The translation of ecological resilience theory into urban systems

by

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Ethics declaration

The author, whose name appears on the title page of this thesis, has obtained, for the research described in this work, the applicable research ethics approval (Addendum C). The author declares that she has observed the ethical standards required in terms of the University of Pretoria's *Code of ethics for researchers* and the *Policy guidelines for responsible research*.

Synopsis

As an interdependent global society enters an era of unprecedented change, resulting from unforeseen natural and social disasters and vulnerabilities, the resilience of global cities to survive is a pressing concern. This dissertation aims to elucidate the application of resilience thinking by showing how ecological resilience concepts can translate into urban systems, using the capital of South Africa, Tshwane, as the exploration ground. Resilience simultaneously embodies the capacity of urban systems to bounce back, adapt or transform. Translating these concepts into a holistic urban resilience approach answers three questions: a) What is resilience theory? b) What are the core concepts of ecological resilience theory? and c) How might these concepts translate to cities?

The dissertation is structured in three parts; to establish the basis of resilience thinking, explore ecological resilience concepts in an urban system and lastly, assimilate findings into an urban resilience approach. Qualitative along with historical-comparative research methods, guided literature studies, and interdisciplinary research designs generated the finding that ecological resilience concepts translate well into the urban system, but that urban resilience is not a panacea for the ills of the urban environment.

An urban resilience approach could comprise a) evolutionary or adaptive urban resilience involving an ongoing study and observation of the city system; and b) transformative urban resilience, that actively changes systems that reflect stronger or weaker resilience, so as to purposefully regenerate or 'collapse' them. This requires responsible and holistic conduct. Urban resilience thinking implies an appreciation for the complexity that underlies life, and modesty about ambitions for managing it.

Declaration

In accordance with Regulation 4(e) of the General Regulations (G.57) for dissertations and theses, I declare that this dissertation, which I hereby submit for the degree Philosophiae Doctor (Real Estate) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution. I further state that no part of my dissertation has already been, or is currently being submitted for any such degree, diploma or other qualification. I further declare that this dissertation is substantially my own work. Where reference is made to the works of others, the extent to which that work has been used is indicated and fully acknowledged in the text and list of references.

While conducting research for this dissertation, ideas contained therein were peer-reviewed and published in conference papers nationally and internationally. In addition, some aspects were presented at talks and seminars in South Africa. This was an important step in testing the interpretation and translation of ecological resilience theory into the urban environment, and in critical thinking. Aspects from the following papers are incorporated:

Peres, E. & Du Plessis, C. 2013. The threat of slow changing disturbances to the resilience of African cities. In: S. Kajewski, K. Manley & K.Hampson (eds.), *Proceedings of the 19th International CIB World Building Congress, 5-6 May. Brisbane*. Brisbane: Queensland University of Technology, 1-13. Available from: http://trustsa.weebly.com/uploads/1/3/2/0/13205680/full_paper_cibwbc2013_submission_199_peres.pdf

Peres, E. & Du Plessis, C. 2014a. Be(A)ware: Resilience is about so much more than poverty alleviation. In: *XXV World Congress of Architecture, 3-7 August, Durban.* Durban: UIA Architecture Otherwhere, 124-132.

Peres, E. & Du Plessis, C. 2014b. Integral Resilience – an indicator and compass for sustainability. In:*World SB14 Barcelona Conference, 28-30 October, Barcelona.* Barcelona: World Sustainable Building 2014, no. 149. Available from: http://trustsa.weebly.com/uploads/1/3/2/0/13205680/wsbc14_-_integral_resilience_-_peres_du_plessis_final.pdf

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From this distant vantage point, the Earth might not seem of any particular interest. But for us, it's different. Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam.

Carl Sagan in Pale Blue Dot: A Vision of the Human Future in Space (Sagan 1997).

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List of Abbreviations and Acronyms

AQAL	All-Quadrants, All-Levels
ANC	African National Congress
CAS	Complex Adaptive System
CRS	Centre for Regenerative Studies
ERT	Ecological Resilience Theory
GBCSA	Green Buildings Council of South Africa
GIS	Geographic Information System
H-C	Historical-Comparative
LEED	Leadership in Environmental and Energy Design
LL	Lower left
LR	Lower right
NDP	National Development Plan
NRF	National Research Foundation
NP	National Party
RDP	Reconstruction and Development Programme
SES	Social-Ecological System
SoCR	State of South African Cities Report
URT	Urban Resilience Theory
UL	Upper left quadrant
UR	Upper right quadrant
ZAR	Zuid-Afrikaansche Republiek

PART ONE

SETTING THE SCENE

CHAPTER ONE

INTRODUCTION TO THE DISSERTATION

1.1 Introduction

> Broadly speaking, the contemporary sustainability movement has been (rightfully) preoccupied with risk mitigation for some time. Yet, as irrevocable global changes of all sorts edge closer, a shift toward adaption – and with it, an increasing focus on resilience – is underway (Zolli & Healy 2012: 22).

This dissertation frames resilience as the way in which we learn to embrace change. Change is the driving force that propels life and characterises its evolution in ways that transcend and include what went before. Without change, there cannot be life. Embracing change means being able to see the opportunities created by it, in order to further the evolution of life toward its greatest potential, complexity and refinement. Resilience provides a perspective from which to embrace change, not only as a means of understanding what is changing (or needs to change), but also how change can be navigated in the most meaningful way possible.

Meaningful change is important in the context of major pressures placed on global resources (both tangible and intangible alike) by an increasingly interdependent and interconnected global community. Its unbridled consumer culture threatens the quality of life going forward. The business-as-usual system driving consumerist 'growth' (in addition to political ideologies about dominance and power) is resistant to change, and this is threatening the resilience of the global system to develop in a sustainable manner. A radical shift in the status quo is required – a shift that acknowledges that to develop the resilience of a system (and thereby make it sustainable over time) requires that some of its parts may need to fundamentally change, adapt, or even collapse to transform the whole. A shift guided by responsibility to inform a holistic transformation toward greater potential needs not be a crisis, but can rather be an opportunity.

1.2 Contextualising the need for this dissertation

> Crises and stress incite growth and change in all life forms. The kind of change that occurs may support or detract from the health and well-being of the system depending upon its level of resilience and intelligence (Ellin 2006: xxiii).

The 21st Century is a time of unpredictable change occurring at an unprecedented scale. Urban areas represent one form of manifestation of this unpredictable and rapid change. They concentrate human activity and their impact on the global system is profound: from physical impacts on ecological systems, to the worldviews influencing social systems. Cities

are therefore not only of concern as the primary human habitat, but also as containers from which decision making ripples far beyond into the global system. This century also marks a time when many of the established development and lifestyle norms upon which human society unquestioningly stands are no longer delivering results. In particular, urban systems are proving difficult to manage in response to economic, social and environmental pressures. For example, given the catastrophic consequences of human driven climate change and the effect of human activity on planetary boundaries (Steffen, Richardson, Rockström, Cornell, Fetzer, Bennet *et al*. 2015: 3), it is becoming increasingly necessary to build cities that can withstand massive environmental disasters as well as the social turmoil that would follow. The above-mentioned scenario requires a review and adaptation of the tangible and intangible systems that underpin our thoughts and actions. If humanity is to navigate and survive through tumultuous change, and more importantly thrive, then this level of holistic review is essential.

A review of our systems affects how we choose to deal with change in our cities, and has a critical influence on future urban trajectories. The primary human habitat is now urban, with more than half of the world's population living in cities rather than rural environments (Burdett & Sudjic 2007: 54; UN Habitat 2010: iii). Future scenarios see cities as being either centres for human flourishing or for post-apocalyptic slum survival (Schultz 2014). Rapid urbanisation, for example, is a major challenge in both these scenarios, but also an opportunity for change. Currently, some of the ripple effects of rapid urbanisation are urban poverty and inequality (UN Habitat 2010: 2). These manifest spatially in the form of unregulated 'informal' settlements in 'abandoned' leftover spaces, and from which 'informal' activities derive subsistence. Internationally, informal activities are viewed as a problem that "fuels crime, violence and social unrest" (UN Habitat 2010: 8), and not as a solution to urban poverty. Informal settlements often have the characteristics of 'slums'. In 2007, it was estimated that one in six people alive was a slum dweller, competing for declining natural resources and opportunities in challenging urban areas (Burdett & Sudjic 2007: 67). These issues are of concern to development in South Africa, since this century will see most rapid urbanisation take place on the African continent (UN Habitat 2010: 41).

Fast-paced and seemingly 'uncontrolled' urbanisation increases pressure on cities to provide basic services and quality of life to citizens. The urgency for services, safety and shelter further burdens finite natural resources, while the inequality between the rich and poor has become extreme (Swilling 2005). In many cases, the sustainability triple-bottom-line is disregarded or watered-down in favour of meeting other targets. Subsequently, 'post-sustainability outlooks' (Du Plessis 2011a; Westley, Olsson, Folke, Homer-Dixon, Vredenburg,

Loobach *et al*. 2011) are emerging as a means to leapfrog the limitations. Among these outlooks are concepts such as resilience. These perspectives also provide an understanding of "how places grow, in order to produce sustainable, resilient new communities" (McGlynn & Samuels 2000: 86). In response to these urbanisation challenges and the perceived limitations of the sustainability movement, the capital city of South Africa has developed a vision for Tshwane in 2055 that brands it as a 'liveable, inclusive and *resilient*' city (City of Tshwane 2013). Resilience offers an attractive perspective, because it can integrate complex systems and contextual relationships into a single dynamic systems based study. It breaks away from generic linear processes, creating the opportunity to not only build the capacity of cities to mitigate disasters, but also to adapt existing environments into healthy and thriving social-ecological systems. However, the massive transformation required in the current urban environment calls for a holistic look at social and ecological systems to see how they can function more resiliently and with integrity. In response to the vision of a *resilient* city, it becomes necessary to define what urban resilience means.

Although the understanding of resilience as a measure of returning to a former state after disturbance has been around since the 1600s (Little, Fowler, Coulson & Friedrichsen 1974: 1807), it was only in the 20th century that the *resilience perspective* emerged from ecological studies as its own field of research (Folke 2006: 254). It described and defined the dynamics of change within ecological systems. In this definition, resilience refers to how much pressure a system can absorb before shifting into alternate states (Folke 2006).

Core concepts in resilience thinking have since evolved, and have been useful for understanding change in other fields of study, like social-ecological systems (SESs) and urban systems (Folke 2006; Walker & Salt 2006; 2012; Pickett, Cadenasso & McGrath 2013b; Anderies 2014; Pearson, Newton & Roberts 2014; Pickett, McGrath, Cadenasso & Felson 2014). However, research into how resilience theory adapts to and manifests in urban environments, particularly in the context of an African city, is yet in its infancy (Du Plessis 2011a). Contextualising 'urban resilience' thinking in the metropolitan City of Tshwane can assist in understanding the effects of change in similar city systems, in order to highlight potential for regenerative design (Du Plessis 2008). Resilience studies may assist in identifying stronger and weaker points in the resilience of a city. Catalytic design interventions that engage change at these points build on the natural potential of a site to survive, thrive and evolve in future.

Change can be a powerful mechanism for informing urban design, planning and management, for building resilience, and to trigger urban transformation. In South Africa,

social and economic change and exchange has been a characteristic and driver of urban growth – seeing 'entanglements' between oppressor and oppressed in the past (Nuttall 2009: 12), and reactive and proactive transformations since democracy. Transformation of the urban system to address the massive social-ecological challenges characterising the 21st Century is necessary globally, and not just in South Africa. Consequently, the University of Pretoria established a research unit called Think tank on Resilient Urban Systems in Transition (TRUST) to investigate resilience strategies for aspirational African cities (Think tank on Resilient Urban Systems in Transition (TRUST) [n.d.]). As part of this initiative, this dissertation serves as a vehicle for research on resilience within the context of the City of Tshwane.

Urban systems under pressure to sustain their populations and thrive find value in exploring urban resilience, firstly for its function as a 'tool' or 'indicator' to identify and harness the potential created by change. Secondly, resilience as a 'compass' guides policy and design that can mitigate disaster and adapt existing urban systems while also, if necessary, transforming them by collapsing dysfunctional sub-systems where they are making the whole system more fragile.

1.2.1 The case for an urbanisation 'rethink': consumption in a finite world

> We have used design cleverly in the service of narrowly defined human interests but have neglected its relationships with our fellow creatures. Such myopic design cannot fail to degrade the living world, and, by extension, our own health (Van der Ryn & Cowan 2007: 25).

In an age when the majority of the world's human populations live in cities (Burdett & Sudjic 2007), it would be naïve to think that development in urban areas can continue on its current trajectory without significant consequences for humanity. The reductionist worldviews framing the built environment and global social systems fuel the belief that unbridled growth and consumption can and should persist indefinitely for the gratification of the individual consumer (Hes & Du Plessis 2015: 24). Persistent consumption culminates in the depletion of finite resources and in over-burdened pollution or waste sinks (Meadows, Meadows & Randers 1992: 44-103). This situation links to fast-paced environmental destruction for the profit of larger powers (but often pushed by less powerful societies for physical and economic survival), and to fast-growing human populations trapped within locked-in consumer-driven economic systems (Jackson 2009: 51) and values.

Between 1960 and 2000, the human population doubled, cultivated ecosystems grew to make up a quarter of the earth's surface, economic activity increased six times, and reservoirs came to hold six times more water than what is flowing in rivers (Walker & Salt 2006: ix). The frightening statistics reflecting exploitation of pressured resource bases,

pollution and soil degradation, increasing consumer populations, and collapsing cultural and natural systems and pristine environments, lead the average compassionate human to desperation. This is especially so when global resource decline is propagated by those who have no choice but to exploit their local systems for economic survival, have no desire to change, or have worldviews that are not working anymore or cannot be sustained (Walker & Salt 2006: 4). These exploitations are most evident in the growth of cities, which proportionally increase the demand on natural resources and waste sinks (Swilling 2005).

Whether in developed or developing cities, consumption propels development (Fernandez 2014) and will continue to dominate urban systems. How it is considered, approached and managed directly informs the experiential and physical quality of the city itself (Fernandez 2014) as well as the (global) hinterland upon which it depends. It also directly informs whether current trajectories of unconsidered consumption are likely to exceed carrying capacities and lead to collapse. Were it that the demands cities place on resources and living systems were limited to their physical footprints, then the collapse of a large city system would not necessarily be of concern. However, the dissipative open systems that characterise cities have made global networks necessary to sustain them, by drawing life from the environment to spew out products and waste in return (Hamilton 2008: 31). At this time, the collapse of a *metacity* (Pickett *et al*. 2013: 23) would likely cascade through the global network, testing its resilience.

Cities profoundly affect the lives of all people, whether they live in them or not. These effects are not always immediately tangible or quantifiable, making an accurate assessment of their full impact very difficult without the aid of a systems approach. Human activity within an interconnected, fast paced and globalised world network consequently impacts directly on remote parts of the world excluded from participating in decision-making.

1.2.2 The case for an urbanisation 'rethink': current growth models

> One thing is certain. As humans take more of the primary productivity of the earth for themselves and the life forms of their choice (such as corn and cows), they leave less for other life forms. The result is a loss of economic value: game, fish, chemicals, medicines, foods may be disappearing with species that no one has even identified. There is also a spiritual and aesthetic loss, a loss of colourful companions in creation. There may be, for all anyone knows, a loss of critical pieces that hold together ecosystems. There is certainly a loss of genetic information that has taken billions of years to evolve – and that humanity is just beginning to learn how to read and use (Meadows et al. 1992: 66).

Growth is a story that contemporary society believes must be true. The narrative follows that growth coupled with techno-economic development, rather than social-ecological vitality, is the solution to poverty, inequality and quality of (materialistic) life (Jacobs 1984; Jackson

2009; Eisenstein 2011; Gilding 2011). Politicians and economists see growth as the means to eradicate poverty and to build prosperity. It is gauged by its quantitative characteristics as a Gross Domestic Product (GDP) or Gross National Product (GNP), rather than by its qualitative characteristics as Gross Domestic Happiness (GDH). So, "as a measure of human welfare, the GNP has been criticised almost from the start as it does not include qualitative aspects of life, learning or well-being, only the money value of final goods and services produced by the economy" (Meadows 2008: 139).

The current growth model is insatiable and requires generating money to sustain it, and consequently more activity to generate money. The effect perpetuates existing restrictions on daily life (both material and immaterial), as well as perpetual differences between the haves and the have-nots, focussed on surviving in a system that is driven to keep the economy growing at all costs. The growth model is based on a worldview of separation between humans and other living systems, as well as between humans themselves. It entraps all systems of life into it, making alternatives to a growth-economy system extremely difficult to imagine and above all, manifest. Yet, there seems to be a deep-seated sense that there must be an alternative to the pervasive frenetic growth model, since "if the growth of money really were driving the technological and cultural meeting of new needs, then wouldn't we be more fulfilled than any humans before us?" (Eisenstein 2011: 64).

To understand the current growth model, one must broadly recognise issues that gave rise to its manifestation. It emerged as a response to closely related global disturbances that forced changes to the status quo. For example, political shifts leading up to and following World Wars I and II transitioned almost all remaining monarchies to populist governments and republics, subsequently affecting their colonial programs. The dissolution of large monarchical economic systems with long-term projections made it possible for corporations to take over the scale and scope of industry and commerce, within the context of short-term government-led investments. This shift from traditional conservative and 'national' perspectives to Modern liberal and 'individual' perspectives meant that, in rebuilding post-war societies, the utopian ideals of the Modern Movement were adopted and transplanted all over the world, almost without consideration for their context (Jackson 2009: 21). In a short period humans changed society profoundly, resulting in irrevocable transformations to "the consumption, distribution and replenishment of the planet's natural resources" (Swilling 2005). One of the manifestations of this is the urban environment.

Following the above changes, the unbridled consumption of non-renewable resources to drive 'economic growth' (in both capitalist and communist societies) aroused the concern

of scientists, ecologists and urbanists. They rejected the seemingly irresponsible consumerist behaviour that had no concept of the Earth's limited resources. Stewardship of finite resources became enhanced when photographs of earth were sent home during the first series of successful voyages into outer space; people could visualise their home as a beautifully fragile planet suspended in a vast and inhospitable cosmos. The awe of this image created awareness that all of life was contained and dependent on planet Earth.

The urgency for what was perceived as the 'survival of Earth against the human onslaught' gave scientists like Meadows, Meadows and Randers (1972) the opportunity to introduce the concept of limits to growth through the lens of systems thinking, by using various growth trajectories as scenarios in their book, *The Limits to Growth: a report for the Club of Rome's project on the predicament of Mankind*. Twenty years later, in *Beyond the Limits: confronting global collapse, envisioning a sustainable future* (Meadows *et al*. 1992), they demonstrated that not only were resources being used and pollution being generated at rates that could not be replenished or absorbed, but also that the initial models were inefficient to cater for rapidly growing populations adopting increasingly consumerist lifestyles.

The economic growth story as the answer to all problems is flawed, because Earth is finite and its resources can be overshot. Despite having regenerative powers, this planet is not able to match the rate at which humans are consuming resources and destroying pollution sinks (Meadows *et al*. 1992: 44-103). In 2005, Millennium Ecosystem Assessment (MEA) released *Ecosystems and Human Well-being: Synthesis,* which stated that, over half of the ecosystem services provided by nature (that scientists are aware of), were severely degraded and may have already passed thresholds of collapse (Millennium Ecosystem Assessment MEA 2005: 6). Recently, the Stockholm Resilience Centre released a paper in which their assessment of nine planetary boundaries essential to maintaining the global system in a state suited to sustain human life, showed that four had already been crossed (Stockholm Resilience Alliance 2015). Two of these were the core boundaries of climate change and biosphere integrity. Crossing these boundaries has kick-started changes and feedback loops in the global system that will move it into a new state (Steffen *et al*. 2015). For the human system, this sets the scene for a global disaster that cannot be averted (Gilding 2011: 48). The scale and magnitude of change will ripple through global ecosystems, profoundly affecting human survival in response to extreme disaster events, resource scarcity and a breakdown of cultural systems.

For the built environment, as a driver of the current economic growth model, these ripples of change could be catastrophic. Urban systems have as their basis a global economic network that they have to sustain and that in turn sustains them, so that cities are described as "open-ended types of economies" (Jacobs 1984: 224). Global cities are already undergoing radical transformations through rapid urbanisation and environmental disaster, and these impact far beyond their physical boundaries to include the vast hinterlands on which they depend.

In a world where the inflexible economic growth model has become entrenched in global cities, one effect has been the flight of communities from rural to urban areas. Rural communities are drawn to urban areas for opportunities, especially when the lure of what lies there outweighs the hardships of rural life. This increase in urbanisation has in part resulted from the pressure exerted on rural life by climate change, resource depletion, environmental degradation as well as insecurity (Intergovernmental Panel on Climate Change (IPCC) 2007; British Broadcasting Corporation (BBC) 2011; National Oceanic & Atmospheric Administration (NOAA) 2011). The result of a rapid influx of people into urban areas exerts pressure on infrastructure, amenities and opportunities for employment, and exacerbates social friction. The dream of a better life in an urban area is often a nightmare. Subsequent sustainability debates regarding global ecological systems support the shift from blaming capitalism entirely for ecological destruction and urban poverty, to an understanding that growing urban overconsumption needs to be addressed (Swilling 2005).

The 'growth story' is not the only option. Considering how many human beings already suffer low-quality existences in rural and urban areas, and how countless degraded natural systems have become dysfunctional, this is not a reality worth sustaining. It is essential for global culture (driven by the insatiable economic growth model) to not only become proactively aware of the limits of ecological functions and the urban environment on which it depends, but also the limits of the economic growth stories it currently uses to justify its actions. As Paul Gilding writes:

> Achieving lasting prosperity relies on providing capabilities for people to flourish - within certain limits. Those limits are established not by us, but by the ecology and the resources of a finite planet. Unbounded freedom to expand our material appetites just isn't sustainable. Change is essential (Gilding 2009, p 157).

An alternative belief is inspiring the pursuit of a different reality and a more promising future (Jackson 2009; Eisenstein 2011). Looking at the processes of development from different perspectives such as well-being and prosperity, it is possible to make a new growth model

contribute to the systems it forms part of, rather than to withdraw from the limited capital of these systems.

1.2.3 The case for an urbanisation 'rethink': anthropogenic climate change

> Many people fear that ecocide has now come to overshadow nuclear war and emerging diseases as a threat to global civilisation. The environmental problems facing us today include the same eight that undermined past societies, plus four new ones: human-caused climate change, build-up of toxic chemicals in the environment, energy shortages, and full human utilization of the Earth's photosynthetic capacity (Diamond 2011: 7).

This is an age that effectively marks the first global mass-extinction event that is driven or propelled by the conscious activity of the species under threat of extinction (Wilber 2000: 12). Human activity and management of land-uses have transformed landscapes to accommodate human needs for food, habitation, production and recreation, an activity which profoundly affects many biophysical planetary systems, thereby becoming a major contributor to the rapid environmental changes that affect global climate systems (Dale & Haeuber 2001: 3). These changes have existed for centuries, but have now reached an acute global scale.

Science has proven that human-driven climate change exists (Gilding 2011: 36; Lovelock: 2007), perpetuated by human activities locked in a 'waste' economy. This economy drives the notion of unlimited growth to eradicate 'poverty' (Meadows 2008: 139) and improve living standards. However, the gap between rich and poor widens, and good living standards do not equate to quality of life or fulfilment. Deep-rooted denial or apathy toward the deeper changes required of global society to arrest the trajectory toward collapse, manifest in inaction or, at best, mitigation attempts that lack cohesive strength to affect change fast enough.

To be prepared for – or survive – the 21st Century challenges that global society faces, Gilding (2011) puts forward that human societies need to build resilience (both in preparing physical terrains and in equipping psychological domains) to deal with the massive changes that will profoundly affect every level of human existence (Gilding 2011: 175). There will be no half measures; if humans do survive as a species, life will most probably never be the same (Lovelock 2007). The reasons he suggests for this massive change derive from four consequences of transformation in our status-quo. Firstly, security and economic stability will falter as a consequence of the physical impacts of climate change, resulting in food insecurity, supply shortages and price hikes (as evidenced in food riots in the developing world: Mexico in 2007, Haiti in 2008 and Maputo in 2011). Climate change will furthermore increase the spread of infectious diseases and heighten allergies. Secondly,

there will be big shifts in global and national economic competitiveness from oil-based to solar and other forms of alternative energy and off-grid living solutions. Thirdly, the moral authority of different cultures and ecosystems will be challenged (as seen with the rise of the Islamic State of Iraq and Il-Sham and Boko Haram against the West, and climate refugees in Syria). Lastly, retribution and accountability will be sought from those entities perceived as being responsible for creating the problem (Gilding 2011: 175).

Although the scale of change is incomprehensible, there are ways in which to "harness this opportunity to think differently about how we see the world, how we define the problems to be solved, and how we can contribute as designers" (Hes & Du Plessis 2015: 12). A way to achieve this is to see the world as a whole living system (Lovelock 2007), where decisions made in one side of the world, may in fact be destroying societies in another; where the effects of what we do today to mitigate natural and social disasters may actually be giving rise to future disasters, and where the problem created by a culture gap may be more urgent to tackle than the environmental problem, since cultures have given rise to the environmental problem in the first place (Wilber 1996: 300). Climate change is forcing the global community to discuss options for future survival, and to think about the future differently. In this, resilience holds potential as a quality underpinning human lifestyle in this century, and as a means of actively engaging the urban system as a major driver of change, survival and hopefully regeneration.

