al., 2010) provides a comparative account of the extent to which 150 major cities coped with the global economic crisis. The overall picture is of strong performance in cities in East Asia (with the exception of Japan and Thailand), weak performance in Europe and mixed performance in North and Latin America. South Africa's three largest metropolitan cities proved relatively resilient compared with many cities in Europe and North America, and even compared with some of the larger cities in Latin America. The global-regional or national location of cities did make a difference but there are also considerable differences within regions and nations which require close attention.

The report revealed the following:

- 35 of the 150 cities experienced no recession and continued to grow despite the crisis (for example, Beijing, Sydney, New Delhi and Bogota)
- 24 experienced depression but were on the road to full recovery (for example, Boston, Istanbul, Montreal and Tokyo)
- 77 had made an at least partial recovery from recession losses (for example, Berlin, London, Johannesburg, New York, Vienna and Copenhagen);
- 14 were continuing to decline (for example, Athens, Lisbon, Rome and Las Vegas). (Berube, et al., 2010)

There have also been some regional and local studies. Forbes and Brookings[2] analyse the relative performance of cities in the USA on an on-going basis, and show considerable variation in performance across the country. Cities like Denver, Dallas and Minneapolis have done well while others including Las Vegas, Detroit and Cincinnati have performed poorly.

Cox *et al* (2014) reveal, for example, the differential impacts of the 2008 crisis on regions in England in the United Kingdom. London held its own with a zero change in employment between 2008 and 2013;

most regions experienced negative change; but a few enjoyed continued growth despite the national recession (for example, Liverpool City Region, Nottingham and Worcestershire). In South Africa we still lack reliable economic data at municipal scale but our preliminary analysis does reveal considerable difference in the level of recovery from the economic shock.

The key analytical challenge is how to explain these differences. Why are some places worse hit than others during economic shock? Why do some places continue to flourish despite an overall crisis?

5.1.3 Explaining the source of economic resilience

The Brookings Institution (Berube, et al., 2010) provides some indication of why there has been differential performance (over and above the clearly significant effects of national differences). Industry specialization and differences in human capital stock were among the key factors identified.

Brookings concluded that:

- Cities with the construction industry as a significant segment of their economy performed poorly during and immediately after the recession (not surprising given the sensitivity of property and construction to economic change);
- Cities (excluding those in East Asia) dependent on export oriented manufacturing struggled to bounce-back after the recession;
- In some global regions cities with a large financial sector component were adversely affected; and,
- Cities with non-market services as a significant component of the economy (government, education, health etc.) tended to weather the storm better.

Industrial structure is certainly important. If a local economy is highly dependent on a sector which is under stress globally or nationally, it is likely to be adversely affected (although local factors may mitigate this). It does not follow however that the focus of a municipality should be on matching the local industrial structure to global trends. What may be an ingredient of success today may not be tomorrow and given global economic volatility it is highly unlikely that even the best minds will successfully predict the best industrial structure for a local economy in the future. In 2008, cities with a large non-market service sector were apparently more resilient than those more dependent on consumers, yet it is not guaranteed that this will be the case in the future. Having said this, however, there are industries which are threatened by market or technological trends, and we may need to ask whether they can be renewed or whether workers should be reskilled and firms supported in making a transition to new industries? The flexibility of the human capital stock – in terms of both capability and willingness to restructure – is clearly critical to the resilience of a local economy.

Although some intervention may be required to support particular sectors (for example, manufacturing or tourism) the most effective way to promote local economic resilience is to support critical resilience-supporting factors across sectors, industries and firms.

We have consolidated below a list of critical factors drawn from the work of a number of scholars (Voss, Bauknecht, & Kemp, 2006; Simmie & Martin, 2010; Wolfe, 2010; Greenham, Cox, & Ryan-Collins, 2013; Cox, Broadbridge, & Raikes, 2014).