1.3 Contextualising the study area: the City of Tshwane

> In this changing world, it is important the City of Tshwane maintains its commitment to continuously improve the quality of life for all its residents…. (City of Tshwane 2013: 45).

The capital of the Republic of South Africa, the metropolitan City of Tshwane (known as Pretoria until 2005), is located in the Gauteng province (shown in Figure 1). Gauteng is the smallest yet most populous province, and is therefore mostly urbanised with high levels of economic and industrial activity. Its urban nodes are Johannesburg, the largest city in South Africa, and the City of Tshwane. A large deal of future government investment is set to characterise development in the capital, as identified in the municipality's *Tshwane Vision 2055* (City of Tshwane 2013). This vision builds on strategic plans developed by the National Development Plan (NDP) for 2030 and formulates how the capital city should tackle climate change, migration, population growth, and economic and social activity, and how to reverse the spatial effects of *apartheid* (City of Tshwane 2013: 26, 40). It alludes to the need to move toward an ideal city in the next forty years that would be substantially different from what currently appears to be undesirable.

Figure 1 - Contextual map of Tshwane within the African continent, the Republic of South Africa, and Gauteng Province (Author 2015)

Part of the city's vision is to create a liveable, resilient and inclusive city, concepts that will "balance the competing needs of social, spatial and environmental issues brought about by the city's ever-changing population dynamics" (City of Tshwane 2013: 108). The urban character of the city is quite modest in scale, reflecting its organisational and administrative origins that supported activity in the rest of the country for over one hundred years.

This section of the dissertation covers a range of topics, to introduce the complexity of social and ecological threads in the web that characterises life in Tshwane. It does not provide an extensive summary of the city's history or current dynamics; it merely puts forward the idea that the city has a unique DNA that is deeply rooted in human and natural ecology. As a capital city in transition, it makes for a fascinating exploration of resilience concepts.

1.3.1 Why use Tshwane to illustrate resilience thinking?

Given the desire for the City of Tshwane to rebrand itself as "igniting excellence" and also "liveable, resilient and inclusive" (City of Tshwane 2013: 42), it is safe to assume there will be extensive public investment to transform the city's built environment in an attempt to reach the stated goals. However, it will not be in reports or policies that this transformation will achieve success. It will be in the built environment itself – its connectivity, accessibility, robustness and quality – and in how it makes people feel and engage with their city (Rochecouste & Pearson 2014). Perhaps the transformation will need to occur in the mind, toward considered development practices.

In many ways, the city is already resilient. The 6 289km^2 Tshwane metropolitan municipal area, shown in Figure 2, is comprised of 2.9 million people with 135 640 households receiving no annual income, and a 24% unemployment rate (City of Tshwane 2013: 42). The fact that the city persists is a sign of its resilience. People suffering various levels of abject poverty are able to survive and demonstrate high levels of personal resilience. However, a breaking point will occur where the resilience of individuals and the physical city fabric start to buckle under the pressure of unmitigated conditions.

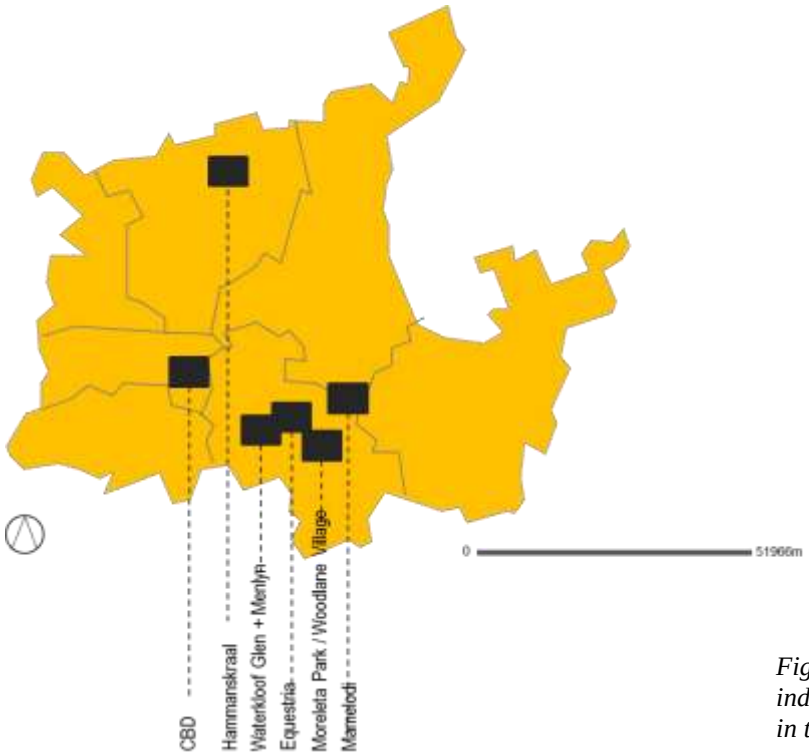

Figure 2 - Map of the City of Tshwane, indicating a few suburbs discussed later in the dissertation (Author 2015).

The *Quality of Life III* survey (Gauteng City-Region Observatory 2013) finds that despite satisfaction with service delivery and their lives as a whole, the citizens of Gauteng are increasingly dissatisfied with government, and "alienation, distance from government, 'phobias' – all are reaching very scary levels" (Gauteng City-Region Observatory 2013: 123). Action must be taken properly and with care to avoid further instances of xenophobia (Mbovu 2015) and social phobias (Wilkinson, 2015). Resilience thinking offers a pathway toward careful and considered action.

1.3.2 Journey to the past

The contextual history of South Africa's capital city, Tshwane (or Pretoria[1]), dates back eons in geological time and only a few centuries in social time. The rich underground water

[1] *While the city council put in a motion to change the name of Pretoria to Tshwane in 2005, fierce court battles have ensued. Generally, the metropolitan area, which consists of the amalgamation of 13 municipalities, is*

reserves that made the establishment of the village of Pretoria possible and give life to the city now, result from natural processes that shaped its land surface, soil and rock types (Dippenaar 2013: 16). In social time, remains of the close ancestor of present day humans, *Australopithecus africanus,* were found in the Sterkfontein caves at the Cradle of Humankind a few kilometres from the city (Dippenaar 2013: 17). From that distant point three million years ago until the more recent 1800s, Iron Age settlements in the broader area (Mason 1962: 415) consisted of smaller settlements that bartered on trade routes to the north and east. These small groups were established over wide areas and acted independently from each other, not relying on a centralised form of power or economic control (Mason 1962: 415).

During this time, according to the municipality of the City of Tshwane, Ndebele Chief Mushi and his eldest son Chief Tshwane moved from present day KwaZulu-Natal to the area close to the Apies River, before moving further north during the early 1600 - 1700s (Waldner 2006; Western Cape Business News 2006). The revised history put forward by local government is supported by a Mr Phistus Tshwane (also known as Thsoane) claiming to have oral and written records proving his ancestors were the first inhabitants of the City of Tshwane (Waldner 2006). Mr Tshwane suggests that his ancestor foresaw the advancement of *Voortrekkers*[2] into the area, and so directed his six sons to move elsewhere, using their first names as a disguise. However, this history is contested due to the lack of recorded history (oral or otherwise), lack of factual accuracy (Western Cape Business News 2006), and conflicting ancestral records from Ndebele Kings who say they have never heard of Chief Tshwane (South African Press Association (SAPA) 2005).

It is likely that this historical account forms part of a political process[3] of rebranding history with a dash of mythology, to better suit the politics of the day (Van den Heever 2008: 4). Given the vast expanse of what forms the City of Tshwane today, it is questionable that the society ruled by Chief Tshwane and his father Mushi were the first or only significant societies living in the area before the *Voortrekkers* arrived. And, if they were still living there by the time the *Difaqane*[4] commenced around 1820, they were probably affected by a number

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called the City of Tshwane, with Pretoria referring to the areas falling under the municipal area of the CBD and its older suburbs.

[2] *Communities of European descent who lived in the Cape Colony and then Natal for many generations, and sought to establish their own nation independent of British rule from about the 1830s onwards. Not the same as* Trekboers.

[3] *A new land-claim including the entire Pretoria CBD and the Union Buildings (seat of the nation's administration) was lodged in 2014, in which 70 000 people now claiming to be descendants of Chief Tshwane have applied for compensation for their loss of land (SA Commercial Property News 2014).*

4 The Difaqane 1822-1836; a period in South African history characterised by social and economic disruptions and large migrations, due to social-ecological pressures culminating in the rise of the Zulu state under Shaka.

of events that caused their migration and incorporation into other societies, not only by persecution by the *Voortrekkers*.

The early 1800s were marked by a period of considerable migration in Southern Africa (Fisher, Le Roux & Maré 1998: 4; Dippenaar 2013: 19), with the *Difaqane* unsettling societies, making it possible for new ones to be established, and marking drastic changes to the history of the land. Among the transitions was the Zulu expansion. Around 1820-1823, Zulu King Shaka's alliance with Ndebele Chief Mzilikazi caused the latter to move with his forces into current day Mpumalanga, destroying Pedi and Kgatla societies as he went and incorporating them into the Ndebele group (Mason 1962: 432). He ruled over areas of the present day City of Tshwane and Rustenburg (Dippenaar 2013). Four prominent groups lived in the broader area – the Griqua, Basotho, *Trekboers* and *Voortrekkers* (Venter 1985: 62) – and in 1832, the Zulu invaded Mzilikazi's territory, forcing him west and making it possible for the *Voortrekkers* to establish settlements further north (Dippenaar 2013: 19). By 1836, the first *Voortrekkers* arrived in the area and established farms. By 1852 they had formed a community of sufficient numbers to recognise the independence of the Boers north of the Vaal River (Venter 1985: 64).

In December 1856, the village of Pretoria, illustrated in Figure 3, was proclaimed the capital of the *Zuid-Afrikaansche Republiek* (ZAR) (Walker 1964: 267). It was only with the discovery of gold in the Witwatersrand in 1886 that the Calvinist agricultural society in the ZAR began to gain economic power in the region. As individuals from various nations flocked to the goldfields, so too did foreign enterprises. Pressures mounting from conflicting ideologies and a battle for control over resources saw the second of two Transvaal Freedom wars or Anglo-Boer wars (1899-1902) being fought in the ZAR. By 1910, the territories in Southern Africa unified to form the Union of South Africa, and Pretoria became its administrative capital. To commemorate this, the Union Buildings were built in Pretoria and became (and continue to be) the seat of government.

By 1961, when South Africa gained independence from Britain, much of the 'DNA' of the older areas of Pretoria was already established. Legislation developed by the National Party (NP) from 1948 to 1984 put in place a 'Grand Apartheid' between racial groups in the country. A number of pass laws and acts prohibited indigenous peoples to own property, move freely, and play an active part in society. However, the segregated spatial character of South African cities long preceded the 'apartheid city' as designed by the NP. 'Black'[5]

[5] Essentially, all South Africans that were not Caucasian, for example mixed-race, indigenous and Asian peoples.

communities lived on the fringes of the 'white' city and as these cities grew, they were frequently forced to relocate further afield from as early as the 1920s (Japha 1998: 423).

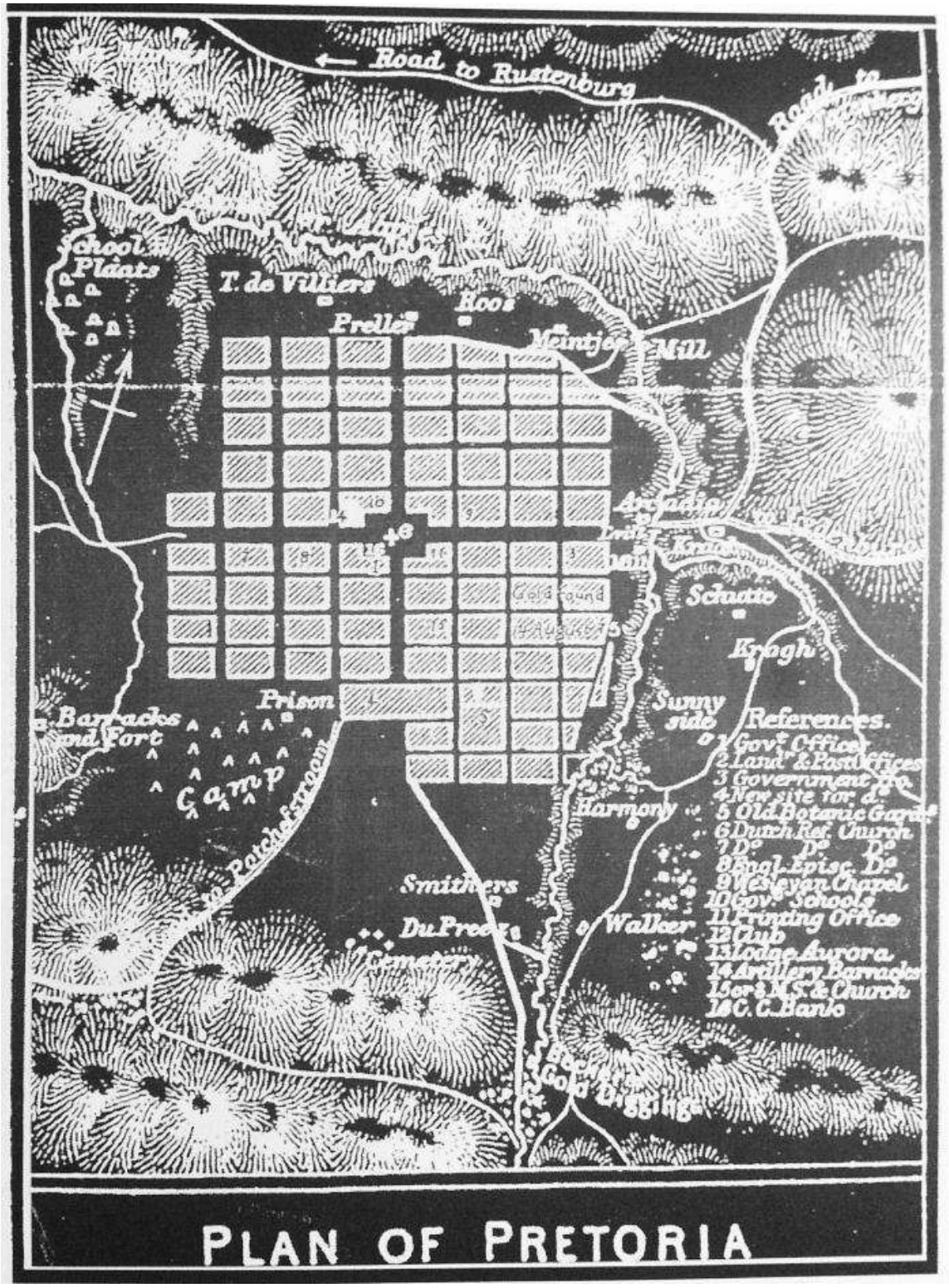


Figure 3 - Early map of Pretoria circa 1887 in Architecture of the Transvaal (Fisher, Le Roux & Maré 1998: 73)

During *apartheid* the 'townships' model presented in Figure 4a was perfected along with the NE 51/9 housing type shown in Figure 4b. These built environments were designed to advance political ideologies of control, and to harness a large workforce in the advancement of an industrialising economy. Townships and housing were based on the global model of the Modern Movement. This model substantially transformed cityscapes in South Africa, adopting the "substitution of Mumford for Le Corbusier, the region and the neighbourhood for the general community of man" (Japha 1998: 437).

Figure 4a (left) & 4b (right) - The apartheid *township model with the NE 51/9 mass housing model. Image from BLANK_ Architecture, apartheid and after (Japha 1998)*

After 1994, the new democratic government promised houses for all. In the years that followed, the government led by the African National Congress (ANC) instituted many policies and changes to correct the wrongs of the past. Unfortunately, many of these did not achieve the desired results. For example, the Reconstruction and Development Programme (RDP), which called for "the need to break down the *apartheid* geography through land reform, more compact cities and decent public transport" (City of Tshwane 2013: 24), perpetuated the problems of the *apartheid* city plan. New subsidised and affordable RDP housing is still being built in existing 'townships' and further afield, perpetuating a divided urban fabric, increasing urban sprawl and dependence on private transportation to get to work opportunities and amenities, and possibly perpetuating ethnic and racial segregation. Due to locked-in decision-making, the segregated *apartheid* city persists in spite of new policy and legislation. This is seen in its gated communities and security complexes separated by income levels and conveniences, an increase in two service delivery industries provided by government versus the private sector, and a heightened sensitivity (Gauteng City-Region Observatory 2013) between races and ethnic groups (Mbovu 2015). In 2015, the city council looks forward to a 2055 capital city that is "liveable, resilient and inclusive"; however, as history shows us, a lot can happen before then.

1.4 Problem and research aim

> The history of resilience thinking can be summarised as a story of how the fundamental assumptions under-pinning natural resource management (assumptions such as equilibrium, stability and predictability) were challenged by new understandings of the dynamics of change in complex, linked social-ecological systems (Wilkinson, Porter, & Colding 2010).

In exploring the crises and stresses that are set to affect future urbanisation, a particular problem emerges: if resilience theory is meant to navigate urban development through disasters and long-term crises, then its core concepts and their application to an urban system must be clear. This dissertation aims to evolve the understanding of resilience concepts within the built environment, from what has mostly been a bounce back approach toward a more dynamic and systemic approach. It takes inspiration from the evolution of *resilience perspectives* in ecological studies from equilibrist to dynamic concepts (Wilkinson *et al*. 2010). As a starting point, it explores how ecological resilience concepts translate into the urban context, thereby enriching the basis of *urban resilience theory.* Ecological resilience concepts were chosen for the fact that ecological and urban (or social-ecological) systems are both complex adaptive systems (Du Plessis 2009), the behaviours of which are said to be governed by "ecological resilience, complexity, self-organisation, and order" (Gunderson, Holling, Pritchard, & Peterson 2002c: 8). The translation of concepts takes place in the City of Tshwane in South Africa.

1.5 Premise of this study

The dissertation argues that it is possible to translate core concepts from ecological resilience theory into urban systems to form the basis of a clear urban resilience theory.

1.6 The main research question & sub-problems

If urban systems are affected by uncertain events that require alternative perspectives, such as resilience theory, to address the finite limits of critical planetary resources, as well as prevent the collapse of living systems of which humans form an integral part, and if resilience theories are already being suggested for city design and management, then:

how do ecological resilience concepts translate into a holistic urban resilience approach?

In order to answer the main question, three sub-questions emerge (as illustrated in Figure 5) which are answered in the course of this dissertation, namely a) What is resilience theory? b) What are the core concepts of ecological resilience theory? and c) How might these concepts translate to cities to inform urban resilience? These sub-questions answer key themes in the overall question, and form the basis for the structure of this dissertation in

engaging the data to prove the premise of the study. In exploring these questions, three clear objectives emerge as essential to the task of answering the main question, furthering the understanding of each of the sub-questions, as well as directing the process of inquiry in the dissertation.

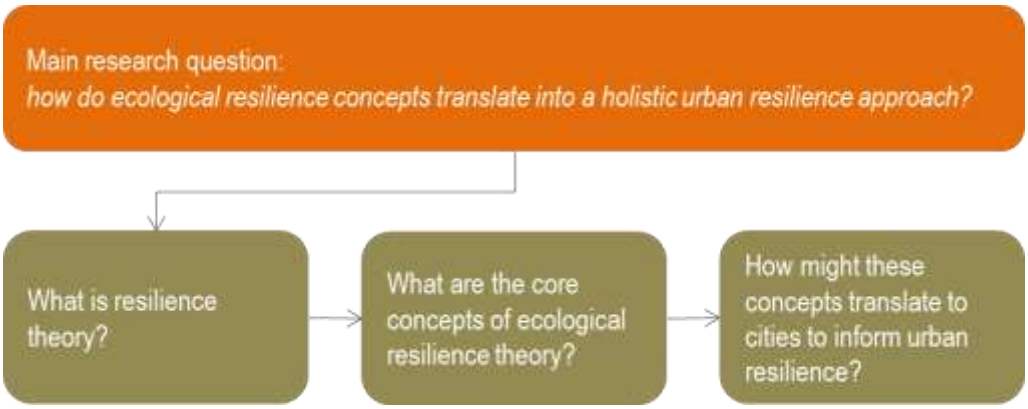


Figure 5 - Flow chart of the main research question and sub-questions (Author 2015).

1.7 Research objectives

This study is undertaken to achieve the following objectives for the following reasons:

Objective One

To refine the definition of urban resilience based on a sound foundation within existing resilience theory.

Currently, resilience is used descriptively in report writing and planning in which "heuristic, metaphorical and normative dimensions" (Brand & Jax 2007) are used, suggesting its role as a panacea for current and future urban problems. However, its application remains limited to climate change mitigation and readiness toward natural disasters. In contrast, for this study objective, a step is taken back to look at the foundational ideas and systems perspectives informing broader resilience theory, from which to frame an urban approach that goes beyond bounce back approaches.

Objective Two

To develop the meaning and conceptual clarity of urban resilience, building on an ecological resilience perspective.

Urban systems and ecological systems share the characteristics of complex adaptive systems in that they are both systems with similar adaptive properties of aggregation, non-linearity, flows and diversity (Holland 1995). In addition, both systems are the result of human-nature relationships called social-ecological systems (in cities these are more tight while in 'natural' areas more indirect). They consequently share a lot of synergy, and an emerging urban resilience approach could benefit from exploring well-established ecological resilience approaches.

Objective Three

To explore how ecological resilience concepts can be translated into an urban system.

While there may be theoretical synergies between urban and ecological systems theories, the actual application of core concepts from ecological resilience theory to urban systems might not work or might not yield any useful results. This objective explores how these concepts translate using Tshwane as the exploration ground for applying these principles, and discusses the findings as a basis for an urban resilience approach.

1.8 Definitions

It is aimed in this dissertation to further the definition of urban resilience by identifying core concepts from ecological resilience and to explore their translation within the built environment of Tshwane. In order to achieve this, the following definitions of terms apply to this study:

- ***Resilience*** is the capacity of a system to maintain the integrity of its functions and its core identity in spite of changes to its context, both tangible and intangible, and ranging from various stresses over time.

- Most global systems are understood to be ***social-ecological systems*** that represent a tight coupling between social systems and ecological systems, where the effects of one are interconnected with and interdependent on the other (Walker & Salt 2006; Du Plessis 2008a). They are complex adaptive systems that cannot be separated or looked at in isolation.

- ***Urban systems*** are social-ecological systems which are visually distinguished by their dense built environment and highly affected ecological areas. They consist of intangible and tangible features that both inform and define the lifestyle that unfolds therein as well as the characteristic built structures that create its identity. They are

rarely self-sustaining and depend on resources from distant regions (Hamilton 2008). Their economic processes produce material opportunities and amenities that attract people from rural areas, and the economy drives urban growth (Fernandez 2014). Cities in their various forms (Pickett *et al.* 2013a: 23) are urban systems, and in this dissertation the terms are used interchangeably.

- ***Natural systems*** are seen to include humans, not exclude them. Humans are an integral part of the Earth's ecology, which represents all living systems. However, limitations in language have made it difficult to capture this holistic understanding, since the terms 'natural' or 'nature' framed in a reductionist worldview usually refer to plants and animals, and exclude humans. Language typically distinguishes between human systems (which is problematic because humans are natural) and natural systems (which is problematic because they include humans). This creates a false dichotomy, since the natural system is but one living system. However, so much global change results from anthropocentric activity that at times it is necessary to distinguish the human element from the rest of the natural system. In this case, the dissertation refers to the human system or humans.

- ***Ecology*** is understood to be the study of the dynamic interactions between organisms and their environment (including landscapes and ecosystems). It includes how these interactions transform themselves and the environment and generate new physical structures. An urban system is considered an ecological living system.

- The concept of ***sustainability*** is not limited to the three-pillar approach described by Barbier (1987) and the Brundtland Commission definition (World Commission on Environment and Development (WCED) 1987), nor to the five capitals (human, natural, social, manufactured and financial) described by Parkin (2005). It includes an ecological approach to sustainability that embeds economy within social systems and social systems within the environment (Van der Ryn & Cowan 2007). It also engages post-sustainable outlooks hinged on an ecological worldview as the premise from which to frame sustainable development (Du Plessis 2009; 2011b).

- ***Integral*** refers to the philosophy comprehensively developed by Ken Wilber and researchers at the Integral Institute, and it is recognised as a theory that "weaves together the significant insights from all the major human disciplines of knowledge, including the natural and social sciences as well as the arts and humanities" (Esbjörn-Hargens 2012).

- Any system consists of components that are simultaneous whole entities as well as parts of a larger whole (Wilber 1996: 45). These components are called ***holons*** and make up the whole of reality; a cell is a holon, a human is a holon, a city is a holon.

- ***Evolution*** is the infinite process of unfolding within systems that "always transcends and includes, incorporates and goes beyond" (Wilber 1996: 5) what went before, in order to reveal more of itself by adding new *holons* and novel relationships at each unfolding. Each wave of evolution ultimately reaches its own limitations that then trigger a self-transcending drive to derive new relationships from the chaos of the old system (Wilber 1996: 45). It is asserted in this dissertation that a resilient or a sustainable system must have the capacity to evolve and transcend its limitations through the infinite process of unfolding.

- Evolution, unfolds in various domains: matter or cosmos, life or biosphere, and mind or noosphere. Combining all three domains creates the ***Kosmos*** – the pattern of all domains and not just the physical or material domain (Wilber 1996: 17).

- The ***holarchy*** is the natural hierarchy that emerges from this creative process of unfolding, or evolution, of *holons*. However, unlike traditional hierarchical systems, a *holarchy* does not differentiate between the importance of holons at initial levels of emergence and those at later stages, since the later stages depend on the initial holons for their existence. *Holarchy* is also a means of achieving *holism* (Smuts 1927), meaning "where the whole is greater than the sum of its parts then the whole is at a higher or deeper level of organisation than the parts alone" (Wilber 1996: 21-26).

- ***Panarchy*** is a term developed and defined by Holling (2002) and can be described "as a hierarchy of nested sets of adaptive cycles. The functioning of those cycles and the communication between them determines the sustainability of a system" (Hamilton 2008: 42). This hierarchy is a means of understanding relationships between different systems, scales, time and disturbances.

1.9 Assumptions

The study forms part of a larger research project at the University of Pretoria investigating resiliency strategies for aspirational African cities. The dissertation deliverable is the conceptual understanding of resilience within the City of Tshwane, by exploring ecological resilience concepts in the urban system at various points of time and space. Its aim is to

generate a clear definition of core urban resilience concepts. Given this background, the following assumptions and points of departure apply:

- No comment will be made on the merits, validity or value of resilience as a theory nor its validity or value in studying urban systems. The development from the 1970s onwards of resilience theory as a descriptive quality within ecological systems (Gunderson *et al*. 2002a; Folke 2006; Walker & Salt 2006) and different fields (Davoudi 2012; Walker & Salt 2012; Zolli & Healy 2012), including the built environment (Du Plessis 2012a; Walker & Salt 2012; Whiston-Spirn 2012; Pickett *et al*. 2013b; Anderies 2014), confirms its merits and validity.

- The world is facing various crises, from climate change and resource depletion to rapid, uncontrolled urbanisation and poverty (Burdett & Sudjic 2007). While all countries are affected to some extent, the African continent is most at risk of not being able to harness the potential generated by these unprecedented changes, in order to surpass the speedy process of the "urbanisation of poverty" (UN Habitat 2003). Furthermore, local government systems in these transitional societies are assumed to be unable to track the social, technical, spatial and biophysical factors that would determine resilience within the urban system.

- It is assumed in this study that current models of sustainable development are insufficient to respond to unprecedented change resulting from growing climate change pressures on resources and the environment, compounded by the demands of sustaining a large (and growing) global society in urban areas. The reasons for this insufficiency may stem from watered down tenets, lack of political will, or varying perspectives regarding the goals for sustainable development. It assumes limits to the planetary resources that form the basis of current development and growth models. It assumes human activity accelerates climate change with disastrous effects on global systems, seen in frequent climate catastrophes and collapsing economic and social systems, including human survival systems like food production, safe drinking water and the spread of infectious disease. It assumes that urban systems as the dominant human habitat contribute to these changes the most (directly through consumption and indirectly through industrial activity).

- Urban systems are assumed to contribute toward developing solutions for the future development of living systems that survive, adapt and flourish. The study accepts that the world comprises various interconnected and interrelated cross-scale

systems, where the effects of changes in one of these systems cannot always be quantified or realised immediately, but can ripple far beyond their boundaries. It assumes that current sustainability models, post-sustainability models, and resilience models are not a means of 'saving the planet', but rather a means of continuing the evolution of life (particularly human life) along some form of positive trajectory. It assumes that resilience thinking offers a means of navigating through challenges in order to generate proactive urban development solutions that build capacity for all forms of life, including human systems. Embracing global societal needs without prejudicing the current state of the planetary system is an absolute necessity if living systems are to be given a chance to regenerate. Equilibrist sustainability models have evolved into dynamic resilience models with new systemic approaches for change; so too can ecological resilience theory, if adapted to urban systems, offer a more dynamic and robust approach for assimilating change into regenerative processes in the urban system. Change cannot be viewed as a linear concept, but rather as a dynamic framework of resilience (Wilkinson et al. 2010).

- Due to the similar systemic properties and structures in ecological and urban systems, it is assumed that translating core concepts from ecological resilience theory to cities will potentially enrich urban resilience thinking and its future practice.

- It is assumed that concepts underpinning the resilience approach discussed and used in this study are generalizable, in that they can be applied to different cities, however there will be differences in how it plays out in different contexts such as the global south versus the global north.

1.10 Delimitations

The following theoretical, temporal and geographic delimitations and boundaries apply:

- This study is explored within the physical fabric of the City of Tshwane. This is a requirement of the National Research Foundation (NRF) grant holder that has formed the overall research framework within which this doctoral dissertation falls. Therefore, no investigation is undertaken to identify which of South Africa's metropolises would be best suited to this investigation, nor is there a comparative study of the application of the principles to different metropolitan areas. The City of Tshwane is such a vast metropolitan area (the third largest by area in the world), that it provides ample opportunities to explore the premise of the study in a range of conditions.

- The time period for exploration is focussed between 1940-2014 with broad references made to the early establishment of the city in the 1800s and broad historical occurrences before then.

- Due to the extent of the metropolitan area of the City of Tshwane, the focus falls on the municipal area formerly known as Pretoria, and on a few sites in the east of the city within the municipal boundary. These sites are undergoing rapid development driven by high levels of ad hoc private investment.

- Given the breadth and scope of resilience theory, the focus is on core concepts from ecological resilience theory only. Ecological systems synergise with urban systems (both are complex adaptive systems) and so form the focus for research.

- In the translation of core concepts from ecological theory into urban systems, aspects of different branches of resilience theory might be touched on. However, they will not form the basis for developing these concepts.

- This study accepts the value of resilience theory as a means of interpreting the state of a system undergoing dynamic change. It also accepts its value as a means of achieving the goals of sustainability.

  Resilience is often interpreted as a new sustainable development trend that repeats the mistakes of past practices (i.e. the prioritisation of a-contextual efficiency of existing systems rather than a revision of the systems themselves). This debate will not be entered into other than to critically engage the understanding that resilience is a property of either sustainable or unsustainable systems, and the way it manifests can indicate the strengths and weaknesses of a system, as well as guide further development. Resilience thinking provides a useful way to observe change in urban systems and to create awareness about their inherent ability to adapt to future changes. Resilience qualities improve the ability of cities to adapt to unpredictable change without securing outcomes, rather opening up potential for variable trajectories. Furthermore, urban resilience promotes a mind-shift from check-box approaches to ongoing systems studies that interrelate responsible top-down governance as well as self-organising bottom-up action. As a result, urban resilience becomes both the lens through which to interpret what is happening in the world, and the path to transition to new states that mitigate, adapt or transform after stress.

- Resilience is not seen as a blanket goal for urban development, but as a characteristic or emergent property of a social-ecological system.

- The study does not contain a proposal for the development of a set of finite and fixed resilience 'design tools', but rather a way of thinking about design and development. Existing tools and methods are utilised under the umbrella theme of creating a 'healthy' and adaptable urban environment that can survive and thrive through unprecedented change.

- The research will focus on descriptive qualitative aspects or conditions that contribute toward general resilience. It will not determine or measure quantitative boundaries of urban resilience, will not provide a checklist to create urban resilience that predicts certain results, nor will it generate an assessment tool to quantify whether a city is resilient to a prescribed set of goals or not.

- Usually, the rich and dynamic dimensions that form a city are understood through physical infrastructure; however, physical infrastructure develops from the ideological constructs of society, which have a direct influence on the way in which the city functions and people experience or engage the city. Future urban resilience studies should include tangible and intangible dimensions, since the layers provide clues as to how the city may respond to change and disturbance in its system.

  It is clear that resilience in an urban system comprises the resilience of the physical city along with its intangible systems (Capra 1996), institutions and individuals. Urban resilience studies require integration of both the external and internal dimensions of the city. While both dimensions are acknowledged, the aim is to explore the resilience of the physical form of the city first from which to expand into the intangible systems in future studies. Hence, the focus of this study will be to explore the external or physical dimension of resilience in the urban system only.

- In exploring the importance of a holistic urban resilience approach, this dissertation will touch on the principles of the *Integral Theory* framework to motivate how resilience can integrate its qualitative and quantitative dimensions, and to provide a framework for decision-making. However, it will not focus on integral theory in detail.

1.11 The importance and benefits of the study

The value and significance of the study lies in both theoretical and practical benefits. In promoting the development of resilience theory, the translation of core concepts from ecological resilience theory into an urban setting aims to refine *urban resilience* concepts. It adds to the body of knowledge in an emerging and increasingly popular research field.

Its theoretical benefits lie in furthering the understanding of urban resilience theory. Even though destructive systems are often highly resilient, resilience is put forward as the goal for development in local policy reports (SACN 2011; City of Tshwane 2013). To normatively suggest that a city must be resilient is to possibly increase the resilience of its perverse relationships. This dissertation suggests that an urban resilience approach should focus on understanding what might be blocking the potential of life to flourish in the city, since resilience arises from structures or properties in an urban system that build its capacity to persist. A systemic rather than normative focus facilitates built environment professionals, city officials and citizenry to navigate perturbations in the system.

Its practical benefits lie in demonstrating how resilience concepts manifest in the urban system. Out of necessity, this study touches on issues which include sustainability and climate change, and new perspectives from which to view urban problems. These aspects contextualise the understanding of urban resilience in contexts such as the Tshwane social-ecological system, highlighting a necessary change in the way we think about urban development in future, from compartmentalised to integrated perspectives. It will show that professionals, practitioners, academics and government officials involved in the built environment need to integrate their efforts and rethink 'change' in urban systems (Wilkinson *et al.* 2010), and to also to see potential therein for 'positive' growth in transitioning societies.

1.12 Contribution of the study

The significant contribution of this study lies in translating concepts and principles from one field of inquiry into another, thereby producing cross-disciplinary work. The study expands resilience interpretations into urban resilience approaches (or practices) within a framework that uses the theoretical underpinnings of existing resilience theory. By translating *ecological resilience theory* concepts into an urban system, namely Tshwane, urban resilience theory and practice knowledge is broadened in a new way.

While numerous studies have explored the conceptual framework of resilience thinking, none have tackled its translation into the Tshwane urban system in the manner it is done in this dissertation. The exploration of resilience concepts, using narrative descriptions and

graphic mapping within Tshwane, contributes to local and global resilience research. Cross-disciplinary research and the site-specific explorations add to urban resilience knowledge in two areas: in describing the resilience properties of a city system, and in exploring a normative goal for development.

1.13 Brief chapter overviews

The dissertation is divided into three parts, as illustrated in Figure 6. Part One is titled "Setting the scene" and consists of four chapters that frame the direction taken in the study in Part Two. Chapter One introduces the study to the reader, provides the motivation behind it, sketches out the problem and the focus of the study in the premise of the study, objectives, delineations, positions, assumptions and contributions. It also provides a list of definitions that are important in framing the study within a holistic worldview.

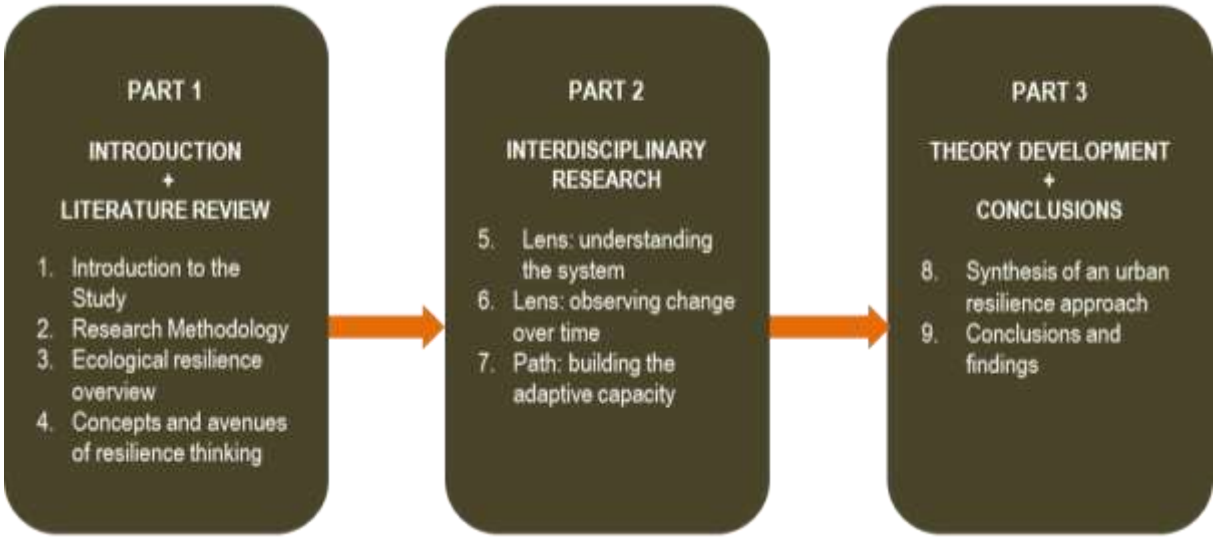


Figure 6 - Chapter outlines (Author 2015).

Of importance in Part One is the research methodology outlined in Chapter Two, which is formative in the genesis of this dissertation. Chapter Three embodies the primary literature review, and focuses on providing an overview of resilience theory, as well as ecological resilience theory in particular, drawing out its key definitions framed within each of the three branches of resilience thinking. Chapter Four provides the essential concepts through which to understand and practice resilience thinking in a systems perspective. It further identifies the fields engaging with resilience and its various manifestations, namely the capacity of a system to bounce back, adapt or transform (the main branches of resilience thinking). These chapters form the basis for explorations in Part Two.

Part Two is titled "Exploring ecological resilience within the Tshwane urban system". In this part, the interdisciplinary research of ecological resilience theory concepts are applied to

the Tshwane city system, using a few chosen sites in the city. It follows on from the core ecological resilience concepts discussed in Chapter Four and divides them into two chapters dedicated to studying resilience in a system, the *lenses*, and then engaging with resilience in a system, the *path*. These are then divided into three themes: understanding the system in Chapter Five, observing change over time in Chapter Six, and building adaptive capacity in Chapter Seven. Chapters Five to Seven each begin by defining and discussing the concept, and then applying the concept to a chosen site in Tshwane. At each application the concept is illustrated and refined.

Part Three synthesises the findings in Part Two into key points of an urban resilience approach. It begins with a review in Chapter Eight of the findings of the explorations in Chapters Five to Seven. This is done in order to further the understanding of what urban resilience is, and puts forward a definition, its purpose, scope and core concepts. It also highlights a possible area for concern in future studies, which relates to the use of transformative resilience. Lastly, Chapter Nine is a synthesis of the study, concluding with the findings, the limitations, and areas for further research.

CHAPTER TWO

RESEARCH METHODOLOGY & ORGANISATION

2.1 Introduction

> The essential distinction between revolutionary science and ordinary science is that the former involves a 'tradition-shattering' as opposed to a 'tradition-preserving' kind of change (Buchanan 2002: 47).

As a field of theory that combines both factual evidence from the physical sciences and the assessment thereof in the social sciences, ecological resilience theory requires a highly integrated approach to reach a useful output. The initial research process for this dissertation aimed at a richer construct of new knowledge in the field, using a phased research process which includes both quantitative and qualitative approaches. Due to the breadth of the study topic however, this study has applied only qualitative investigation and interpretation methods to explore the premise of the study. The motivation for a qualitative approach was strategic. From a solid qualitative understanding of the concepts, further qualitative and quantitative research can be done in future, but without the qualitative understanding of core concepts, quantitative research would be rendered unfocused. In the form of an argument, the logic for the synthesis of ideas is approached in a reflective process of research, discussion and application. A desktop approach is used to find data that can be used to generate a deeper understanding of concepts in this theory. Data are not used to develop rules or specific mathematical or scientific models as might be used in a quantitative process.

2.2 Research approach

The dissertation is rooted in a qualitative research method, in order to understand and describe resilience concepts in the urban environment. This method aims to explore, observe and interpret data in order to understand the complexity related to resilience thinking in the urban environment (Leedy & Ormrod 2005: 94-96). It follows a flexible, 'holistic' and iterative process emerging from the complexity of the data available. As context-bound patterns and information emerge, concepts and theories are augmented (Leedy & Ormrod 2005: 95).

Specific observations regarding the translation of ecological resilience concepts into the urban realm are used to "draw inferences about larger and more general phenomena" (Leedy & Ormrod 2005: 96) and are supported through logical argumentation. Narratives form the basis of this interpretation to capture the complexity of the study topic, and are communicated using quotes, and a personal voice. Although all efforts are made to keep

a non-biased and open-minded approach to the interpretation of data, qualitative methods remain subjective and extra care is taken in presenting the research findings.

2.3 Challenges in defining a method, design and methodology

Many studies have investigated ecological resilience theory as well as urban systems. However, they do not put forward a comprehensive view of how ecological resilience translates to the urban social-ecological system. Therefore, in trying to develop the epistemology of urban resilience, it is clear that an integrative approach to the study is required that contains the flexibility of iterative methods and methodologies as research progresses.

This flexible and multi-perspectival approach to method, design and methodology also responds to the following challenge: a living system contains both quantitative and qualitative aspects; in ecological as well as social-ecological systems (including cities), both of these dimensions need consideration. The resilience of the physical environment and the social domain is suited to combined qualitative and quantitative research. Concepts informing resilience research originate from the social domain, therefore the study benefits from the development of a qualitative conceptual exploration of the physical environment. This naturally points to a mixed approach to research design that responds to the particular requirements of each section.

Lastly, the credibility of the research design and methodology needs to relate to internal and external accuracy. The conclusion drawn from the data selected must be reliable and relevant to situations beyond itself (Leedy & Ormrod 2005: 99). While the results of the research can generally be applied to other urban systems, their results are not necessarily replicable. To ensure the dependability of data, various data sources are used in search of common themes to support the findings. In this regard, the limitations of language and terminologies to describe complex, integrative and multi-dimensional topics proved to be a drawback.

2.4 Research design

Research designs are described as being "logical plans involving strategic decisions to maximise the validity of findings" (Du Toit 2010) or as "the overall approach used to test your thesis statement" (Hofstee 2006: 113) or as in this study, the premise. Primarily, the design of this study could be summarised as a desktop analysis and literature review. However, it is not so simple. Identifying a single design for the research conducted in this study is difficult because of the complex nature of the problem studied. Research has to combine various

viewpoints, practices and fields of study into one coherent approach to understand the concept of urban resilience in a social-ecological system. This complexity arises from the fact that principles from one discipline are being translated into another, namely from a) ecological science concepts of resilience theory into b) an urban system. This raises a few problems.

Firstly, extensive research exists on ecological resilience theory, but urban resilience is still a nascent theory; its very interpretation is precarious due to the lack of understanding of its broad manifestations and adaptations. Secondly, without a clear definition for urban resilience, it is nearly impossible to apply its principles to an urban social-ecological system (SES), which in itself is a moving target. For this dissertation, the researcher consequently relies on an iterative process of investigation, where aspects of various methodologies refine the findings of the study, where useful.

The dissertation synergises with four prominent research designs. Firstly, in the application of ecological resilience (ecological concepts) to the development of urban resilience (an urban setting), Interdisciplinary Research emerges, where concepts from one discipline are applied to a problem in another discipline (Hofstee 130). The application of ecological concepts to cities in one form or another is not new, with influential research conducted by various researchers over the past century (Whiston-Spirn 2012). However, the translation of ecological resilience concepts into the Tshwane urban system is an exploration that is only beginning, and which can benefit from Interdisciplinary Research designs.

The second research design that is suited to the broader intent of this study is Theory Development. This design is orientated toward understanding and observing aspects of the world in order to "bring order out of chaos" (Hofstee 2006: 130). Given the urgent necessity to try to make sense of what urban resilience can be, this method seems prudent in refining existing theories. Furthermore, it may increase the likelihood for urban resilience theory to be used to harness unpredictable change, to expand its theoretical applicability, or enhance its 'predictive power' (Hofstee). In developing urban resilience theory, new insights refine understanding.

Thirdly, a Literature Review provides an overview of the resilience theory field. The purpose in exploring this research design is to identify whether there is not a new, or less regularly articulated yet important, perspective. This review is essential in providing a solid conceptual understanding of core concepts within ecological resilience theory, as well as avenues for new thinking in urban resilience that are beneficial to the theory.

Lastly, but perhaps most importantly, the Historical-Comparative (H-C) research design is particularly useful. With its origins in the nineteenth century, sociological thinkers developed historical-comparative research to blend sociology, history, political science and economics (Kreuger & Neuman 2006: 419). It is aimed at answering the 'big questions' and described as a powerful method for achieving answers (Kreuger & Neuman 420). It looks at factors that play out in social systems and their resultant effects over a long time. This type of research design can strengthen the way theoretical concepts evolve, grounding them in a broader context with some generalisations. In the study, H-C research focuses on what occurred within focal areas in Tshwane over a few decades, using qualitative data to develop an understanding of historical change. The research is conducted across scales to integrate micro and macro levels so that "instead of describing micro-level or macro-level processes alone, the researcher describes both levels or layers of reality and links them to each other" (Kreuger & Neuman 426).

Together, these designs organise the research to deliver a few key results for a specific aspect or section of the study. They a) identify core concepts from ecological resilience theory, b) translate these core concepts to urban systems, c) explore these concepts in the Tshwane urban system, and d) provide a basis from which further research into urban resilience can be conducted. These results provide a clearer picture of the full scope and potential of urban resilience thinking in developing a sustainable and hopefully regenerative future for the capital city of Tshwane.

2.4.1 Advantages and limitations

Each research design has advantages and limitations. Interdisciplinary Research requires the mastery of two or more disciplines to successfully apply principles from one field to another, and the principles, concepts or ideas can often be unsuited to the second field or inappropriately used (Hofstee 2006: 130). In this study, the disciplines are ecological resilience and an urban system. Given a natural compatibility and synergy between the two disciplines (in that both are complex adaptive systems), this design can render highly valuable results. The scope of interdisciplinary research in this study is limited to the identification of core concepts from ecological resilience theory, and their application within a few focal areas in Tshwane.

A literature review is largely derived from available literature and chosen sources, which can cause limitations in the interpretation of the conclusions and contributions of other scholars in the field. There is also the risk of bias toward the literature, or that limited time factors make a comprehensive synthesis of the literature difficult (Hofstee 2006: 121). However, with

interest in urban resilience increasing, it is useful to broadly evaluate where resilience theory applicable to urbanism stands at this moment, where main themes and concepts lie, and how these relate to each other. This may also be of benefit to other researchers in the field. In this dissertation a literature review is used to provide an overview of resilience thinking, its benefits and relationship to urbanism and sustainability, its use in other fields, the core branches of resilience thinking, and the focus on core concepts that underpin ecological resilience in particular.

Those aspects of the study explored by using Theory Development seek to apply ecological resilience theory to the Tshwane system to refine the definition of urban resilience. In this case, urban resilience theory concepts will be derived from the exploration of core ecological resilience concepts. These concepts will be developed from existing ecological resilience and resilience theory literature, as well as desktop observations of focal areas within the Tshwane urban system. The benefit of using this research design is that urban resilience theory is already under development within the context of discourse and practice in South Africa, but needs refinement. The weakness of this research design lies in the difficulty involved in maintaining the internal consistency of the theory while remaining realistic (Hofstee 130). Further challenges are the limitations on gathering reliable data and the specific focus areas of the study, namely the physical aspects of resilience in the urban realm only (chosen in view of time constraints) and the focus on core concepts of ecological resilience theory. Care should be taken to not make assumptions about the observations, and consequently the theory as a whole.

Historical-Comparative (H-C) research is limited by the researcher's broader contextual knowledge of past events and historical context. In addition, this interpretive design is often criticised by positivist scientists as creating generalisations based on few qualitative examples and data, and is thereby said to not be a 'true' science (Kreuger & Neuman 2006: 423). However, since H-C research is largely based on past events and evidence, data is usually indirect and must therefore be reconstructed. In this process, interpretations will need to be made. To strengthen the basis for interpretation, H-C researchers approach the whole study through multiple perspectives to go beyond surface appearances and to "reveal the general, hidden structures, unseen mechanisms and causal processes" (Kreuger & Neuman 2006: 426). While doing so, researchers have to be cognisant of the potential for a Western cultural bias which does affect thinking and, for this reason, researchers should include multiple perspectives to attempt to reach a more holistic interpretation.

2.5 Research process

In developing a methodology for this doctoral dissertation, the Historical-Comparative (H-C) research method was particularly valuable (Kreuger & Neuman 2006: 428-430). The first step entailed conceptualising the object of inquiry by exploring a set of concepts and applying them to a specific setting. Next, evidence and data gathered from a range of sources established themes used to refine and adjust the initial concepts. The evidence was then analysed for quality, accuracy and discrepancies. Themes were then organised according to theoretical insight and critical engagement with the data. Lastly, the concepts were further refined in response to the data and synthesised into a general model that explains the data and findings. This search for new meaning forms a major task of the H-C method and is reflected in the research report along with the evidence and concepts.