- Strong intelligence capacity within local government structures to ensure a good on-going understanding of the nature of the local economies and of external trends;
- A responsive and adaptive public sector that works consistently to strengthen the local economy;
- Active citizens engaged in debate, decision-making and action around local development;
- Responsible business supporting local development and the creation of good jobs;
- Strong networks of collaboration and trust between the different segments of society (government,

business, labour, civil society, higher education & research) in support of common visions and actions to promote inclusive economic growth[3];

- A strong and diverse local asset base in relation to infrastructure and financial resources but also in relation to attitudes, skills and knowledge;
- Economic variety or diversity;
- Continually upgraded technological capabilities;
- On-going investment in social capital;
- Strong connections into economic and social networks that extend beyond the locality; and
- Local innovative capacity supported by factors such as entrepreneurial ability, access to venture capital, local networks of trust, investment in research and development, and knowledge partnerships.

A municipality may be fortunate to have many of these capabilities in place but a lack of these conditions for resilience does not mean invariable failure. A number of writers have referred to "self-made economic resilience" (for example, Cordina, 2004). The research has been conducted in relation to national economies but is equally applicable to regional or local economies. The so-called "Singapore paradox" refers to the way in which a small and vulnerable economy with few internal resources achieved rapid sustainable growth through careful nurturing.[4]

It is important to note that a locality may withstand a shock or bounce-back rapidly from the disturbance but not prove resilient in the long-term. Cox *et al* (2014) are critical of the approaches taken in the UK to support local economic recovery after the 2008 economic crisis. They warn that the focus is primarily on short term recovery rather than on building long-term resilience and sustainability with preparing for a future of natural resource scarcity and rapid climate change a key element in this.

BOX 5.1 The New Climate Economy Report

The New Climate Economy Report in (World Resources Institute, 2014a) marks a key moment in the long standing debate on the relationship between environmental sustainability and economic growth. It argues strongly that "countries at all income levels have the opportunity to build lasting economic growth and at the same time reduce the immense risk of climate change" (World Resources Institute, 2014a, p. 1).

The report was prepared by a Commission led by a previous President of Mexico, Felipe Calderón, and advised by some of the world's leading economists. It was established as a partnership between a number of the world's leading research institutions. The report of the Commission offers a strong narrative on the relationship between the economy and climate resilience and sets out a ten-point Global Action Plan to achieve robust economic development within a low-carbon economy.

The message of the report is timely and critical. The next two decades or so can be a period of great progress and growth even as we make the necessary transition to a low-carbon path. This challenges the idea that there is a necessary trade-off between the two.

The report argues that the transition to a low-carbon economy provides numerous opportunities for growth and development, and will also assist in removing rigidities and inefficiencies in the economy that are bad for both growth and the environment. These include, for example, the wasteful use of resources such as energy, water and land. An

example of a bad practice is the fossil fuel subsidy which is bad for the environment and, in the long run, for sustainable economic growth. The report advises the elimination of this form of subsidy and the introduction of "a strong, predictable and rising carbon tax". At the municipal level, the report proposes regulatory incentives that reward households that are becoming more energy efficient.

Importantly the report recognizes that cities are crucial to this transition as they account for 80 percent of global economic output and 70 percent of global energy use. Also, almost all of the world's net increase in population will happen in cities. The report reminds city-builders that "the structures we build now, including roads and buildings, could last for a century or more, setting the trajectory for greenhouse gas emissions at a critical time for reining these in" (World Resources Institute, 2014b, p. 3). Importantly, the report includes as one of its ten proposals "making connected and compact cities the preferred form of urban development".

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NOTES

1 The increasing influence of this idea is illustrated for example by the establishment of an Office for Economic Resilience by the Obama Administration in the USA. See the website of the Office for Economic Resilience on http://portal.hud.gov/hudportal/HUD?src=/program_offices/economic_resilience

2 See http://www.brookings.edu/research/interactives/metromonitor#/M10420

3 The quality and density of networks within and between segments of society may be referred to as "civic capital" (Cox et al, 2014).