2.6 Organisation specific to this dissertation

This section explains in detail how each research design was used to cover aspects of the study. As mentioned, a literature review was compiled to derive an overview of resilience theory and to determine the core concepts of ecological resilience theory in particular (Chapters 3-4 for the overview, and 5-7 for core concepts). The Historical-Comparative (H-C) design was used to generate findings where concepts derived from traditionally ecological settings were applied to urban settings, and processes from one field were tested in the other (Chapters 4-7). This interdisciplinary research provided a frame within which to direct a practical application of urban resilience. Observations were made in this process and the results were used to inform the development of an ecologically rooted urban resilience theory and approach (Chapter 8).

2.7 Data sources

The dissertation data were sourced primarily from existing resilience literature and this formed an important informant of the research method. Most of the literature sourced consists of peer-reviewed books and papers by experts in the field – these form the secondary data. Data were sourced from literature that deals with resilience as a general topic in terms of surviving the challenges of the 21st Century, with resilience specific to the ecological resilience perspective and existing applications in the built environment. Further data were sourced from additional sources related to the topic of resilience, but not specific to it. In these cases, the sources were chosen for their value in contributing to a holistic view of the broader urbanisation challenges, ways of thinking about these challenges, and how they can enrich the formation of an urban resilience perspective. The

sources were found using the University of Pretoria's library catalogue of books, its online journals, as well as books in the author's personal collection.

In addition, data were used to explore the extent to which ecological resilience concepts could be translated into the urban realm. For this purpose, the sourcing of maps and GIS data was influenced by the matter of accessibility. Even at a tertiary institution, the control over and cost of data makes it difficult to access high quality data. The decision was made to find reliable data that was accessible to the public with relative ease. Archival information in the form of topographical maps and aerial photo's dating from 1900 to the 1990s was obtained from the Chief Directorate: National Geo-Spatial Information at its head office in Mowbray, Cape Town. All geo-spatial information gathered for South Africa is recorded at this department as part of governmental services, and so forms the most consistent record of change in Tshwane over intervals of time. Maps were surveyed by the trigonometrical survey office. Recent aerial photographs were obtained from Google Earth satellite imagery for the period 2001 to 2014. These data sources form part of the primary data used in this dissertation. The strategy behind this source was to illustrate the ease with which the resilience thinking approach can be used to explore the urban environment in Tshwane, i.e. one needs not be constrained by access to data to investigate and observe general resilience trends, and to make decisions in reaction to the findings. Both sources were considered to be highly reliable and accurate.

The author collected the data directly, and then used it to observe whether resilience concepts could apply to the urban realm, in order to explore the more, or less, resilient points in the design of a focal area in the city. The observations were looking to assess the ease with which concepts translated, and if there were instances where they did not translate at all. The areas chosen for observation are located in three areas in the east of the city that are experiencing high levels of change, bringing conflict, concern, and at times condemnation. Observations were made as follows: a focal area was chosen that appeared to synergise with the issues highlighted in one of the ecological resilience concepts. Then the ecological resilience concept was investigated and its principles used as the lens through which to analyse the area. The analysis looked to discover a) the method of application, b) ease of translation, c) whether the principles of the concept had been met, and d) how the design of the focal area could be adjusted in response to the concept and principles.

In this analysis, methods and protocols changed in each instance according to the concept being explored. Other than the four aims outlined above, the analysis process was

adjusted to the principles and methods inherent to the concept being explored. For example, in thresholds and regimes, a timeline of development was explored to identify critical thresholds and regime shifts in a suburb, while for modularity, the increasing vulnerability of a fast developing neighbourhood was explored on the basis of vehicular and non-motorised accessibility. Overall, the concepts explored applied different methodologies for analysis; however, there was one key factor that was consistently explored in all examples, and that was change over time.

2.8 Data

The data retrieved from the National Geo-Spatial Information Analysis department is considered to be reliable and accurate. Older data may have a few discrepancies or human errors, but these are negligible for the purposes of this study. Unfortunately, records for the areas in question do not go back further than 1944, leaving about 90 years of what can be called active city making unrecorded in the sources retrieved. Google Earth satellite imagery is similarly highly reliable and accurate if it is based only on the aerial photo itself (which is the case in this dissertation). The additional layers and information on Google Earth are often outdated and inaccurate, and for this reason were not included.

For the purposes of this study, the data are considered to be unbiased. The observations explore various core concepts of ecological resilience, using contrasting contexts in Tshwane characterised by changing urban morphologies like established suburban areas in transition toward new business nodes, densification of low-density areas, and peripheral affordable housing townships emerging in higher-income areas. In gathering data for this investigation as a form of exemplification, Tshwane provides a useful urban system for exploration for three reasons. Firstly, and perhaps most importantly it is a city undergoing rapid transformation (social, political, economic and environmental). Secondly, it offers a diversity of urban conditions that reflect many emerging global issues (migration, political instability, formal or self-organised economies and climate change). As an exploration ground for multiple issues affecting the rest of the world, this capital city could be argued not to lag behind more developed countries, but rather to be leading in manifestations of a form of urbanisation that will become more prevalent the world over. Lastly, as a capital city promoted as 'resilient' by local government, this dissertation explores what resilience actually means for an African capital city. In developing the core concepts of urban resilience, a better understanding of the core characteristics of a general urban resilience emerges as guidelines or general principles that can build the overall resilience of the physical properties of a city. In this sense, a very low level of predictive power might emerge; the system might however be better equipped for future unknowns.

2.9 Analysis

In order to organise the research and develop the argument, the following framework, described by Figure 7, forms the basis from which this document has been produced. At the foundation of this dissertation lies the identification of the core concepts from ecological resilience theory, and the commonalities to be found in translating these core concepts into the urban social-ecological system so that urban resilience concepts can emerge.

In Part One the scene is set for the study and an in-depth literature review is developed as the basis for further discussion. During this period of analysis, common and emerging themes were extracted from various texts, and used to create a base of core resilience concepts (Chapters 3 & 4). In order to develop the literature study, it was important to test whether the core concepts derived from literature were unbiased and critically engaged. Consequently, participation in resilience theory workshops, writing of papers and presenting at conferences and seminars became an important aspect of the process of analysis.

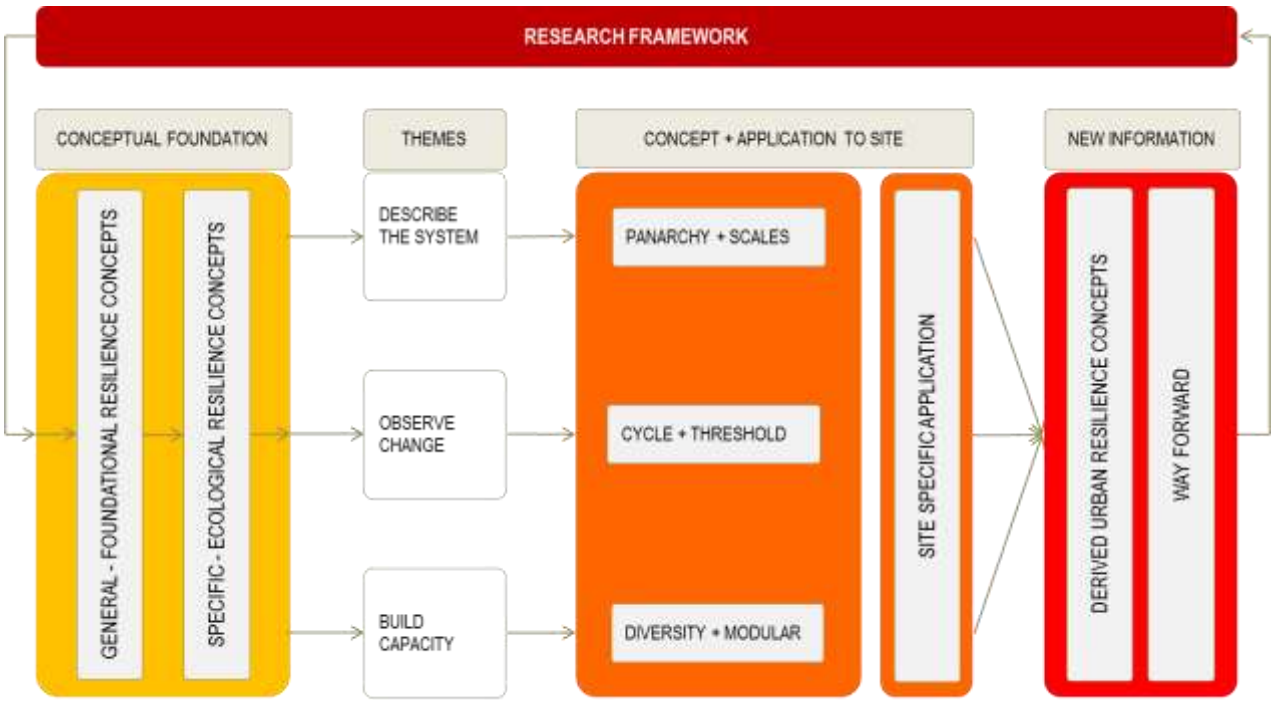


Figure 7 – The research framework for the dissertation (Author 2015)

Part Two comprises the translation of core concepts from ecological resilience theory into urban systems. In this section, each chapter outlines a core ecological resilience concept which is defined and explained in detail. It then takes these core concepts and applies them to a focal area that is undergoing rapid change in the east of Tshwane. The east was chosen over other areas in Tshwane, because it signals the pull of large-scale private

development and investment in the city aside from local government (which is focussed more on redeveloping the CBD, the north and west, and the former townships). Ad-hoc private development without a unifying vision or approach has already significantly altered the fabric of the city; a resilience approach could provide a good unifying approach to synergise future development in these rapidly urbanising environments. Core concepts were analysed graphically over aerial photo's, where applicable (see Data Sources). The graphic overlays were used as the basis for discussing whether a) the application works, b) if so, whether the design shows the qualities being discussed, and c) whether the findings can be used to inform future development differently or, if required, to physically transform the environment to mediate the findings. In the latter case, transformation of the physical environment poses a problem in that the intangible environment might not be willing or able to transform substantially, or the changes may actually have adverse and unpredictable effects. As a result, transformative resilience should be dealt with using great care and consideration.

2.10 Limitations

The largest limitations to the research design are the complexity and scope of the topic. The use of only one research design in its entirety would be inadequate; however, the use of four for different parts of the study also poses problems. Each research design is used partially, and perhaps there is not a clear broad overview using a single design, which may allow gaps or inconsistencies to appear. For that reason, rather than trying to find exact similarities or a replication of findings between different methods, the aim was rather to find a coherence in thinking among the data.

Another challenge is that the research designs have focused on the development of the tangible aspects of resilience in the city or, in other words, how they relate to the physical fabric of the city. They do not include the intangible aspects of the city, the cultures, beliefs, perceptions, hopes and dreams of its inhabitants. The designs did not have the capacity to include extensive interviews or questionnaires with members of the public, nor with built environment thinkers, managers and leaders. Here, the analysis identified two gaps for future research in other studies: firstly, there is a need to include other research designs to investigate additional aspects of resilience theory so as to enrich the core concepts derived. Secondly, there is a need to use research methods that include intangible aspects of cities in urban resilience practice as well, since resilient infrastructure means nothing if the citizens or government are not aligned with developing the resilience of the city in a holistic manner (Hamilton 2008).

2.11 Ethical procedures

The use of personal information from individuals is avoided in the dissertation by basing data largely on existing literature, and on interpretations by the author of the physical fabric of the urban realm as well as fictional narratives in the case of section 5.2 and section 6.5. However, in section 6.3, electronic communication was entered into via email with a former resident of the focal area being studied, in order to gain insight into and clarity on important thresholds of change that the focal area went through in the social domain, which could not be identified solely from the aerial photographs. The former resident has granted permission to the author to use the information provided to create the narrative described in section 6.3, and ethical clearance was obtained from the University of Pretoria.

2.12 Conclusion

The research methods, designs and methodologies were used to direct research, to identify themes, and to refine understanding thereof given the context of Tshwane. The methods provided a comfortable framework from which to develop a thorough conceptual understanding of the topic, and a good synthesis of its value and limitations concerning the urban realm. The limitations of singular methodological approaches in complex systems research were discussed, and the use of multiple approaches were found to enrich the thinking and research process in the dissertation. Data were sourced and synthesised according to various methods in order to further explore the complexity of the topic, and of the context. This dissertation benefitted from these multi-perspectival approaches as they provided the flexibility required for investigating complex topics.

CHAPTER THREE

AN OVERVIEW OF ECOLOGICAL RESILIENCE

3.1 Introduction

> We are re-defining the edge and entering a complex world of new paradigms. A new worldview is forming. At its core is the interconnectedness of the sun, sky, land, you, me and the myriad creatures and resources of the Earth … Should you choose to accept the challenge, architects and designers can be at the leading edge of positive change – Susan S. Szenasy (Ellin 2006: 135).

Chapter Three contributes to understanding the scope of *ecological* resilience, and demonstrates its usefulness in observing the characteristics of urban systems. It focuses on defining and exploring ecological resilience theory concepts, while the following chapter explores broader resilience thinking concepts. As described in Chapter One, resilience is gaining ground both as a tool and as a goal for urban development. Multiple understandings about the meaning of resilience make its application to the urban realm tricky. On the one hand, properties of resilience emerge from complex adaptive systems such as ecological systems and cities, while on the other hand resilience represents a normative position.

Whether the translation of ecological resilience concepts into urban systems succeeds depends largely on its foundational concepts. These have potential to allow the theory to develop further. To establish a solid basis from which urban resilience theory can advance, it becomes useful to differentiate ecological resilience theory from a broader resilience paradigm. Ecological resilience theory is of particular interest to this dissertation as a means of understanding the properties of resilience that emerge in cities, and also because it has evolved considerably from its equilibrist origins toward more dynamic approaches.

In the early 20th century, Austrian forester Viktor Schauberger (1885-1958) believed that, through deep observation of the way Nature works, he could generate energy based on Nature's constructive systems of generation rather than its finite resources, and that this revelation would be of benefit to the whole of life (Cobbald 2013: 23). His inquiry into the hidden 'truths' suppressed by the norms and assumptions of his time represents the same quest that drives designers and developers at this time in history to explore alternatives for urbanisation.

In a Schauberger inspired exploration, learning from nature suggests that the city is an ecosystem of connected networks and systems that comprise the biophysical and social environment. Within this anthropogenic ecology *Homo sapiens* finds its primary habitat. The

city system is sustained by massive resource flows "in which human cultural processes create a place quite different from undisturbed nature, yet united to it through the common flow of natural processes" (Whiston-Spirn 1984: 13). A city is consequently a living system, where humans and nature are part of the same system that converges in the urban realm (Du Plessis 2008). The principles guiding the flows of materials and energy in a forest conservation area are the same as those in a city. The difference lies in how these flows transform the environment and manifest spatially.

As custodians of urban habitats, humans must adapt behaviours and practices if they hope to continue to derive benefit from urban systems. Practices should emulate natural systems in the way they generate thriving environments with the potential to sustain and allow humans to survive and flourish in conjunction with diverse forms of life. As Schauberger suggested, we can learn from Nature. Learning what makes living systems resilient provides clues about what qualities make a city persist through shocks and allow it to regenerate after disturbance.

3.2 Brief outline of the development of ecological resilience theory

> A new paradigm, or set of background assumptions is in place now, and ecology has been invigorated by connections made with other disciplines in the earth and physical sciences, the social sciences and engineering (Pickett, Cadenasso & McGrath 2013: 25).

Although resilience has become popular in the built environment over the last decade, it has been studied in science for many centuries. Generally, resilience refers to the notion of bounce back, of the time it takes to return to a previous state before a disturbance hit and devastated equilibrium (Martin-Breen & Anderies 2011: 43). This is the most basic definition of resilience, but it has evolved over time to include dynamic non-equilibrist definitions (Davoudi 2012: 302) that have interesting implications for the built environment.

In the English language, the definition of resilience as the act of rebounding or springing back dates from 1626. In 1824 the definition expanded to include the idea of elasticity, with the capacity to resume an original shape or position after compression (Little *et al.* 1974: 1807). In the 1970s, resilience was identified as an essential characteristic of an ecological system (Folke 2006). With resilience framed within a systems perspective, it became a definitive ecological concept when Crawford Holling (1973) wrote his seminal paper entitled "Resilience and stability of ecological systems." Holling introduced resilience as a descriptive quality within an ecological system, and further defined two predominant types of resilience – engineering and ecological resilience (Walker & Salt 2006; Brand & Jax 2007; Davoudi 2012). He identified resilience as a characteristic of a healthy ecological system that

corresponds to the ability and speed of a system to return to an equilibrium or steady state after a disturbance (Folke 2006).

Holling's paper laid the foundation for a rich and potent concept to develop, making it possible for a number of disciplines such as emergency response, psychology and business to engage with each other for the first time, using a common language (Zolli & Healy 2012). Also included is the built environment (Martin-Breen & Anderies 2011; Du Plessis 2012a; Whiston-Spirn 2012; Walker & Salt 2012; Anderies 2014). The use of resilience theory in the study of ecological and social systems to understand what causes the collapse of some systems and not others, how much change can be absorbed, and what qualities are contributing factors, is increasingly of concern in a world where stability is being acknowledged as non-existent (Zolli & Healy 2012: 5). Resilience becomes the means to navigate unpredictable and volatile changes affecting the global system. Furthermore, purposefully collapsing the resilience of some systems in order to transform the larger system into a more positive state is an area of research gaining ground.

An example in South Africa occurs through the (in this case unintentional) deterioration of existing coal-fired power stations through lack of maintenance, upgrades, fewer cheap coal resources and limited system capacity leading to instability of electrical supply and consequently an increase in the costs of coal energy. This time of transition offers an opportunity to shift the dependence on coal-fired power stations toward renewable energy sources like solar or wind where applicable, with an adaptation of the electricity grid toward decentralised, at-source energy production. In the South African context, this transformation of the variables in the system (not the electrical system itself) toward a renewable resource is positive in that it reduces the environmental impact, increases job opportunities in the long-term, reduces risk and contributes to the development of the local economy.

3.3 Definitions of ecological resilience de

> Negative impacts of development might be avoided or mitigated by some forethought (Dale & Haeuber 2001: 22).

The advancement of ecological resilience formed part of a paradigm shift from reductionism to holism, that began in the 1960s with ground-breaking books like *The Silent Spring* by Rachel Carson (1962), and later *Small is Beautiful* by E.F. Schumacher (1974). Their work, among those of many others, generated a consciousness of the effects of unchecked anthropocentric development on the planetary system. In an attempt to demonstrate the urgency required in rethinking development models and policies in a global system that is unwilling to change, sustainability emerged as a development model

that considers finite planetary resources. However, as a response to the limitations of sustainable development, dynamic resilience perspectives that deal with unpredictable change had to be developed.

Resilience, often framed as a normative position, is seen as a powerful symbol for development where change is harnessed for the better. But to use resilience as a symbol for development, one must first understand and engage with why and how change happens, as it depends on those properties of a system that give rise to resilience. Within an urban system, resilience (a product of a specific system state) represents capacity for absorbing change. To build resilience, the urban ecology first needs to be studied from an ecological resilience perspective, and in light of this becomes what Walker & Salt call a "constructive alternative" (2006: xiii) that creates options rather than limits them.

Ecological Resilience does not entail a 'pure equilibrist' approach to resilience (Walker & Salt 2012); rather, it acknowledges that resilient systems are dynamic and undergo change while trying to avoid collapse. Ecological resilience is rooted in system-based perspectives aimed at understanding the behaviour of the whole system from which resilience emerges as a property. However, merely studying the component parts in a complex adaptive system cannot predict its resilience capacity (Walker & Salt 2006: 11). Ecological resilience theory has an existing and well-defined framework, with its concepts operating over many scales of time and place. These concepts have been adapted to social-ecological resilience as a means of analysing and engaging with systems (Resilience Alliance 2010).

Ecological and social-ecological resilience are often used interchangeably (Folke 2006; Du Plessis 2012a; Anderies 2014). The argument holds that firstly, in the age of the *anthropocene,* all ecological systems are impacted by social systems and secondly, humans form part of natural systems and therefore there is only one holistic ecology of all living organisms. Social-ecological resilience is also called evolutionary resilience (Davoudi 2012), because of its capacity to persist over time.

Ecological resilience perspectives, as shown in Figure 8, range from systems-based analysis that seeks to understand the dynamics of a system, to normative principles that infer that a system *should* be resilient and that resilience should be *managed* to achieve desired limits. Between these lies a hybrid response that both seeks to understand the system and includes some normative principles that encourage the system to evolve in any direction.

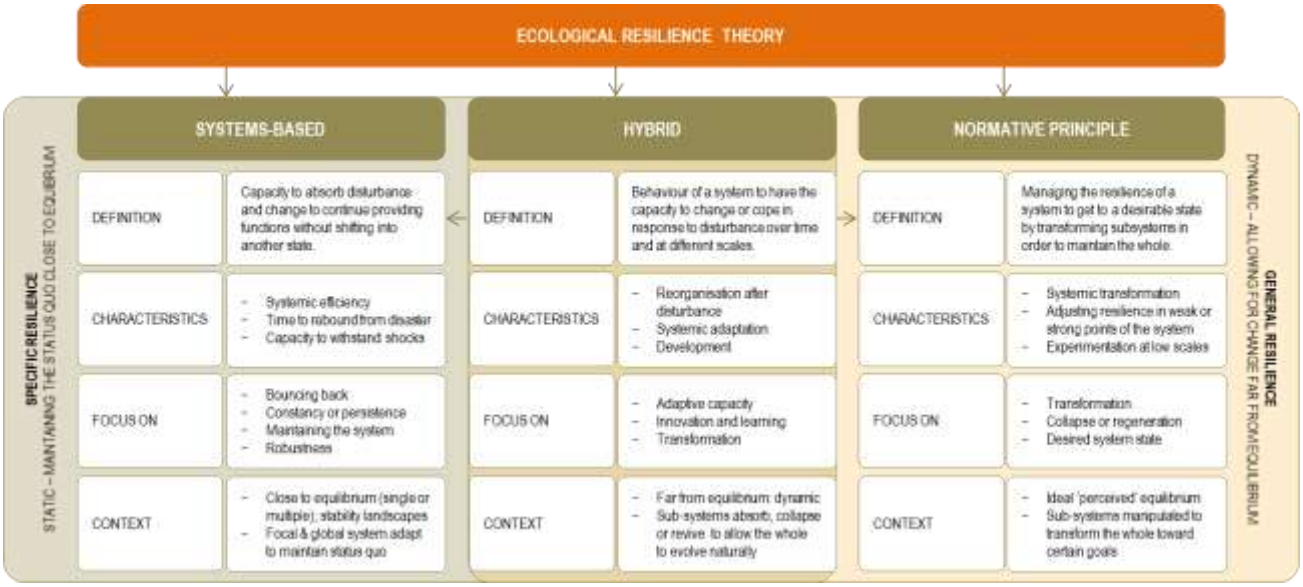


Figure 8 - Exploring the three perspectives of the definitions of ecological resilience, as adapted from Folke (2006)

3.3.1 Definition Set 1 – systems-based perspective (equilibrist)

Originally, it was proposed that in an ecological system, "resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling 1973: 17). More recently it has been refined to include notions that ecological resilience "refers not to the speed with which a system will bounce back after a disturbance so much as the system's capacity to absorb disturbance and still behave in the same way" (Walker & Salt 2006: 62). As a result, descriptions of ecological resilience as "the capacity of a system to absorb disturbance without shifting to another regime" (Holling 1973; Walker *et al.* 2004) promote notions of systems in dynamic equilibrium. In terms of an urban system, this desired dynamic system state is one that supports quality of human life where "a resilient social-ecological system has a greater capacity to avoid unwelcome surprises (regime shifts) in the face of external disturbances, and so has a greater capacity to continue to provide us with the goods and services that support our quality of life" (Walker & Salt 2006: 37). The focus of this perspective is to allow dynamic changes that maintain the current state.

3.3.2 Definition Set 2 – hybrid perspective (equilibrist and dynamic)

From the viewpoint of a hybrid ecological resilience perspective, the focus shifts beyond absorbing change to studying change. This is done by observing relationships, feedbacks and structures that are more, or less, resilient within the system over long periods. It provides "a framework for viewing a social-ecological system as one system operating over many linked scales of time and space" and focuses on "how systems change or cope with

disturbance" (Walker & Salt 2006: 38). From this viewpoint it can be observed how the system adapts to cope with change where "disturbance has the potential to create opportunity for doing new things, for innovation and for development" (Folke 2006: 253). The focus of this definition is to allow the system to evolve (perhaps even into a new state) in response to disturbances.

3.3.3 Definition Set 3 – normative perspective (managing resilience through transformation)

Ecological resilience is increasingly seen as a means of understanding how to navigate and manage a system's resilience to change, since "resilience thinking is about understanding and engaging with a changing world. By understanding how and why the system as a whole is changing, we are better placed to build capacity to work with change, as opposed to being a victim of it" (Walker & Salt 2006: 14). In this perspective, the management of a system's resilience is seen as a good thing when aspects of a *perverse* system can be transformed or collapsed for the benefit of the whole. As described below:

> Resilience per se is not good or bad. [...] When it comes to managing resilience, you can aim to maintain the identity of your system; in other words, you can adapt and build up the resilience of the current state of your system. Or if the system is in an undesirable state, you can try to get back into the desirable state by reducing the resilience of the undesirable state. But sometimes that is impossible. When that is the case, you can aim not to adapt, but to reimagine your system as something else, to transform – in other words, become a different system (Walker & Salt 2006: 20).

In this dissertation, these definitions of ecological resilience form the background against which ecological resilience concepts are translated into an urban system using the contemporary Tshwane urban system as the exploration ground. They are fundamentally systems-based, although in some instances, normative references to 'ideal' urban states exist. In the dissertation the ideal urban state refers to a *healthy* urban system described by the World Health Organisation (WHO) as "continually creating and improving those physical and social environments and expanding community resources which enable people to mutually support each other in performing all the functions of life and in developing their maximum potential" (WHO n.d.). In other words, a healthy city has evolutionary potential and "is defined by process rather than outcome" (Hamilton 2008: 59).

These three definitions inform the exploration of ecological resilience concepts as they translate into an urban system. They also provide *lenses* through which to observe how the urban system changes over time, they help to narrate behaviour, and lastly, they create the basis from which to explore broader concepts said to increase the capacity for resilience.

3.4 Main themes and concepts underscoring ecological resilience

> A city is a congestion of animals whose biological history is enclosed within its boundaries, and yet every conscious and rational act on the part of these creatures helps to shape the city's eventual character. By its form as by the manner of its birth, the city has elements at once of biological procreation, organic evolution, and aesthetic creation. It is both a natural object and a thing to be cultivated; individual and group; something lived and something dreamed – Claude Levi-Strauss (Whiston-Spirn 1984).

Ecological resilience thinking is set against the backdrop of evolutionary development, based on the notion that living systems consisting of humans and nature together need to be supple to accommodate change, and not frozen in a specific set of conditions deemed to be optimal, because these can be inaccurate abstractions of a very complex, hidden set of processes. For this reason, applying ecological resilience thinking to any social-ecological system, of which a city is but one manifestation, requires a deep investigation of the context at hand. A one-size-fits-all solution is impossible, because each system is inherently different and each has different types and numbers of linkages to other systems. Checklist approaches for achieving an ideal urban resilience are obsolete within a complex urban system, and the closest replicable practice is the method through which to explore the particular resilience of a system.

The basis of resilience thinking as applied to ecological systems – of which human beings form an integral part – relies on a *systems thinking* approach, described by Walker and Salt as relying on three fundamental precepts (2006: 11):

- The world needs to be understood as a holistic system comprised of an unpredictable web within which nature and humans are deeply interlinked and interdependent. Changes within ecosystems impact on many other domains; without an appreciation of the systemic qualities of the world, sustainability and resilience practices are unachievable. However, while systems are strongly connected, not everything is connected to everything else.

- Resilience is a product of complex adaptive systems (CASs), and can be observed through two models: thresholds (moving from one stable system state to another) and adaptive cycles (the dynamics within the system that cause it to move and change from rapid growth, to conservation, release, and lastly reorganisation, over many scales and time).

- Resilience thinking is the cornerstone of the sustainability of systems. It needs to be actively applied to the real world through policy and management. This requires a

re-imagining of what a resilient world could be like. In this reimagining, a resilient world would have the capacity to absorb disturbance and undergo change while retaining its functions, structure and feedbacks.

As described in Figure 9, the method for the study and practice of ecological resilience entails two distinct approaches. Firstly, as a *lens* it comprises investigating the relationships, structures, functions, identity and behaviours of the system over time, and forms the basis of ecological resilience study. These are used to contextualise the resilience of what to what. To understand the adaptive cycles and system regimes, contextual investigation of the

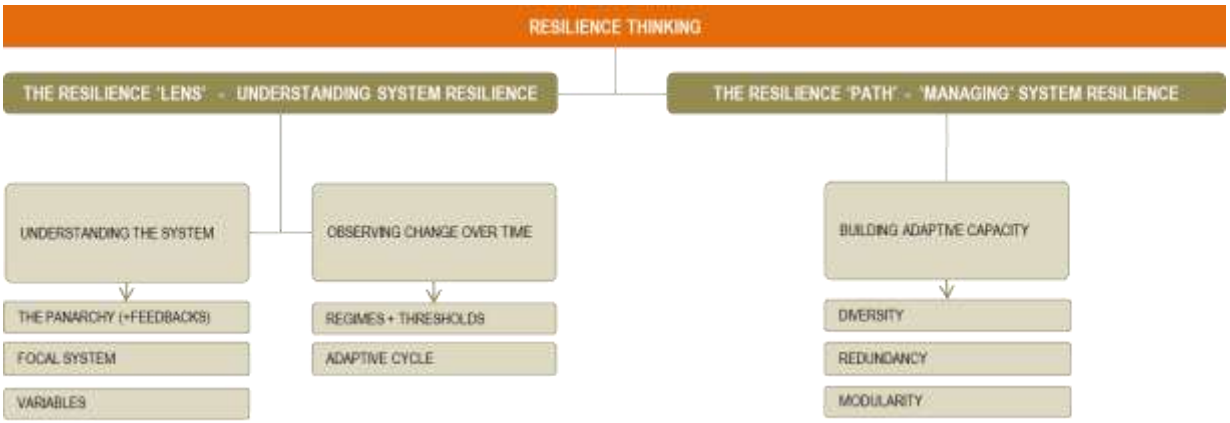


Figure 9 - The approaches to resilience thinking (a lens and a path) and their main concepts (Author 2015)

system can be done through historical timelines consisting of trends and models of past events (Resilience Alliance 2010). This raises questions of scale, relationships and disturbances that are particular to a system and can assist in understanding behaviours. More value lies in using timeline information not to predict the future, but to explore different "structured narrative" (Walker & Salt 2006: 101) scenarios of what may happen if certain actions were taken. Historical understanding creates awareness of the potential to harness cycles of growth and probability, as well as the creative destruction and new beginnings that all systems go through.

The second step in the ecological resilience approach is a map or *path* derived from the analysis of a particular system and which provides vital information about its resilience in terms of its critical thresholds, its drivers of change, and its inherent structural patterns. From these, scenarios can be explored by bringing together as much information about the current condition of the study area (biophysical, social and economic) and then identifying key uncertainties, vulnerabilities, sources of resilience, and the hopes and fears of people for the future of the region. Knowledge of a system's characteristics, its history, and its current capacity for adaptation provides opportunities for the conscious management of a

system's resilience to either bounce back, adapt or evolve, and to transform aspects of the system if they are 'failing' the whole.

3.5 Resilience is a whole systems approach

> The city is not a system of parts, but a whole system of the human species that has characteristics as a whole that transcend but include communities, organizations, groups, families and individuals and the built environment that we have created to contain us (Hamilton 2008: 31).

A system is described as a "set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours" (Meadows 2008). These give rise to the function or purpose of the system. Integration, interdependence and connectivity are fundamental to a whole systems approach. When the distinction between humans and 'wild nature out there' is removed to see the world as a holistic living system in which all of life is embedded and interconnected as a single entity, we realise the significance of our actions.

As parts in a single planetary system, the consequences of what humans design or destroy ripple through the living system (Mau: 2004). In the vast and intricate web of life (Capra 1982; 1996), what we do to each other and other living things we are inevitably doing to ourselves. When we limit the potential of life to flourish, we limit our own potential. And when we limit our own potential, we block the course of evolution toward greater depth and complexity (Wilber 1996). Our 'resilience' to adversity may allow us to persist, but the quality of that existence and its potential is sure to be limited, unless it stems from changes in the reductionist worldview – currently dominating development – toward holism or ecological thinking (Capra 1982; Hes & Du Plessis 2015).

3.5.1 From parts to wholes – an integral perspective

A whole systems approach allows one to understand the underlying structure that causes the symptoms that are of concern (Meadows 2008: 3). This understanding is essential in creating a successful intervention in an urban system. Despite volumes of evidence that cities result from complex relationships between dynamic interconnected hierarchies of sub-systems, which Holling *et al*. term the *panarchy* (2002), in practice the tendency is to make them comprehensible by isolating their parts. Built environment practitioners, broadly including civil engineers, developers, architects, urban designers, traffic engineers, town planners, real estate agents, quantity surveyors, builders and environmentalists, specialise in niche areas of concern. They rarely step out of their professional comfort zones to interrogate development from a holistic perspective, rather than exclusively in accordance

with economic profit (Ellin 2006: 87). Urban planners and architects for example, relinquish their role and responsibility in specifying technical solutions to engineers, who assert their designs as irrefutable truths (Swilling 2005). Simplifying the city into its sub-systems and seeking individual efficiency for each, results in a decrease of the whole system's general resilience (Salat 2011: 476), making it more fragile in light of unpredictable change, since a system that is not resilient is brittle or rigid (Meadows 2008: 76) and risks collapse.

The Modern tradition of controlled and predictive built environment practice, based on division through specialisation (Capra, 1982; Swilling 2005; De Kay 2011; Hes & Du Plessis 2015: 24), leads to weak design solutions resulting from bitter compromise. Controlled efficiency within the visible world becomes the sole objective, at the exclusion of intangible aspects that contribute to the experience of life (Wilber 2007). Ancient knowledge, popular culture and many theorists and scientists concur that the world is an integrated and interconnected system (Hes & Du Plessis 2015: 25) where humans are neither separate nor superior, but rather an expression among many of a larger *Kosmos*.

The *Kosmos,* as described by Ken Wilber (2000), consists of the "cosmos (or the physiosphere), the bios (or biosphere), the psyche or nous (the noosphere), and the theos (the theosphere or divine domain)" (Wilber 1996: 16), and is an exploration of the fullness of existence, not just its physical manifestation. This perspective, based on an integral approach, has led to the advancement of Integral Theory (Wilber 1996; 2000; 2007; Wilber *et al*. 2008; Hamilton 2008; De Kay 2011; Esbjörn-Hargens 2012; Buchanan 2013; Peres & Du Plessis 2014b), which critiques the reductionism by which reality is consistently represented as the material or biophysical dimension. It calls for the inclusion of the intangible aspects of the universe, namely the noos- and theospheres, in the tangible aspects, namely the physio- and bio-spheres, as a full expression of the *Kosmos*.

Over the past 37 years, Integral Theory has developed as a systematic approach with capacity to interrelate multiple dimensions of reality, offering possibilities for the successful holistic assessment and resolution of many 21st Century crises (Esbjörn-Hargens 2012). It has advanced the conceptual framework from which to explore the partial truths in various external and internal dimensions of life from which a richer collective truth may derive. It has seen significant adaptation to alternative disciplines, including sustainable architectural design (De Kay 2011) and urbanism (Hamilton 2008), implying that integral design can result in a more resilient solution for the built environment. This is the first understanding of a whole system, i.e. the entirety of the system (Hes & Du Plessis 2015: 26), and will be discussed later in this chapter.

3.5.2 The continuation of integrity and purpose

The second understanding of a whole system has to do with the continuation of the integrity and functionality of the system (Hes & Du Plessis 2015: 26), in other words, how 'healthy' the system is. Here, resilience comes into play as a characteristic of a complex adaptive system (Hamilton 2008: 31; Meadows 2008; Walker & Salt 2012) that can give insight into its functionality and long-term vitality. Urban development requires a whole systems approach for viewing, studying, living and engaging with city ecologies. Resilience in an urban context is a characteristic or a property resulting from the complex relationships within a city system. This allows for the study of a city from which the "purpose, alignment and coherence" (Hamilton 2008: 50) can be discerned along with "its embedded wisdom for surviving its unique life conditions" and the context on which decisions can be based (Hamilton 50).

A whole system has certain qualities that give rise to its unique complexities, and these, as suggested by Hamilton (2008, p 23), include aliveness, survival, adaptability, regeneration, sustainability and emergence. As these qualities persist over time, they give rise to physical patterns that underlie the city character (Salat 2011) and inform social responses. These patterns are often synonymous with the resilience of a city and its capacity to respond to multiple disasters (both slow or invisible, and fast and catastrophic), as well as its ability to navigate the thresholds at which the entire city system would tip into collapse.

Awareness of the holistic properties of the Earth system, brought to life by the early sustainability movement, has generated government and public action toward global environmental issues over the past fifty years. However, awareness alone fails to address the impacts of current outdated growth models that impact the quality and vitality of the living systems on which they depend (Du Plessis 2011b). Post-sustainability outlooks suggest that the next step in the awareness campaign for fostering healthy living systems is an ecological, whole or living systems worldview, which "describes a world that is a fundamentally interconnected and interdependent set of ever-changing processes and relationships structured in nested systems of increasing complexity" (Du Plessis 2011b). The purpose of a holistic living system would be to advance the evolution of life as a whole.

Urbanism with a whole systems view is not "necessarily about how to make 'correct' choices of technology or ideology or fix perennial problems, but about understanding the dynamics that give rise to desirable and undesirable urban phenomena, so as to participate most effectively in the natural evolution of the city as a healthy social-ecological system" (Du Plessis 2011b). Understanding resilience from a whole systems perspective facilitates

engagement with bounce back, adaptive or transformative practices, but especially allows for a city to evolve.

3.6 Engaging cities as social-ecological systems

> Nature is a continuum, with wilderness at one pole and the city at the other. The same natural processes operate in the wilderness and in the city (Whiston-Spirn 1984: 4).

While the term "social-ecological system" is relatively new, the concept is not. This viewpoint of a single ecology of humans and nature has surfaced many times over the last century. It was emphasised by acclaimed urbanists like Patrick Geddes (1915), who put forward his holistic view of life-processes as an evolving organic whole where city, culture and natural environment are part of the same system. Later, Lewis Mumford (1923), Kevin Lynch (1972) and Ian McHarg (1969) acknowledged the need for developers, designers, politicians and humans in general to see cities and all the flows of life within them as extensions of the 'natural' or biophysical environment. Jane Jacobs said it best in her seminal book *The Death and Life of Great American Cities,* "human beings are … a part of nature" (1964: 457).

In the ecological perspective, humans are a part of the living system and therefore a component of natural systems. Integrative ecology sees humans as a part of nature (Swilling 2005; Esbjörn-Hargens & Zimmerman 2009) with their decisions, institutions, culture, actions and creations forming an extension of natural systems (Du Plessis 2008). Human societies are embedded within an integrated system of ecosystems with "reciprocal feedbacks and interdependence" (Resilience Alliance 2010: 52). The term social-ecological system (SES) stems from this perspective of 'humans-in-nature', where processes in the social dimension interact, influence and integrate with processes in the ecological dimension and vice versa. An SES views the biophysical system and the social system as a single ecosystem.

Social-ecological systems (SESs) emerge from whole systems thinking that includes human consciousness as a fundamentally important manifestation in the ecosystem. The shift in urban resilience practice toward a social-ecological approach contrasts with the sustainability movement that sees ecological problems as separate from the social setting, and traditional urban design (and planning) that focuses on social issues rather than ecological ones. Rather, social-ecological urbanism aligns development with the resilience of social and ecological systems in partnership with one another (Barthel *et al*. 2013: 7), since neither can be resilient without the other.

An SES is a complex adaptive system that is self-organising (i.e. cannot be controlled by anyone) and that can be identified by its emergent behaviour; in other words, cannot be predicted by analysing individual mechanisms, component parts or pairs of interactions (Walker & Salt 2006: 31). Understanding component parts does not predict overall function. Furthermore, the resilience of an SES emerges from its self-organising capacities. These capacities are long-term evolutions, and consequently are often ignored in the design of instantaneous new developments in cities (Salat 2011: 478).

SESs can also have more than one *stable state*, where a change in the system can move it into an alternate stable state or *stability regime*. In other words, the inherent properties of the system have not changed, but aspects of it have. For a system to be complex (versus simply complicated) it has independent and interacting components, a selection process at work on these components and the results of their interactions, and lastly, variation and novelty constantly being added to the system (through components changing over time or new ones coming in) (Walker & Salt 2006: 36). This complexity gives rise to Du Plessis (2008) proposing the following to be the departure points for understanding SESs:

- *Proposition 1*: An SES is one integrated system (or *holarchy*) that spans across "three distinct, but nested and interpenetrating, spheres or domains of existence: the geosphere (matter), the biosphere (life), and [human social and cultural phenomena] making up the noosphere (mind). These spheres represent a continuum of increasing complexity and consciousness, with matter as the first (lowest) level, life as the next level emerging from (and thus including) matter, and mind as the last (highest) level emerging from life" (Du Plessis 2008). For life to exist, matter is required, while for the mind to exist, both life and matter are required. Life or the mind can be destroyed without affecting matter, but matter cannot be destroyed without subsequently destroying life and mind.

- *Proposition 2*: An SES consists of relationships between elements at a number of scales and within nested systems. It is described by the term panarchy, putting forward the idea of a hierarchy of level and scale within a whole system. It is based on the idea of a phased adaptive cycle, where the levels of the panarchy are shown as nested adaptive cycles arranged in a dynamic hierarchy of increasing complexity, with cycles interacting and affecting each other at higher and lower levels.

- *Proposition 3*: SESs are complex and adaptive, with properties of self-organization and emergence. These properties arise when "microlevel agents interact to create the global properties of the system", which then feed back into the microlevel interactions in both physical and social systems so that "what differentiates physical systems from social systems is that the agents in social systems often alter their behaviour in response to anticipated outcomes" (Du Plessis 2008).

- *Proposition 4*: What differentiates SESs from other systems is the introduction of abstract thought and symbolic construction, or in other words, human consciousness, with its social rules of signification, domination, and legitimisation. This differentiation allows for novel social and technological developments that affect matter, life and mind, but also allow for human reflection regarding the meaning and consequences of interactions.

Resilience thinking in urban systems is therefore a social-ecological endeavour, since to sustain human life, the natural world needs to be sustained. Resilience is also a whole system approach, comprising a web of matter, life and mind.

3.6.1 Cities as social-ecological systems

Seen as ecological systems, cities have organised complexities akin to that within any living organism; as such, the loss of any one component may cascade into the resultant destruction of the whole (Whiston-Spirn 2012: 4). The established umbrella principle of ecological urbanism has formed one of the ways to appreciate and negotiate cities as a complex ecology of humans and nature. It has developed over the past 30 years in landscape planning, sustainable design and planning, green architecture and infrastructure, industrial ecology, as well as green urbanism (McHarg 1969; Van der Ryn & Cowan 2007; De Kay 2011; Whiston-Spirn 2012). While the methods of these professions may be divergent, they converge in their intent "to demonstrate how cities can be designed in concert with natural processes" (Whiston-Spirn 2012). In realising this intent, principles emerge to gain a richer understanding of city ecologies to make informed decisions regarding appropriate interventions (that support a more resilient urban form and its biophysical 'immune' system). As described by Whiston-Spirn (2012: 6), these principles include:

- Seeing cities as inextricable parts of the natural world;
- Exploring cities as habitats for a diverse range of life forms (of which humans are one of many species);
- Acknowledging that cities are urban ecosystems that are dynamic and interconnected;
- Understanding the deep, enduring context that forms the basis of every city;
- and lastly, embracing urban design as a tool for human adaptation (that can allow for a transition toward a more thriving and vigorous urban environment).

A city generated from a deep understanding of its context and the broader ecological system contains greater possibilities to foster conditions for life to thrive in, and consequently offers the preconditions with which a city withstands or adapts to disturbance without collapsing its identity – in other words, its resilience. The aim is therefore not to create a resilient city system, but rather to create a thriving urban system that functions in partnership with social and ecological systems.

Cities as social-ecological systems have social dimensions (Walker & Salt 2006: 1; Du Plessis 2008) comprising *holarchic*, complex adaptive, *panarchic* and conscious qualities. Their structures arise from cross-scale interactions between social (including economic, institutional and cultural) and biophysical processes at lower scales, that result in emergent patterns at higher scales (Alberti & Marzluff, 2004). For any study or practice within the urban realm, the message is therefore clear: an urban system comprises social and natural elements in a single entity. It is self-evident that the City of Tshwane is an SES with close relationships and networks flowing between human-nature systems. The impact of social decisions and processes on the environment primarily through development has shifted the flows between flora and fauna, which at times significantly affected social systems in return. The description in section 5.5.3.3 further illustrates this close relationship.

Patterns of emergence provide clues as to general urban trends, but the complex and non-linear results of interactions in a city system result in a city that is in constant flux; events cannot be predicted nor can the consequences of interventions be controlled. At best, cities can absorb or adapt to disturbances. While urban SESs cannot be understood,

defined, or quantified absolutely, most development policies, businesses, industries and the built environment neglect this characteristic. Instead, they strip systems down to their essential elements and exploit them for maximum profit (not even maximum yield) without concern for resource limits or their resilience to the resultant long-term pressure.

Command and control measures eventually fail, because the very nature of an urban SES as a complex adaptive living system is that it is always in flux. If anything, actions should do as little or as much as needed to keep options open for the system to evolve, rather than try to stagnate and predict its course. When cities are seen as SESs, with complex relationships between humans, economics, nature and services, it becomes clear that the impact and ripple effects of changes across many scales may permanently alter city form and society. This supports the notion that a fundamental shift needs to occur in the attitudes that industries and societies have toward systems of life (Du Plessis 2009; Lipton & Bhaerman 2009). Enhancing the resilience of living systems to accommodate change, adapt to shocks that threaten their existence, and in return allow life to thrive in an urban system, is seen as one of the ways this might be achieved.

3.6.2 The pitfalls of translating resilience into social-ecological systems

While a social-ecological approach to resilience seems to fit in with the understanding of cities as non-linear urban systems that are constantly in flux, there are a few concerns related to the application of this approach as a framework for exploring and intervening in cities. Because of the unpredictable and uncertain state of operations characterising the city context, Davoudi (2012) identifies four challenges that become apparent when translating the concept of resilience from a purely ecological realm into a social one.

Firstly, human intervention plays a crucial part in building or breaking the resilience of an urban system by breaching the adaptive cycle of a city. Human resilience in response to adversity should not only include self-reliance and self-organisation at a community scale, but also responsible governance that encapsulates aspects of transformative resilience. Secondly, the purpose of resilience practice is questioned. Ecologically the purpose of resilience practice is to achieve 'sustainability'; however, socially the 'desirable' purpose of resilience is linked to normative judgements. Yet sustainability itself can be said to be an anthropocentric normative judgement, where its sole aim is the management of the biophysical world to ensure the survival of the human species. Thirdly, defining the boundary of a system becomes a problem. In ecology boundaries are established by answering a straightforward question, 'resilience of what to what'? However, these exclusions are problematic in trying to understand the far-reaching influences that impact upon SESs.

Lastly, and perhaps where most of the impact lies, is the issue of resilience being used politically or as a means of brokering power, where resilience for some may mean vulnerability for others (Davoudi 2012: 305-6) (Porter & Davoudi, 2012, p.333).

In view of the last point in particular, the application of resilience to urban systems needs to be guided by ethics of fairness and justice. While ecological resilience is characteristic of a biophysical system and therefore a value neutral concept, in urban systems, humans and their cultural ideologies play such a large role in shaping cities that the preference for resilience of some urban aspects versus others will vary from place to place, and over time, as gauged by cultural bias.

The use of transformative resilience to collapse or regenerate aspects of a city may lead to disaster at higher levels of the system. Its unguided use might lead to the use of resilience as a buzzword devoid of real functional meaning (as is increasingly becoming the norm in governance and planning), or as a means of making certain ideologies more resilient at the expense of others (which poses a greater threat). As Davoudi (2012: 306) then asks, what are the desired outcomes in using resilience and for whom is resilience realised? In Part Three of this dissertation, these points will be discussed further.

3.6.3 Cities as adaptive habitats that sustain human life

Cities exist because of the human need to dream, defend, dominate, expand, create and achieve comfort … in order to advance society. Humans have developed their ability to manage the environment in ways that increase their chances for survival against the elements and, consequently, the chance of survival of some societies over others (Diamond 2011). They evolve out of a desire for control, a need for exchange between people on material and emotional terms, as well as a consciousness about the brevity of life and the need to create a legacy for generations to come. Cities are crystallised versions of their societies and a tangible record of their values and the choices they make.

Cities have two faces: they are places of opportunity, refuge, independence, ambition and safety, but also of hardship, stress, dependence, delusion, and conflict (Sudjic 1992). This uncomfortable contradiction characterises the city and defines its appeal. Cities are a manipulation of 'natural' landscapes into spaces where humans engage each other on their own terms, but they are also an extension of the 'natural' landscape from which they have traditionally been designed to be separated. Cities become personified, loved or loathed, and sometimes more powerful than the nations in which they are located. They are the primary habitat of the human species (Burdett & Sudjic 2007), and as such are

beginning to represent ever more homogeneous characteristics: their blueprint, a consumer-driven environment. Global cities of the 21st century serve as laboratories for technological advances made familiar by globalisation. Their copy-paste identity causes building typologies to serve "anxiety wrought by rapid change through escapist and self-serving means" (Ellin 2006: 102). Urban problems accrue due to the fact that present-day developments are largely unsustainable (Ellin 102).