4 This included, for example, government support for savings and capital formation, and high levels of investment in growth-creating infrastructure. Apart from Singapore other countries with similar constraints and similar levels of success include Estonia, Kuwait, Mauritius and Luxembourg.

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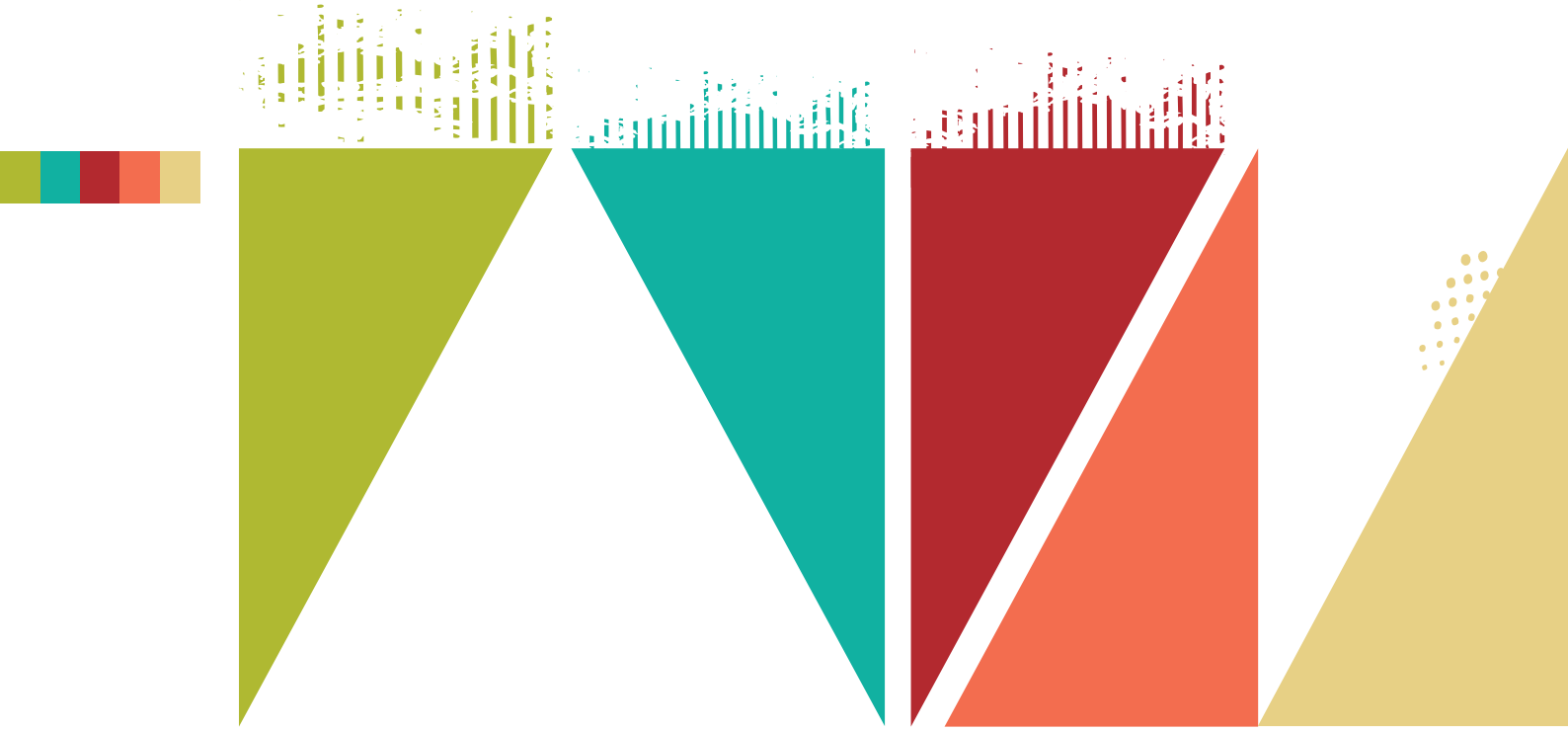

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