The current geologic epoch was informally termed the *Anthropocene* by Stoermer in the 1980s, but has earlier historical precedents (Steffen *et al*. 2011). It describes the time in which human planetary domination has resulted in global impacts like climate change (Steffen *et al*. 2011). As a key human habitat, cities play a large role in the *Anthropocene*. A focus for sustainable urban living and resilience in the face of unpredictable changes lies in the way cities are designed, developed and managed, and their ability to accommodate changes in climate, technology, society, politics etc. Since cities are the predominant habitat of the human species, to sustain cities is therefore primarily to sustain human life.

Human survival depends largely on the ability to manipulate the urban environment for safe habitation, while the urban environment depends on creative economic growth for its survival (Jacobs 1984: 224). In addition, cities have a direct bearing on quality of life and lifestyle impacts (Fernandez 2014). In relation to other areas where humans have impacted upon the landscape (argued to be the entire planet), cities are most likely the most manipulated and greatly disturbed habitat wherein the majority of the human population resides. Cities contribute to the disturbance of other landscapes for agricultural, industrial and mining activities. They facilitate exchanges between local and global resources and ecological services which can result in major transformations of urban systems and even their collapse (Alberti & Marzluff 2004). It becomes imperative to understand the impact that urban development has on the ability of humans to survive unprecedented disasters and to transition toward holistic urban development. We may argue that human survival depends largely on the persistence of cities, but that this requires transformation toward thriving systems that operate within the limits of the planetary system.

3.6.4 The gap between the external and internal dimensions of cities

Resilience and sustainability of an urban system that persists and regenerates over time requires its tangible aspects (physical fabric and structure) as well as its intangible aspects (the thinking that guides its development) to be built up. Tangible and intangible realms of practice are traditionally separated, with the focus in urban resilience lying in specific tangible bounce back approaches. However, since cities are complex adaptive systems

with multiple dimensions, an urban resilience strategy must take into account multiple resilience perspectives that respond to different situations.

In the last few decades, resilience theory has developed into various fields of inquiry (Zolli & Healy 2012). However, in the investigation of resilience in urban systems, the advances appear to focus on the external aspects of the city – on measuring or managing the effects of change on the built environment. The importance of developing the resilience and awareness of the humans and cultures inhabiting cities as the major role players in the future trajectory of this environment (and consequently as victims of disasters within these habitats), sees less emphasis. Inasmuch as external aspects are essential in directing development of the built environment, they are fuelled by internal dimensions; the worldviews, thoughts, beliefs and aspirations of its citizens. Links between spirituality and sustainability are recognised (Gardner 2001); however, they are not carried through to urban development practices despite their potential to enrich urban experience. In response, practical spirituality may influence an awakening toward sustainable living, lifestyle and culture in contemporary cities (Woiwode 2014). If resilience is a characteristic of sustainability, then its internal dimensions require exploration. For urban resilience theory and its application to urban systems to be meaningful, both external and internal manifestations of resilience thinking will need to be addressed.

Addressing this dissonance between the external and internal dimensions of resilience in a fast-changing, increasingly global cityscape requires a framework of thinking that can address existing messy and disconnected dogmas that have influenced the course of history. Academia and various professions are benefitting from transdisciplinary collaboration as a means of solving complex problems that could not have been resolved in isolation. In addition, links between the tangible and intangible world are becoming clearer and it is apparent that life is multi-dimensional, with truth being a mosaic of many truths. As a means of navigating through the many truths or perspectives that underlie our thinking about life to form that 'bigger picture', there emerges a 'theory of everything' – Integral Theory developed by Ken Wilber (Wilber 1996).

3.6.4.1 A (very) brief overview of Integral Theory

Integral Theory is a meta-theory that combines multiple perspectives to form a full spectrum approach to the study and practice of life (in all its external and internal manifestations) to create "a comprehensive framework for understanding the complexity of multiple competing theories" (De Kay 2011). The abundance of information and strategies available on virtually any topic can lead to confusion and inaction stemming from inflexible strategies

or compartmentalised and contradictory information. Theories have developed over the centuries to give expression to the collective fear and aspirations of humans through the course of their evolution. These theories dominate worldviews and inform paradigms that manifest the way that humans develop, control and co-ordinate themselves and their context.

As the world transforms, the search for meaning in outdated paradigms and theories continues. To embrace and transcend these paradigms, humans need to make sense of competing perspectives and realise what can be kept and what ought to be released. Esbjörn-Hargens suggests that a) "… without a way of linking, leveraging, correlating, and aligning these perspectives, their contribution to the problems we face are largely lost or compromised", and as human systems become increasingly interrelated and interconnected, b) a framework is required "that can hold the variety of valid perspectives that have something to offer our individual efforts and collective solution building" (Esbjörn-Hargens 2012: 1). Integral Theory provides clarity to marry these perspectives in a holistic approach.

Described as a radically inclusive approach, Integral Theory provides the tools required to study and engage with various manifestations of life in "very broad yet precise terms" (Wilber *et al*. 2008: 9), in order to understand what is best for the system, now and over time. This theory of everything applies to various fields of inquiry such as personal life, urban systems, politics, philosophy, business and medicine, for example. This is possible because the premise of Integral Theory is that the *Kosmos* – the universe consisting of both physical and ephemeral realms, of all existence, in other words everything – is propelled by the same self-transcending drive from which its on-going evolution is made possible (Wilber 1996: 17).

Problems are best explored from a different frame of reference than the one in which they originated. In urban systems this means an emerging worldview that transcends the modernist and postmodernist realms and yet embeds their wisdom within a more inclusive understanding and a new consciousness (Wilber 64). This worldview comprises four different terrains to form a framework of reality. These terrains are mapped using a flexible All Quadrants, All Levels (AQAL) framework that incorporates multiple perspectives in the quest to discover cohesive and holistic expressions of reality and not in a singular process.

Integral Theory acknowledges objective (external and empirical) and subjective (internal and experiential) perspectives, as well as their manifestations in individual versus the collective domains, as shown in Figure 10.1 and Figure 10.2. The result is four co-existing

quadrants or *quadrivia* of life: the behavioural, social, cultural and experiential terrains, illustrated in Figure 10.3, each with its own unique wisdom that unfolds across a line of development (such as from body to mind and resulting in spirit or from group to nation resulting in global), as shown in Figure 10.4. This line of development wisdom progressively displays higher levels of depth, complexity, transcendence and integration (Esbjörn-Hargens 2012: 6). Each quadrant develops along this line and relates to the other quadrants at the same level (body to group, for example).

3.6.4.2 The map – All Quadrants, All Levels, the AQAL model

Life unfolds in rich and intricate ways, and while its vast scale and dimension cannot be fully abstracted, a mosaic of smaller truths can be pieced together to reveal parts of a bigger picture. When certain aspects of reality are investigated they inform a particular perspective or philosophy. This gives rise to various descriptions, philosophies and beliefs that are rooted in what often appear to be competing 'either-or' approaches. While on the surface these descriptions appear to bear irreconcilable differences, there are generalising patterns of

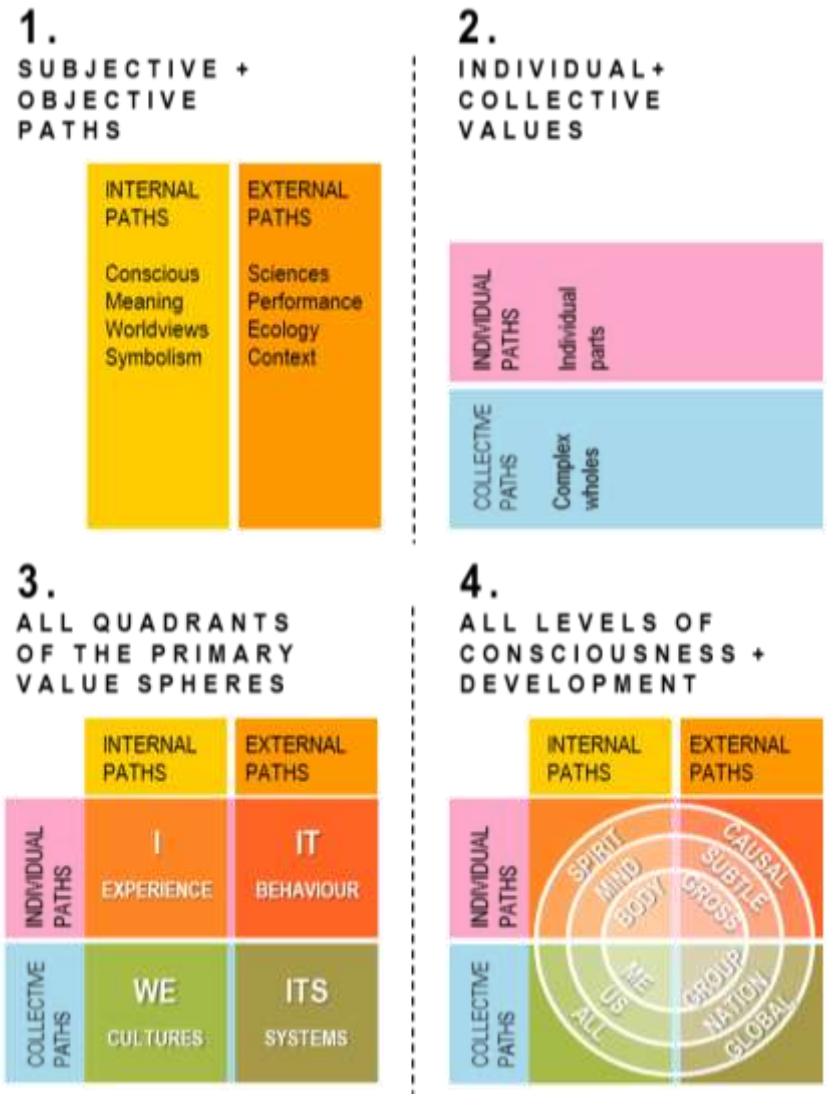


Figure 10 - Graphic summary of Integral Theory in Peres & Du Plessis (2014b), based on Wilber (1996) and De Kay (2011)

truth inherent in all of them: they are all partially right (De Kay 2011: xxiv). Through an analysis of various 'maps' of the world originating from multiple sources, Wilber (1996: 66) realised that the maps were representing different types of holarchies or holistic sequences that engage four different perspectives of reality.

The above analysis resulted in a conceptual *holarchical* map called All Quadrants, All Levels (AQAL) that represents the *Kosmos* and human development in all its dimensions and depths. AQAL is described as a "map of maps or a *meta-theory* that incorporates the core truths from hundreds of other theories" (Wilber *et al*. 2008: 10), and is therefore able to assimilate the many ways of thinking that have informed our present understanding of life and living systems. As illustrated in Figure 10, AQAL represents four aspects of being which appear to be the minimum that we need to understand any subject under investigation. A partial approach will not work because "… we need an integral approach that will include all four quadrants and all four faces of Spirit" (Wilber 1996: 75) in the hope of achieving balanced and complete transformation. Integral Theory emerges as a useful framework from which humans can orientate themselves and better understand their role in the web of life that makes up the challenging landscape of the 21st Century (Esbjörn-Hargens 2012).

The AQAL framework underpins integral discourse. It has developed over a number of decades and is used in over 30 professions (Esbjörn-Hagens & Zimmerman 2009). It is not a detailed map, but rather a framework that can 'create space' for details to emerge (Wilber *et al*. 2008: 72) and thereby potentially evolve. Contemporary Integral Theory creates the intellectual framework wherein differences can be transcended and included and can therefore exist simultaneously and in harmony.

3.6.4.3 The four quadrants or quadrivia – domains of experience

Generalising themes underpin the structure of the different terrains of life and these reflect within their own specific progression. The themes emerge from the four basic views of a *holon* (be it a person or situation); from within (inside) or observed from the exterior (outside), and as an whole (individual) or a part of something else (collective). These four fundamental perspectives overlap in order to intersect "individual and collective phenomena with objective and subjective knowledge" (De Kay 2011: xxv) and result in four quadrants, or *quadrivia*, that represent the perspectives with which to look at any person or phenomenon (see Figure 11).

Quadrants refer to an individual's experience of various dimensions of reality, or "the native ways in which we experience reality in each moment" (Esbjörn-Hargens 2012). *Quadrivia*

refer to the different perspectives assumed in engaging with a phenomenon, or "the most common ways we can and often do look at reality to understand it" (Esbjörn-Hargens 2012). The four dimensions or perspectives of being (moving in a clockwise direction from top left in Figure 11) are described briefly as follows (Wilber 1996; Wilber *et al*. 2008; Esbjörn-Hagens & Zimmerman 2009; De Kay 2011):

– Upper Left [UL]: Individual Interiors are explored as the **experiences** perspective. This quadrant is comprised of the distinct self and consciousness and is expressed using the pronoun 'I'. It includes qualitative aspects formed by thoughts, feelings, sensations, perception, meanings and meditative practice. It represents Beauty, in the classic sense that manifests in Art.

– Upper Right [UR]: Individual Exteriors are described as the **behaviours** represented by science, mechanics and performance. This quadrant is expressed through the pronoun 'it'. It includes quantitative aspects that can be measured, such as atoms, cells, brains, bodies and behaviours that represent the classic value of Truth as expressed through scientific inquiry.

Figure 11 - The four quadrants/ quadrivia of the AQAL framework in Peres & Du Plessis (2014b)

- Lower Right [LR]: Collective Exteriors are reconstructed using the **systems** perspective, where social and natural ecologies and contexts interact. They are described using the pronoun 'its', and represent classic truth or Science.

- Lower Left [LL]: Collective Interiors are described as the **cultures** perspective, where meaning, worldviews and symbolism interact to give form to creativity. They are described using the pronoun 'we', and are underpinned by the value of goodness which informs the Morals of a society.

Events and phenomena manifest in all four domains simultaneously. Each domain functions as a lens through which to explore an event, a 'snapshot' of a point-of-view. While these four domains are simplifications of highly complicated relationships that span across quadrants, they are useful in making sense of complexity. The domains also represent the four minimum perspectives or starting points for a holistic exploration of any subject (Wilber 1996: 71). Collapsing the interior domains into exterior terrains results in what is termed a *flatland*, i.e. systems-based analyses that leave out the nuances of felt experiences (Esbjörn-Hargens 2012: 3). In order to avoid this inaccurate understanding, "integral practitioners often use the quadrants as their first move to scan a situation or issue and bring multiple perspectives to bear on the inquiry or exploration at hand" (Esbjörn-Hargens 2012).

An example of an integral understanding of an event from the four domains could potentially unfold as follows: I am an architect commissioned to design a new building. This phenomenon will manifest in the mental processes I undertake to design a building (research, strategy, problem solving, design), as well as the physical actions I will perform (site visits, meetings, council runs and inspections).

These processes and actions have at least four dimensions that co-arise (the *tetra-mesh*) (Esbjörn-Hargens 2012) to inform each other. I will experience (UL) a number of emotions informed by my psychological outlooks and my feelings that might include excitement at the prospect of designing something new and meaningful, or anxiety about the potential problems. Simultaneously, my body will have physical reactions to these thoughts (UR), my heart might beat faster due to excitement, my brain may register more activity, and my body might feel the effects of longer hours in front of the computer.

While these internal effects occur, external realities affect my actions: the social, political, economic and institutional systems (LR), coupled to broader global systems in which I am operating, will dictate what I may design and build within the constraints of the law, the budget, and the market. Lastly, the culture that contextualises my worldview (LL) determines

what I understand to be my role as an architect, my responsibility toward my client, my expectations of professionals in the team, my frame of reference for the architectural style and identity, and the norms or expectations regarding the building's relationship to its broader environment.

To have a full appreciation of the complex process that underlies any activity or event or even a city, multiple perspectives are essential. Given the unpredictable challenges faced in cities, design must consider as many perspectives as possible that can make cities resilient habitats in which living systems can thrive. Applying an integral, holistic, whole system perspective to urban resilience going forward, will avoid a fragmented and skewed understanding of resilience in urban environments.

3.7 Conclusions

This chapter sought to define and discuss concepts relating to ecological resilience theory, as they form the basis for the dissertation and further exploration of resilience concepts in the next chapter, and for the translation of ecological resilience concepts in Part Two. Exploring core concepts is important to the development of an urban resilience approach, since urban systems have a strong resemblance to ecological systems in their structures and functions. Translating ecological resilience frameworks into urban environments can be of benefit to urban resilience practices.

This chapter explored the main definitions of ecological resilience, from static to dynamic. It touched on the themes related to an ecological approach, namely a whole systems viewpoint, observing change, and building capacity to bounce back or adapt. In addition to exploring ecological resilience definitions, the chapter touched on engaging cities as social-ecological cities. Ecological processes can make change and resilience easier to understand, but care must be taken in this regard; firstly in identifying the gaps created when translating resilience concepts from ecological to social systems, secondly in directing development toward ecologically healthy urban habitats and lastly, in bridging the gap between the internal and external dimensions in the city.

PART TWO

ESTABLISHING THE CONCEPTUAL BASIS FOR URBAN RESILIENCE THINKING

CHAPTER FOUR

EXPLORING CONCEPTS AND AVENUES OF RESILIENCE THINKING

4.1 Introduction

> Is resilience in danger of becoming just another buzzword? Does its malleability mean that many divergent measures, including those that might otherwise appear indefensible, can be justified in the name of resilience? Or, is it a promising concept for planning theory and practice? And if so, what are the opportunities and limitations of translating resilience from the field of ecology into planning? (Davoudi 2012).

This chapter touches on the development of resilience theory over the last 40 years, and investigates key concepts that underpin its practice within a systems perspective. It also suggests the use of resilience as a means of reverting to the holistic priorities set out in the sustainability movement. It identifies ecological resilience as a well-researched theory and one that has informed resilience practices. The broader manifestations of resilience thinking and its concepts and applications therefore form the focus of this chapter.

The increased interest in and use of resilience theory in other professional fields and branches of practice is evident with resilience trends in the built environment as well. Given this increased interest, the chapter argues for a deeply grounded holistic investigative approach (rather than a development trend) that engages with interventions that contribute toward a reconfiguration of the system, rather than a perpetuation of the status quo.

This can be achieved by rooting the urban resilience approach within ecological resilience theory. The motivation lies in ecological systems and urban systems sharing properties of complex adaptive systems. They follow similar systems rules of which resilience is one. To understand how the rules of resilience can be adapted from ecological systems to urban systems, the 'operating system' or key concepts underpinning resilience practice require definition. This applies to resilience as a systemic property, and as a normative position.

4.2 A brief overview of the development of resilience theory beyond the ecological sciences

> If we cannot control the volatile tides of change, we can learn to build better boats (Zolli & Healy 2012: 5).

Since the 1970s, resilience theory has branched into the social sciences (Zolli & Healy 2012; Anderies 2014), becoming a rich and dynamic theory with institutes such as the Stockholm Resilience Centre dedicating their research to resilience (Stockholm Resilience Centre 2007). Its application to cities has mostly focused on anti-adaptive 'bounce back' attempts to manage or maintain the urban status quo in the face of pulse disturbances like natural

disasters (Vale & Campanella 2005; Local Governments for Sustainability (ICLEI) 2012; The Rockefeller Foundation - Ove Arup 2014). Looked at from a broad perspective, resilience theory provides a rich umbrella concept to bring together the built environment professions and equip them with a common language to approach, and find solutions for, unprecedented development pressures and risks (Brand & Jax 2007: 23). It bridges study areas, practices and sciences that have previously been working in isolation, and through this process a holistic approach to urban futures can be unlocked.

In terms of its use in sustainability, the last few decades have seen development in the fields of ecological design and green building, making the built environment more efficient and theoretically more sustainable. However, the challenges affecting the sustainability of rich and complex life-forms on earth have accelerated beyond available innovative technological solutions (Van der Ryn & Cowan 2007: 5; Stocker *et al*. 2014). According to Zolli & Healy (2012), sustainability falls short in two respects: its goal to find a single equilibrium and "its lack of practical prescriptions for contending with disruptions precisely at the moment we're experiencing more and more of them" (Zolli & Healy 2012: 21). This indicates that the problem does not only lie with inefficient systems (resource use), but also with their ineffectiveness (systemic structure) to thrive beyond new challenges; a different perspective should be adopted. Resilience thinking offers a different take on the effectiveness of the systems as well as the solutions put forward, so much so that, "as volatility continues to hold sway, resilience thinking may soon come to augment or supplant the sustainability regime altogether" (Zolli & Healy 21).

Brand and Jax (2007) describe two distinct meanings of resilience that dominate literature. The first, engineering resilience, could commonly be described as 'bounce back' resilience, which refers to the time it takes to return to a state of dynamic equilibrium after a disturbance hits a system; these dynamics are close to equilibrium. The second meaning is defined as "the amount of disturbance that a system can absorb before changing to another stable state", in a system of which the dynamics are far from equilibrium; this type of resilience is known as ecosystem or ecological resilience (Brand & Jax 2007). Both of these meanings rely on systems equilibrium in their definitions, whether pre-existing or desired. Definitions of resilience in other disciplines also rely on equilibrium as the gauge against which resilience is measured (Davoudi 2012).

Apart from these two foundational meanings, there is a growing understanding that resilience also implies transformation in systems. In this instance, aspects of a system may collapse or regenerate toward certain qualities that bolster its general resilience (Walker &

Salt 2012) and increase the system's overall chances of survival. In view of this, a third meaning of resilience is proposed, i.e. evolutionary or social-ecological resilience that is far from equilibrium (Davoudi 2012: 302).

The first branch of resilience thinking to have developed, and therefore a prominent area of research, is that of ecological systems science (Folke 2006). In its subsequent application to fields of study like the social sciences and the built environment, its precise use becomes vague when used as a bridging concept between disciplines in which research is conducted together (Brand & Jax 2007: 8). In transdisciplinary work, resilience is not used to measure the capacity of a system to rebound from or absorb disturbances. Rather, it becomes a 'metaphor' that stands for a quality desired in a system, and thereby creates common ground when there may not be consensus (Brand & Jax 2007: 9; Pickett *et al*. 2013: 16). Resilience in this form is a symbol for a new way of thinking and engaging with social-ecological systems (Brand & Jax 2007: 8).

This realm of resilience theory engages with humans and the broader natural system as part of the same urban ecology, influencing, interacting with and responding directly and indirectly to each other (Du Plessis 2008). Splitting humans from the 'natural' environment has been the anthropocentric tradition for centuries, causing the arrogant ideology that humans are custodians of their environment and have the authority and power to determine how to use it for their own ends (Whiston-Spirn 1984: 91). To adopt a social-ecological or evolutionary viewpoint of resilience is extremely powerful in facilitating new integrative development paradigms. This perspective implies that dynamic urban systems where human-nature partnerships exist can emerge as resilience. All three meanings of resilience – engineering, ecological and evolutionary – are necessary and useful within the urban realm; however, for the purpose of this study, the focus lies in exploring how ecological resilience can be translated into the urban realm.

4.3 The purpose of resilience theory

Resilience thinking offers an alternative way to understand change in social-ecological systems (SESs), and challenges the norms of interpreting the world. Rather than trying to maintain conditions in a static realm of control, resilience embraces a dynamic world that responds to disturbances affecting systems. It explains how functional systems can become dysfunctional due a loss of resilience when critical system thresholds are crossed. It concerns not only the ability to absorb shocks and continue, but also to unlock potential after a disturbance for "doing new things, for innovation and for development" (Folke 2006).

Ecological resilience perspectives are also evolving in which "the newer view shows continual change, periodic evolution or shifts of ecological systems rather than permanence" (Pickett et al. 2014: 146). Thus the understanding of the value and purpose of resilience theory is fundamentally shifted, from one that manages the stasis of prescribed conditions to one that adaptively responds to the flows of evolutionary change and its volatile fluctuations.

For built environment practitioners, a resilience approach alludes to making informed decisions regarding living systems and their future urban trajectories, so that these can be "about weighing up options, keeping them open, and creating new options when old ones close" (Walker & Salt 2012: 140). Resilience theory has the dual purpose of trying to keep systems functioning as they are through mitigation, and also to build capacity for healthy adaptation when key thresholds within the system are crossed (Zolli & Healy 2012: 8).

4.4 The different perspectives of resilience theory and their definitions

> First introduced as a descriptive ecological term (Holling 1973), resilience has been frequently redefined and extended by heuristic, metaphorical, or normative dimensions […] (Brand & Jax 2007).

The use of resilience theory as a common perspective from which various disciplines engage with change and partake in transdisciplinary work is of value to city systems. However, the specific definition or meaning that each discipline holds of resilience is not always easy to bridge in multi-disciplinary environments. The range of resilience thinking perspectives and lack of cohesiveness in how it is engaged in practice (i.e. resilience as an emergent property of a system versus resilience as a normative principle) can be attributed to seemingly contradictory yet potentially simultaneous manifestations of resilience in a system – namely to absorb disturbances, to adapt to disturbances, or to transform aspects of the system so that the functionality of the whole continues. These manifestations relate to the primary definitions of resilience, namely engineering, ecological (Gunderson *et al*. 2002: 4; Folke 2006) and evolutionary (Davoudi 2012: 302).

In two separate studies, Brand and Jax (2007) and Davoudi (2012) have undertaken to extract established 'types' or 'perspectives' of resilience meaning, interpretation and engagement. Resilience is primarily interpreted in two ways, with a hybrid of both representing a third option (see Figure 12.) Firstly, as a descriptive systems concept, it delimits and defines a predictable stable regime of behaviour in a system (as used in the ecological and social sciences) (Gunderson *et al*. 2002: 4; Brand & Jax 2007). It aims to mitigate disturbance or adapt systems functionality. Secondly, as a normative concept or

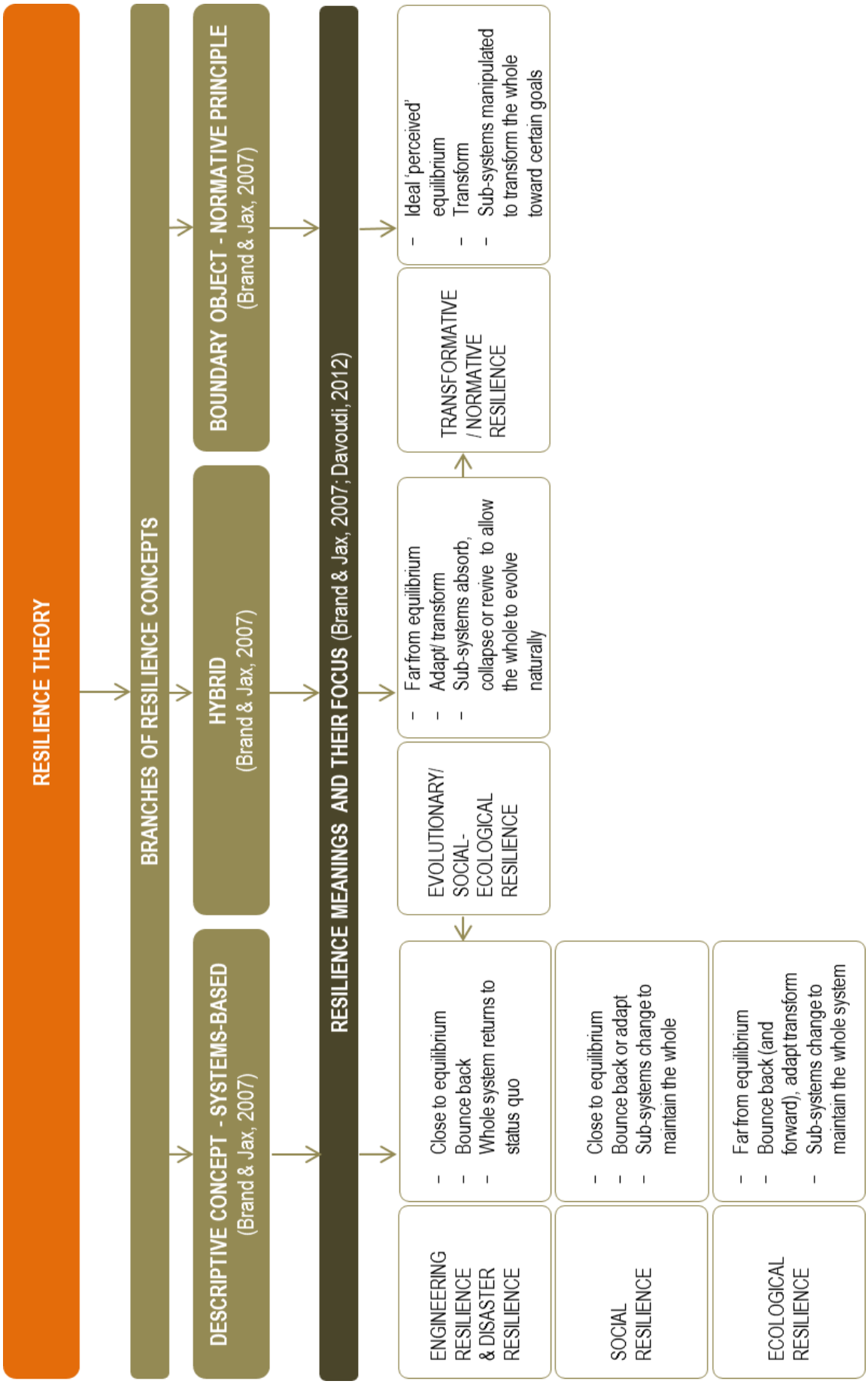


Figure 12 - Diagram showing the primary branches of resilience and their underpinning viewpoints, as adapted from Brand & Jax (2007) and Davoudi (2012)(Author 2015).

boundary object, it provides value as a broad term for research and practice between disciplines (to facilitate multi-disciplinary discussion, advance sustainability principles, argue for transformative design, or as a metaphor for survival) (Brand & Jax 2007). Resilience in this sense may include the means of purposefully transforming current systems so that they are directed toward sustainable goals (Anderies 2014: 138). Lastly, as a hybrid term, Zolli and Healy's book *Resilience* (2012) provides examples of evolutionary resilience, otherwise known as social-ecological resilience (Davoudi 2012: 306), to illustrate how complex planetary exchanges occur. The descriptive aspects of this perspective provide insight about adaptive and transformative capacities in a system, and thereby inform engagement and experimentation.

Within the descriptive systems-based branches of resilience, Davoudi (2012) describes three definitions: engineering resilience and ecological resilience, which have dominated research thus far, and thirdly, social-ecological or evolutionary resilience. Engineering and ecological resilience are well-established perspectives within ecological literature, with the engineering (stable) approach aiming to maintain system constancy and efficiency within a predictable range, while the ecological (unstable) approach focuses on the persistence of the system's functionality despite "change and unpredictability" (Gunderson *et al*. 2002: 4-5). In cities, the engineering approach measures the ability of a city system to return to a former state after a devastating disaster, which is increasingly necessary due to the fragility of the urban habitat in withstanding unprecedented natural and human disasters (Meadows 2008: 198).

Unlike engineered and ecological approaches that are predictive, social-ecological or evolutionary approaches embrace complexity and change. Urban systems can change rapidly or transform over time in response to stresses and strains in unpredictable ways that may be profoundly different from what preceded them (Davoudi 2012). In complex unpredictable and non-linear systems, the cascading effects that small changes can have on larger systems are often more powerful in changing the system than large interventions. Since change may follow unpredictable trajectories, resilience should rather be "the life sustaining aspect of nature that yields to external forces and in that yielding keeps the system from failing or being destroyed" (Du Plessis 2013: 35).

As illustrated in Figure 12, a synthesis of definitions of resilience (Davoudi 2012) and the three branches or interpretive frameworks wherein they tend to be viewed (based on the intention behind which they tend to be applied) (Brand & Jax 2007), follows:

- *Engineering resilience*: the ability of a system to bounce back to a 'pre-disturbance state' and the speed it takes to do so, including its efficiency, predictability and constancy. It is used to try to manage, mitigate and rebuild after a disaster and is linked to *bounce back or disaster management resilience*, focused on the capacity to rebound to the status quo after destruction. It manifests in fields like urban theory, psychology, economy, environmental planning, governance and climate adaptation. This definition requires a system of which the dynamics are close to equilibrium and is a descriptive concept with clear delimitations.

- *Social resilience:* the ability of groups to cope with external stress and disturbance resulting from change. This implies that a degree of equilibrium is maintained over time and represents a descriptive concept with clear delimitations.

- *Ecological resilience*: the magnitude of disturbance a system can absorb without severely compromising its survival within a range of permissible fluctuations. It is used to try to improve the capacity of the system to survive a perturbation without collapse. System dynamics may be far from equilibrium, but the critical threshold between one regime and another has not been crossed.

- *Evolutionary or social-ecological resilience* acknowledges that complex social-ecological systems change, adapt and, very importantly, transform after a disturbance in ways that transcend but include all the previous states. Aspects of sub-systems may change, but not the core identity or functionality of the whole system. Within this view, at times sub-systems may collapse in order for the whole system to continue, albeit on a different trajectory.

- *Normative or transformative resilience* acknowledges that change can be used to harness transformation within the system in order to move closer to a desired normative state. In this view, resilience is seen as a good thing, and the goal for developing a sustainable, just and thriving built environment.

Investigating system resilience from the perspective of a descriptive or hybrid concept embodies engineering, or ecological resilience, or both, depending on the situation and its response to specific events or persistent pressures in the system over time. Descriptive or hybrid concepts of resilience engage with a system perspective and are concerned with process rather than outcome, and because of this, "resilience may be viewed as either desirable or undesirable in a specific case; this depends on the state of concern" (Brand &

Jax 2007). In this systemic view of resilience, the focus is on allowing a system to evolve, but not prescribing what the outcome must be.

In the descriptive or normative concept of resilience, a resilient system is perceived as 'a good thing' since it allows for open-ended flexibility over time that is able to meet unpredictable challenges, sustainability qualities, or other normative values. In this case, proponents of an ecological sustainability worldview are supportive of the positive potential depicted by the transformative resilience narrative. However, punting resilience as a means of achieving certain goals by transforming certain aspects of the system requires careful engagement, since this type of purposeful transformative resilience practice is based on value judgements behind 'who' makes decisions (Vale 2014: 191), and why and how choices are made regarding 'strong' and 'weak' points in a system.

Resilience theory can shift urban perspectives from equilibrium-managed to thriving and dynamic social-ecological systems. To achieve these thriving, dynamic habitats may require certain aspects of life within the status quo to collapse to make room for new life to take root in a site's latent potentials (to be identified) (Du Plessis 2013: 38). Resilience can be approached as a systemic property describing the ability of cities to adapt to change, or as a transformative tool for reshaping the future. Either can be applicable depending on the situation. However, the branch and definition of resilience engaged should be clear and articulated when conducting multidisciplinary work, to prevent misinterpretation and confusion.

4.5 The various fields applying resilience theory

> The concept of resilience is a powerful lens through which we can view major issues afresh: from business planning […] to social development […] to urban planning […] to national energy security (Zolli & Healy 2012: 16).

Expansive resilience research has been done in various fields or disciplines since the 1970s, when resilience was understood to be a vital characteristic of a healthy ecological system (Davoudi 2012). From its roots as a means of managing change, the understanding now is one that accepts the possibility that, despite all human efforts to manage change, there is always the possibility that systems can exceed their limits and fail (Zolli & Healy 2012: 16).

In view of this constant potential for failure, the power of resilience lies in making conscious choices that build capacity to resist failure. At times, however, its power may lie in allowing failure to occur in the interest of the survival of the whole. In research and in practice, this creates the possibility for various disciplines to converge and see global change from a joint

perspective that looks at the bigger picture and engages it in a more conscious manner (Zolli & Healy 16).

Since resilience is a resultant characteristic of interactions between components or conditions in a system, a number of research and practice fields based on systemic thinking are able to apply resilience concepts. These include ecological disaster or risk management (to prevent ecosystems from becoming permanently degraded), engineering (to mitigate against known risks and to make mechanical systems more robust), psychology or sociological development (to increase the capacity of an individual or community to survive and thrive beyond stress and disaster), business (to limit the risk of investment losses and to sustain the growth model), urban planning (to adapt and evolve over time in response to unpredictable change), and emergency response, policing and warfare (to support the continuity of essential infrastructure in the face of natural or man-made disaster) (Brand & Jax 2007; Zolli & Healy 2012: 16).

The ripple effects of actions due to globalisation can be localised, global, immediate or may take a long time to manifest. In view of this, it is becoming increasingly necessary to practice resilience across disciplines (Walker & Salt 2012: 146) to navigate messy global complexities. This is important for two reasons. Firstly, to create multi-disciplinary scenarios for what the effects of actions might be on the system in order to arrive at considered responses (Bina, Balula & Ricci 2014). Secondly, to ensure that interventions include multiple perspectives (derived from transdisciplinary investigations), and are rooted in conscious and holistic decision-making processes (De Kay 2011) that consider the overall resilience of a system.

The diversity of methods, practices and perspectives represented by the various fields or disciplines conducting resilience research makes it important to redefine resilience so that it remains a clear, useful and valid resource. Increasingly, the understanding is that specific resilience to disaster-related events does not cater for the complexity of unknown risks and disasters to come. Consequently, the push is toward building overall system resilience across scales, as is being seen increasingly in urban resilience research (Walker & Salt 2012; Anderies 2014).

Resilience in an urban system requires combining resilience fields, given that urban systems are their aggregate manifestation. These combined definitions are required in the holistic study of an ecologically sustainable urban system that integrates tangible and intangible qualities. Holistic resilience practice in a city develops external and internal dimensions

simultaneously, and requires an overarching framework to navigate through the complexity of this task. A post-post-modern or post-structural pathway called Integral Theory has evolved for dealing with this level of complexity and the 'messy' challenges that characterise life on earth (Ellin 2006: 142). As described in section 3.6.4, Integral Theory can provide a basis for finding clarity when engaging with various resilience fields, by providing a framework for holistic engagement and practice.

4.6 Resilience in the context of sustainability – creating new stories for life

> We live in two interpenetrating worlds. The first is the living world, which has been forged in an evolutionary crucible over a period of four billion years. The second is the world of roads and cities, farms and artefacts, that people have been designing for themselves over the last few millennia. The condition that threatens both worlds – unsustainability – results from a lack of integration between them (Van der Ryn & Cowan 2007: 33).

Sustainability is evolving, and where it remains unchanged it is due to inflexible world views. From a systems perspective, it is difficult to disentangle or even differentiate the human species from the rest of the Earth system, thereby highlighting the interdependence of the broader web, the flows of life, and the environment (Capra 1996). It emphasises the point that to sustain the environment is to sustain humanity. Sustainability is an anthropocentric endeavour – at worst it strives for the survival of human life on earth and at best, a complete flourishing of living systems.

To say that sustainable development will save the planet is a misunderstanding of the order of dependence between humans and their environment in the *Kosmic* holarchy; the planet will continue to exist with or without humanity. Should the environmental conditions that have allowed humanity to thrive thus far collapse, humans may very likely disappear from the planet. This would mark the first species to knowingly perpetuate its own extinction. To maximise the benefit of resilience in the context of sustainability, both its evolution as well as the current blockages preventing its assimilation across scales, sectors and geographies must be explored.

"Blue Marble", the first full-view image of Earth as taken on 7 December 1972 as the Apollo 17 crew left Earth's orbit (NASA), contributed to the understanding that human existence is dependent on the continuation of life on this magnificent planet humans call home. It also framed Earth's fragile beauty within a vast and mysterious universe, turning it into a cherished resource. Awareness that global resources are finite and their limits within sight, propelled the sustainability movement into 'doom-and-gloom' responses highlighted by interest groups such as the Club of Rome (Meadows *et al*. 1992; Diamond 2011) and the

Brundtland Commission (WCED 1987), and led to summits on sustainable development and international agreements like Agenda 21 and the Kyoto Protocol.

Over time, the principles outlined by these initiatives evolved to fit commercial interests, resulting in trendy consumer culture with 'greenwash' branding of so-called sustainable initiatives, products, ideas, and developments, marketed with words like 'eco-estate', 'green-building', or 'organic'. Most 'green' initiatives focus on the efficient use of resources, but fail to address the destructive systems that are driving insatiable resource consumption and eroding quality of life for future generations. Illustrated in Figure 13, a recent example shows Sasol, South Africa's primary synthetic fuels company, marketing a sustainability message that claims it adds value to natural resources, yet the image shown portrays an industrial process that extracts natural resources without replenishing them.

Figure 13 - A photograph of an advertising billboard inside the Sandton Gautrain Rapid Rail Station in Johannesburg, taken during November 2014 by the Author

Sustainable development aims to fulfil the needs and quality of life of current generations (or 'powerful' groups) without destroying the ability of future generations (or less 'powerful' groups) to fulfil their own needs (De Kay 2011). This well-accepted definition was promoted during the 1987 Brundtland Commission, and was articulated through Barbier's established model of the three primary pillars or spheres of development (Barbier 1987), namely environmental integrity, social well-being and economic feasibility.

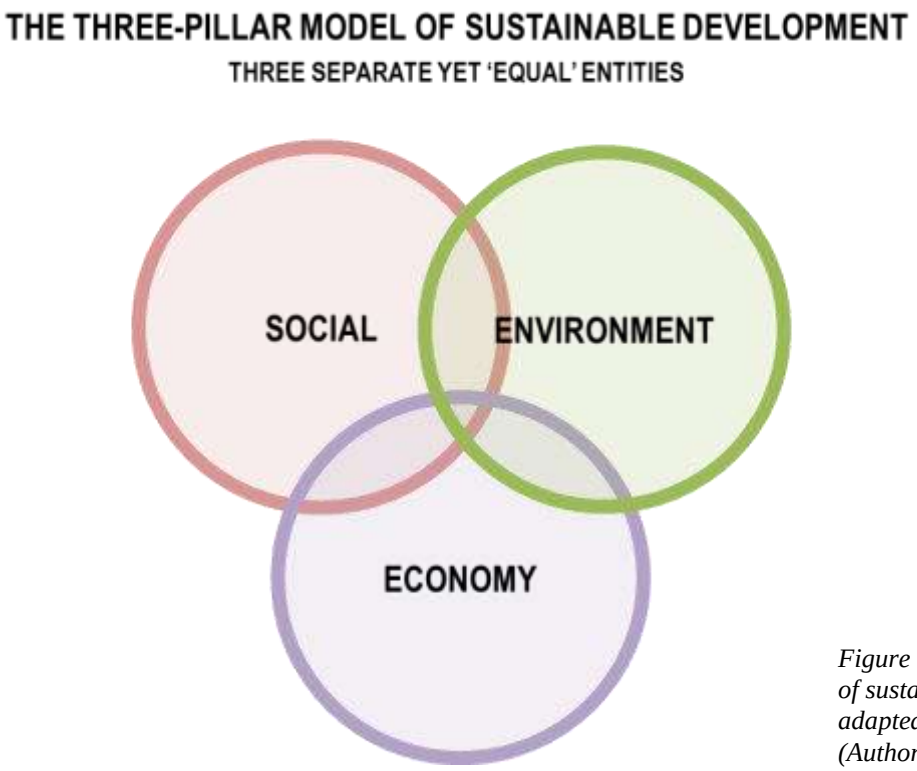


Figure 14 - A three-pillar model of sustainability. Diagram adapted from Barbier (1987) (Author 2015).

In theory, sustainable development should see equal consideration in all three spheres as shown in Figure 14; however, economic motivations drive the bottom line of sustainable development and without economic incentives, social and environmental issues are sidelined (De Kay 2011). The triple bottom line alone cannot ensure the quality of what is left for future generations (Pickett *et al*. 2014: 145) without being underpinned by an alternative to the reductionist worldview that has dominated sustainable thinking thus far (Du Plessis 2011b).

Reductionism is evident in the way in which the three spheres are structured in the model as being 'equal' yet separate entities, which overlap to create 'sustainability' (see Figure 14). This model gives the false impression that the spheres can be explored independently and that actions within them do not affect the other spheres. For example, economic concerns are often justified to overtake social or environmental values, because their full impact is not immediately evident. Green cities where net-zero energy is used are difficult to achieve, because cities depend on the consumption associated with urban lifestyles for their survival; the built environment directly contributes to levels and types of consumption (Fernandez 2014). This situation highlights the complexity and contradiction inherent in urbanism – it drives the consumption that destroys living systems while being the vehicle that sustains the majority of human life. The question then is whether efficiency based sustainable practices are capable of dealing with these twisted realities.

Sustainable construction (as opposed to sustainability) focuses on tools and rating systems that aim to mitigate change and increase efficiency (Du Plessis & Cole 2011; Cole 2012). Current tools and rating systems fail to provide an accurate response to the overwhelming number, scale and frequency of interconnected disasters set to cripple global social-ecological and economic systems (Gilding 2011; Cole 2012; Zolli & Healy 2012: 21; Hes & Du Plessis 2015).

For example, South Africa's sustainable built environment rating system, the voluntary GreenStar rating system from the Green Building Council of South Africa (GBCSA), promotes design efficiency using imported a-contextual technologies from Australian, American and European tools as the basis for its sustainable building initiatives. As long as efficient technologies are used, the overall conceptual rigor or validity of the design and development is unquestioned. These tools reduce sustainability concepts to mono-dimensional generic checklists that serve very different social-ecological spaces from which they originate (Du Plessis 2011b).

While they foster awareness in high-end projects, it is doubtful whether they influence the deeper values that shape consumption-hungry societies. These tools focus on prescriptive small-scale efficiencies of individual buildings and, increasingly, precincts. They do not consider how built environments influence the well-being of society, or how these environments adapt to fluctuating conditions resulting from anthropogenic climate change, for example. In other words, they fail to analyse designs for their capacity to build resilience in cities toward an unpredictable future. They leave little room for green buildings or neighbourhoods to evolve and to continue to provide quality habitats without intensive and expensive retrofitting – or to fail gracefully if necessary (Zolli & Healy 2012: 14). Transplanting tools from one region to another prevents the assimilation of vernacular wisdom based on a social-cultural worldspace, and limits individual and collective behaviours in the practice of sustainability (De Kay 2011).

The global building industry is reflecting upon the success (and speed) with which it has been able to promote its sustainable building agenda in the three focal areas of economy, society and environment. At the 2014 World Sustainable Building conference it asked, "are we moving as quickly as we should?" to which the answer is "no" (WSB14 2014). In spite of significant strides to develop sustainably, the 5th Intergovernmental Panel on Climate Change (IPCC) report indicates that accelerated ecological destruction is becoming the norm (Stocker *et al*. 2014). Researchers consistently argue that the sustainability movement is therefore not achieving enough (Meadows *et al*. 1992; Fox 2000; Brown 2005; Van der

Ryn & Cowan 2007; Meadows 2008; Jackson 2009; Du Plessis & Cole 2011; De Kay 2011; Hes & Du Plessis 2015) and that in many ways it sustains a destructive status quo.

Life in a globalised society is increasingly impacted by economic recession, which can be linked to the consequences of climate change on biophysical and social systems in affected regions like China, central and northern Africa and the Middle East (IPCC 2007; BBC 2011; NOAA 2011). These place long-term pressure on local social-ecological systems, giving rise to fundamentalist groups and revolutionaries set to cripple the Western systems perceived to be at fault, or perceived to threaten their ideologies (BBC News Europe 2015; The Independent 2015). At the same time, a counter-culture eager to question and protest current operational systems is developing in the West (Wilber 2007; Eisenstein 2011). Its members seek to envision new (or adapt old) alternatives that are more ethically oriented on a holistic ecological worldview (Hes & Du Plessis 2015), and are locally rooted, ready for transition (Zolli & Healy 2012: 20), self-sufficient and small-scaled.

In response to these and other changes, sustainability experts suggest the 'efficiency' green agenda that represents the current status quo and is based on a mechanistic or reductionist world view can only go so far (Van der Ryn & Cowan 2007; Du Plessis 2011b; Cole 2012). It must be adapted to include more integrative and holistic perspectives. They argue that enabling this adaptation within the built environment does not require a complete redesign of current efficiency or rating systems. Rather, it requires alignment with an ecological worldview (Du Plessis 2009) that recognises change as inevitable. It addresses the social-ecological aspects of sustainability with the same intensity as economic ones, since "we cannot exclude major dimensions of reality and expect comprehensive, sustainable results" (Esbjörn-Hargens 2012: 14). The alternative holistic vision of sustainability, whether ecological, regenerative or resilient, puts forward the idea that we need to transform the way we build (and live) in order to boost nourished, thriving and renewable living systems (Hes & Du Plessis 2015: 11).

The focus of this perspective is on the ability of sustainability to become a positive catalyst for change that reassesses processes, practices and beliefs regarding our planetary roles and responsibilities. For sustainability, this change embodies nurturing the quality and diversity of life on earth, rather than sustaining the damaging systems that perpetuate destructive consumption versus considered consumption. The entire status quo needs to be redefined, refined and aligned with the goals envisaged for the collective future of humanity (Eisenstein 2011).

The message is not to stop consuming, but rather that consumption be underpinned by considered choices that harness and maximise resources in ways that allow them to be replenished and rejuvenated. The goal is to enhance living systems and protect the quality of human life and habitats. Achieving this goal depends largely on how humans manage their choices, based on their appreciation of the natural system of which they form part.

This appreciation is built on an alternative worldview based on a whole- or living-systems perspective (Du Plessis 2012 b). At its core, this ecological worldview sees that humans and the broader natural living systems (nature) are not separate entities, but rather different expressions of a single "integrated holarchic global social-ecological system that spans across matter, life and human social and cultural phenomena and in which humans co-evolve with other entities in the system" (Du Plessis 2009). As integral parts of a complex living system, humans are creating natural processes along with all forms of life (Lipton & Bhaerman 2009), and therefore form an extension of the natural laws that govern life. To align human activity with this worldview would require actions that "learn from and follow the laws of nature, and cooperate with and participate in its processes so that the outcomes of actions contribute to the well-being, nourishment and regeneration of the world" (Du Plessis 2011b).

This worldview requires a shift in the way humans see and define problems, and in how design can contribute to shaping a solution (Hes & Du Plessis 2015). Primarily, the shift begins when humans perceive themselves as an integral part of natural systems – what they do to nature, they do to themselves (Wilber 2000). As illustrated in Figure 15, a review of the three spheres sustainability model from this ecological perspective re-orders the three separate entities into a single entity as shown in Figure 15, in which the spheres of society and economy are dependent on and embedded within the health and well-being of environmental systems (Scott Cato 2009). This holistic model is crucial to the survival of human beings (Van der Ryn & Cowan 2007; Du Plessis 2011b). Ecological sustainability creates opportunities to see the holistic interrelationships and dependencies between the three spheres, where economy is a product of society that is embedded within an environmental consciousness (Van der Ryn & Cowan 2007; Scott Cato 2009: 36-37).

If sustainability practice is responsible for guiding development toward creating prosperous habitats for all forms of life, then sustaining and, more importantly, regenerating cities necessitates building their capacity to absorb, adapt and evolve to changing conditions over time, without compromising their functional identity (Walker & Salt 2012: 3) as thriving human habitats within an integrated living system. Sustainability requires resilience since "the

bottom line for sustainability is that any proposal for sustainable development that does not explicitly acknowledge a system's resilience is simply not going to keep delivering the goods (or services)" (Walker & Salt 2006).

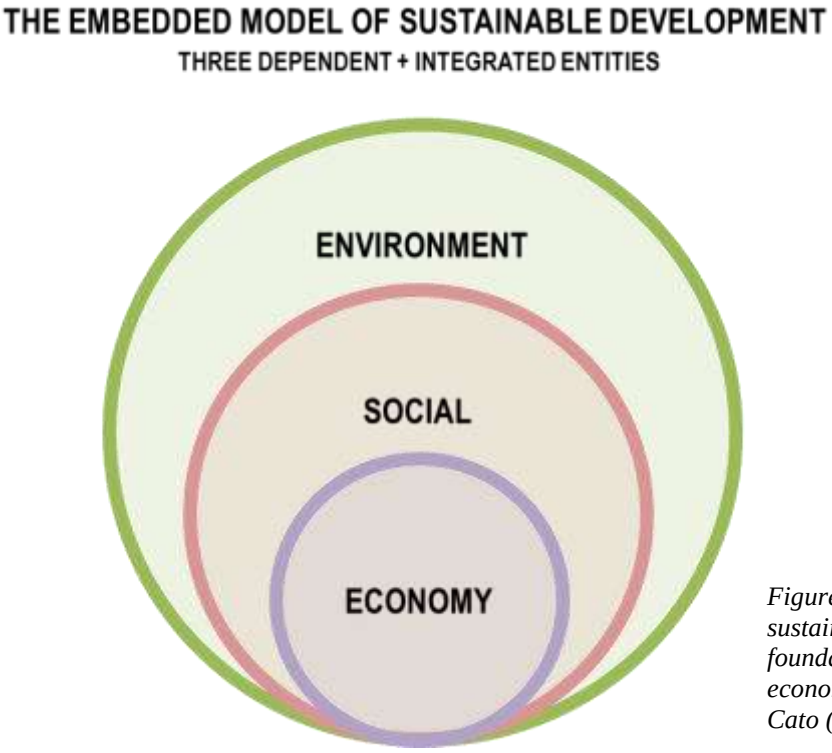


Figure 15 - An embedded model of sustainability where environment is the foundation from which society and economy emerge, as adapted from Scott Cato (2009: 37) (Author 2015).

Resilience thinking recognises the blockages to the evolution of a system, and so it can become the means to propel fast, long-term and large-scale change from individual, to urban and thereby global systems (Du Plessis 2011b; Walker & Salt 2012). It also reconciles the short-term argument for the efficient use of resources with a more long-term and "generic responsibility of maintaining a diversity [and quality] of options" for the future (Gunderson *et al*. 2002: 251). The key to sustainability lies in enhancing the resilience of SESs, not in optimising isolated components (Walker & Salt 2012: 9). Sustainable resilience practice proposes to allow key variables to interact, to change, and to reinforce functional diversity, replication and overlap across scales (Gunderson *et al*. 2002: 215-254).

Described as a conceptual framework with the capability of 'operationalizing sustainability', resilience is gaining ground as a built environment tool (Pickett *et al*. 2014). However, in such descriptions it is not always obvious which sustainability perspective or ethos is promoted – efficiency or ecology, or the separate or holistic three-sphere model? Generally, the objective aspects of sustainability practice are clear; the subjective qualities, the deeper 'why' and 'how' questions, need however to be reflected in practice (De Kay 2011: 12).

Societal value systems and worldviews dominate and drive sustainability, but are subject to change. Currently, the sustainability movement is evolving from equilibrist to adaptive thinking. Within this adaptive frame of reference, alternative goals for sustainability practice can be envisioned … not merely to sustain life, but to allow it to change and flourish (Hes & Du Plessis 2015). Principles of resilience (absorbing, adapting disturbance or transforming systems) and regeneration (renewing dysfunctional systems) can guide this progression of sustainability ideas to create new stories for life. So, if sustainability is the goal and resilience is the path, then what steps need to be taken on the resilience path?

4.7 Core concepts for thinking about resilience in urban contexts

> Resilience is a dynamic property of a social-ecological system, and managing for it requires a dynamic and adaptive approach (Walker & Salt 2012: 1).

A few core concepts underpin the translation of ecological resilience into urban systems. Gunderson *et al*. (2002: 17) put forward four propositions to explore resilience in large-scale SESs. Firstly, systems emerge from the interaction of a few variables; secondly, as complex systems they have multiple stable states; thirdly, they have functional diversity and overlap within and across scales; and lastly, they become vulnerable when novelty, diversity and overlap are eliminated. These propositions introduce four foundational precepts under which to engage with resilience thinking in complex adaptive systems. Fundamentally, as discussed in section 3.5, a whole systems approach is required which focuses on a descriptive concept of resilience as a) an emergent property of a complex, interconnected system. This would contribute toward an understanding of the urban system, its drivers of change, and the exchanges within the system. From this viewpoint it becomes easier to see levels of resilience in different aspects of the system.

As an emergent property of a system, resilience is b) value neutral – systems displaying positive or perverse conditions can both be highly resilient. In addition, resilience c) manifests in a system in response to its structures and networks in either providing capacity to bounce back, adapt, transform, or a combination of the three. Resilience manifests either as stasis or change. Each manifestation has a different consequence for the local and overall resilience of the system and also has d) different scales and areas of intervention, specific or general. These concepts create the frame within which to undertake urban resilience studies, and are explored in the following sections.

4.8 The two foundational understandings of resilience: stasis vs. change

> Urban transformation is not a process that of necessity runs from a juvenile frontier to some inevitable mature industrial or sustainable stage. Rather, urban transformations can intentionally or accidentally lead to quite unsustainable conditions, judged from the three pillars of sustainability (Pickett, McGrath, Cadenasso & Felson, 2014: 144).

Within an urban system, resilience has paradoxical meanings. On the one hand resilience is seen to promote predictable stasis, while on the other it promotes change – "resilience thinking is really about changing in order not to change" (Walker & Salt 2012: 23). Both meanings are correct and necessary, since on a systemic level resilience is concerned with maintaining the functionality of a system, which at times might mean to bounce back, change or even collapse sub-systems in order to do so (see Figure 16). Apart from resilience being present in a system that absorbs change and bounces back, it is present in a system that absorbs change, but adapts itself to the new conditions. It can also be present in a system that transforms significant parts of itself (either through collapse or regeneration) in order to ensure that the functional identity of higher scales of the system continues.

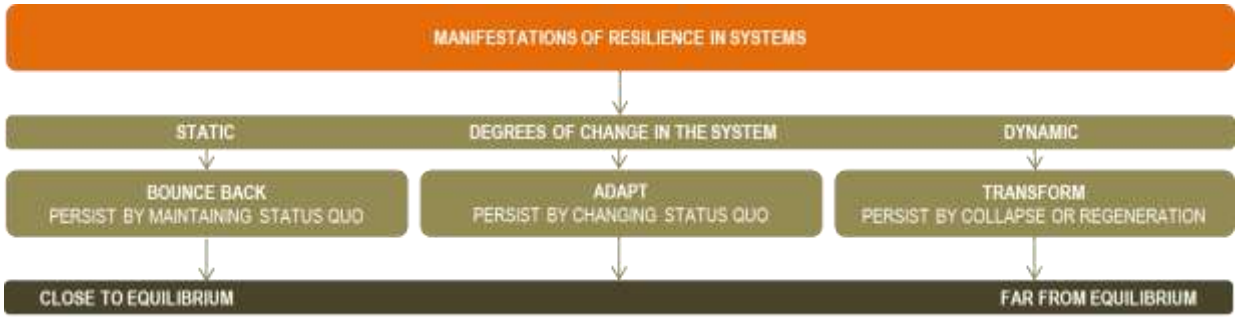


Figure 16 - Foundational understandings of resilience: stasis versus change diagram adapted from Walker & Salt (2006) (Author 2015).

Early understandings of resilience as a characteristic of an ecological system that described the ability and speed of a system to return to equilibrium after a disturbance (Gunderson *et al*. 2002: 4; Folke 2006; Davoudi 2012) have shifted to far more dynamic descriptions (Pickett *et al*. 2014). In practice resilience is often used to maintain a system as 'static'. This interpretation of resilience comes from the perspective of maintaining a system within a 'desirable' range of conditions; beyond these are thresholds to essential conditions which, if crossed, create a tipping point that collapses the conditions that gave rise to the system (Resilience Alliance 2010: 27). This control-based equilibrist approach is often termed 'engineering resilience', as it returns a system to a previous state of narrowly defined stability and is very much a control or stasis of a system within narrow margins.

Maintaining equilibrium in response to disturbance is a valid and in many instances essential form of resilience within well-defined scenarios: the safety parameters in the design of a building or car or machine. However, within complex adaptive systems (CASs), the very nature of which is dynamic, this approach can be fatal to the long-term resilience of the system. CASs are constantly changing, influenced by internal conditions within the sub-systems of the larger system, as well as by outside impacts and unpredictable disturbances. In this instance, the resilience of the system depends on how it adapts to pressures exerted when they can no longer be absorbed without leading to collapse. Once a system has collapsed and transformed into a different state, it is possible that it cannot be restored to a previous state (Peterson 2002: 243).

Urban systems can hold these paradoxical manifestations of resilience simultaneously: either as the capacity of a city system to resist change and to maintain its subsystems as they are (close to equilibrium), with short return times after disturbance (Gunderson *et al*. 2002: 59, 127), or to be able to adapt their relationships or transform subsystems in order to keep the whole city system going (far from equilibrium). However, resilience is often practiced with a pathological pattern, namely to manage complex systems to achieve a narrow set of goals. This is described as "the Holling Frustration: the pathology of constancy versus the viability of variability" (Gunderson *et al*. 250). The very 'resilience approaches' meant to maintain the system erode its variability and make it vulnerable to collapse following disturbances that could previously have been absorbed.

System conditions previously termed 'desirable' may need to transform through regeneration or collapse, in order to allow key subsystems to change completely so that the integrity of the whole can be maintained. The idea of resilience as a means to create change, as described by the transformational branch of resilience thinking, is aligned to the idea of flexible and adaptive systems that are far from equilibrium, but which might require being moved closer toward a desired state of equilibrium. In an urban system, resilience is as much about maintaining things as they are (static), as it is about allowing for change to happen (dynamic) in order for a system to evolve and thereby adapt its resilience.

4.9 Three manifestations of systemic resilience: to bounce back, adapt or transform

> ... [T]he capacity to adapt and transform for persistence is thought to be core to the general resilience of social-ecological systems (Elmqvist, Barnett & Wilkinson 2014: 21).

As an emergent property in a system, resilience represents the ability of the system to persist over time through three clear responses to disturbance that operate at different scales and in reaction to different disturbances. As illustrated in Figure 17, resilient systems have the ability to bounce back to a previous state, to adapt subsystem relationships in order to absorb disturbances while maintaining existing functionality, integrity, structure and feedbacks (Resilience Alliance 2010: 51), and lastly, to transform subsystems in order for the whole system to persist (Folke *et al*. 2010; Elmqvist *et al.* 2014).

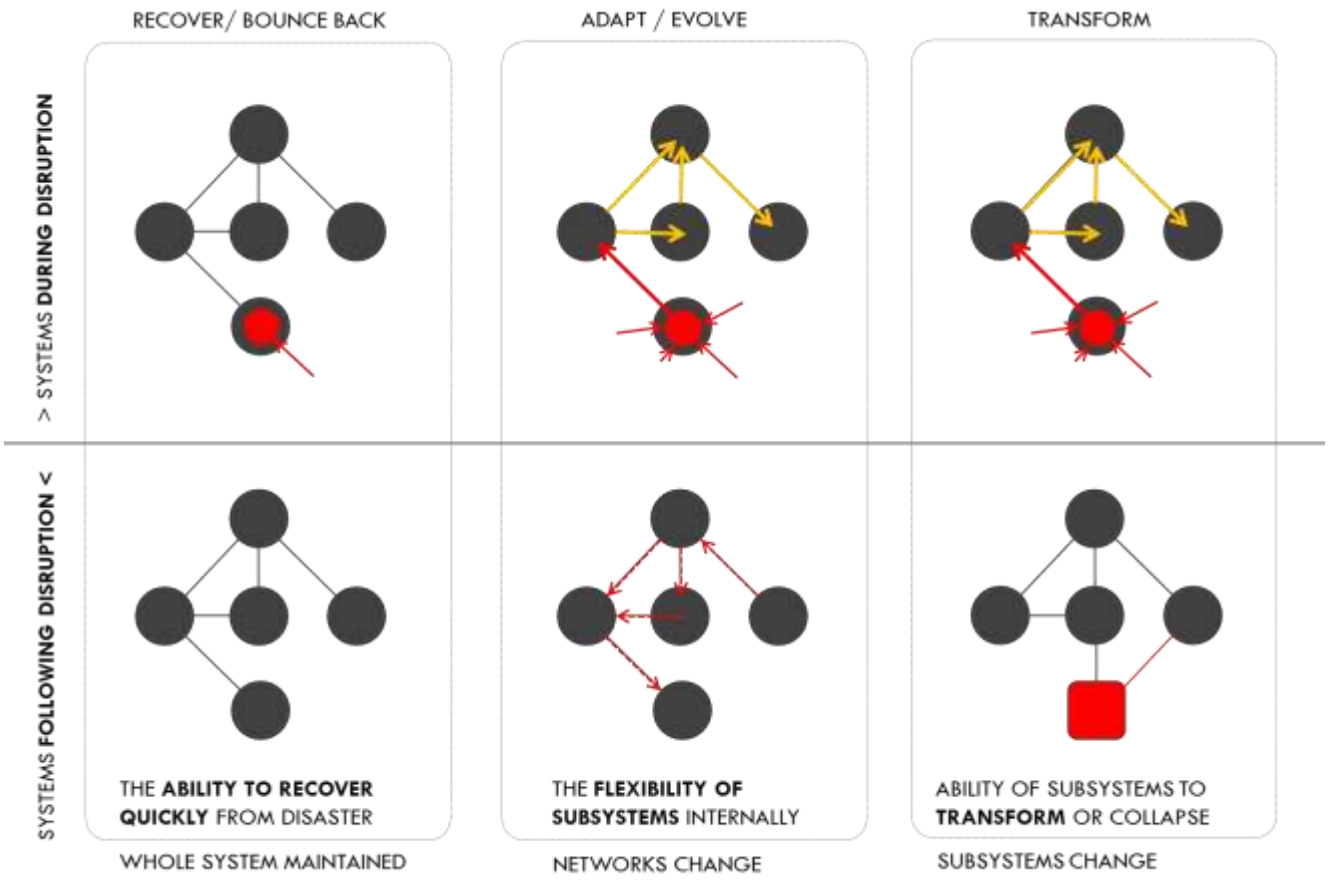


Figure 17 - Three manifestation of resilience in response to a disturbance in the same system: bounce back, adapt and transform. Diagram adapted from Walker & Salt (2006), Brand & Jax (2007), Folke et al. (2010) and Davoudi (2012) (Author 2015).

Transformability or the transformative capacity of a city is sometimes necessary to allow the urban system to mould to change. At times, moulding to change means the collapse of subsystems that are weakening the structure, integrity, function and feedbacks of the system. When value-judgements are made to transform a system like a city, then transformation is best interrogated at lower levels of the system where small-scale

experimentation is safer (Walker & Salt 2012: 100). Transformations at higher scales in the city can lead to the collapse of a large portion of the system. The more resilient a system is, the more graceful the collapse, because it has the capacity to "employ strategies for avoiding dangerous circumstances" (Zolli & Healy 2012: 14). Consequently, large-scale, resource intensive projects underway at higher scales in cities could potentially be weakening the resilience and functionality of its subsystems.

Arguably, the transformation of subsystems (which could include regeneration or collapse) in response to disturbances might be essential to systemic resilience. In fact, a system's overall production can increase due to disturbances (Gunderson *et al*. 2002: 115). In ecological systems, disturbance types, intensities and duration influence the character of the ecosystem and the people in it, meaning that the fragmentation or restriction of natural disturbances can increase vulnerability rather than mitigate the impact of disturbance (Dale & Haeuber 2001: 13).

In the application of resilience theory to the city, it is important to understand that certain conditions that arise from the system manifest certain types of resilience. This requires comprehension of the system and its relationships. It is possible for the same system to hold capacity for bounce back, adaptive and transformative manifestations of resilience within its subsystems. These three manifestations can simultaneously operate at different scales in the city in order to ensure that the functionality of the whole system persists.

4.10 General versus specified resilience

> But the biggest challenge and the weakest part of current resilience practice is the erosion of general resilience, worldwide, at all scales (Walker & Salt 2012: 197).

Within the wide spectrum of resilience thinking, two scales and focal areas of resilience practice occur. On the one hand, there is *specific resilience*, as it applies to engineering, strict ecological, and disaster recovery resilience, which focuses on the efficiency and optimisation of one aspect of the system (usually at a specific or lower scale, but not limited to it). Generally, specific or specified resilience applies to a high-impact disturbance or disaster with clear boundaries, which happens quickly and is quick to dissipate. It is the resilience to disturbances that we are aware of (Walker & Salt 2006: 121). As illustrated in Figure 18, specific resilience applies to maintaining a specific range of conditions, seen in the application of systems close to equilibrium.

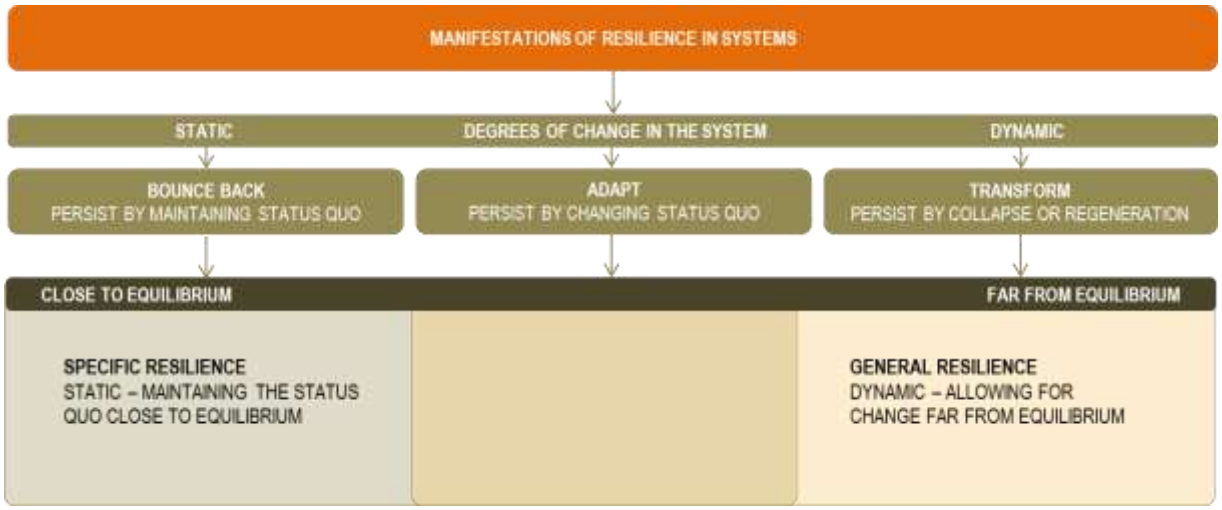


Figure 18 - The two focal scales of resilience: specific (localised subsystem) and general (larger system) (Walker & Salt 2006) (Author 2015).

On the other hand, there is *general resilience*, as it applies to broader ecological, social-ecological or evolutionary and transformative resilience of the system as a whole, to maintain the functionality, integrity, structure and feedbacks of the whole system (usually working across scales or at higher scales). In contrast to specific resilience, general resilience represents the ability of a system to respond to long-term pressure or cross-scale disturbances in the system that take a long time to manifest, have complex causes and consequences, and are not immediately visible. In other words, this is resilience to disturbances we are not even aware of (Walker & Salt 2006: 121; Walker & Salt 2012: 90). Both specific and general resilience are scale dependent. Contingent on the scale at which resilience is being studied, the system can embody specific and general resilience simultaneously (Anderies 2014). It is imperative that cities respond to both scales of resilience, since they must not only be more resource efficient, but also better able to absorb fluctuations in their social-ecological environments (Salat 2011: 475).

When cities are seen as holistic human-nature partnerships (Whiston-Spirn 1984), it becomes clear that *general resilience* has a greater ability to accommodate change within its systems. General rather than specific resilience of the urban fabric depends on complex structures that evolve in order to develop strong connections, like those seen in a leaf (Salat 2011: 465), which are better able to absorb disturbances. In contrast, *specific resilience* restricts or manages change through focused efficiency and optimisation of selective components of the system – these are especially important to engineering resilience when it comes to describing how quickly a (mechanical) system can return to some point of equilibrium after being disturbed, as a measure of its stability (Walker & Salt 2006: 62) close to equilibrium.

General resilience can be likened to robustness in a system; however, robustness is a design feature that mitigates limits of uncertainty, whereas general resilience is directly related to the capacity that a system has to keep functioning in spite of random shocks (Walker & Salt 2012: 90) or continued pressure on the system. In applying a 'command and control' approach to predict eventualities in complex adaptive urban systems, essential dimensions (the full range of tangible and intangible resources) are usually excluded, resulting in gaps in overall resilience (Walker & Salt 2006: 11). In this context, the efficiency of immediately beneficial or 'optimal' components is achieved, but with the loss of general resilience.

General resilience in a system builds capacity in three ways: a) it allows the system to respond quickly and effectively, b) hold resource reserves, and c) have options available for change. There are also a number of systemic attributes which contribute toward resilience (although not all of them need to be present in a system), which include diversity, openness, reserves, tightness of feedbacks and modularity. A system with resilience is able to adapt and evolve in harmony with the natural flow of change that occurs over time; specifying the resilience of aspects of the system over others decreases this potential. In Part Two, these aspects will be explored in detail within the context of Tshwane.

4.11 Resilience as a value neutral characteristic of a system

> From an ecological perspective, 'resilience is not about the speed of the bounce back, as much as the ability to get back' or in other words to recover in the direction of something like it was before a disturbance. This does not mean however that resilience is automatically desirable; there may be some changes or regimes that are negative to the overall quality and health of an overall system; negative changes or regimes could be allowed to collapse in order for the system to regenerate, however this may be challenging if they prove too resilient to change (Walker & Salt 2012: 37).

Both valuable and, alternatively, undesirable systems can be resilient and stable for long periods (Gunderson *et al*. 2002: 65). Resilience results from the configurations of a system that can often be 'locked-in' (Elmqvist *et al*. 2014: 19) and may need to be dismantled and reconfigured for the system to continue to function. When dealing with long-term, 'slow-burn' pressures like climate change, crime, corruption, rapid urbanisation and pervasive urban poverty (that includes a lack of quality education, basic services and safety), these press disturbances are themselves highly resilient. A subsystem might sometimes be so problematic or dysfunctional that for the larger system to withstand pressure in its case might mean having to cross a tipping point and collapse part of its subsystems.

Resilience itself is value neutral, because it is simply a characteristic of a complex-system. It is an objective measure of the capacity of a system to absorb change while maintaining its

functional integrity and structure. As such, 'resilience' could be present in both highly functional and dysfunctional systems.

In making full use of resilience as a theory for design and action and not just as a normative position, it is imperative to know that resilience is neither good nor bad, nor is it the solution or the goal. Resilience emerges from a system that can have structural qualities that make it more resilient or more fragile. By seeing resilience as a property of a system, the risk of resilience becoming a vague notion diminishes, and it rather becomes a gauge for the health of systems of concern. Resilience holds potential to act like a 'lens' through which to find the strengths and weaknesses of a city system (Walker & Salt 2012: 20; Pickett *et al*. 2014: 151).

Normative perspectives of urban resilience interpret resilience as a positive quality or goal (Elmqvist *et al*. 2014: 21). It must be emphasised that resilience is not (nor can it be) the final goal for development from a systems perspective; rather, it is a tool for studying systems and exploring development.

Despite active efforts to eradicate or reverse negative urban pressures, perverse systems remain locked-in over decades. Perverse resilience is a reality in which systems like terrorism and disease "persist and even thrive under sustained and powerful assaults intended to root them out and eliminate them" (Zolli & Healy 2012: 61), because of their well-modulated systems with enough reserves to take over failing functions. Basing a city's development policy on resilience as the 'goal', without specifying the resilience of 'what to what' within that urban system, might make the status quo producing the problems more resilient, only to perpetuate pressures.

4.11.1 Examples of resilience that could be interpreted as positive or perverse

In a city context, resilience can be present as both positive in what is perceived to be a positive functional system, as well as perverse in what is perceived to be a dysfunctional system. It is also possible that the same system is seen as a positively or perversely resilient system, as illustrated in Table 1, depending on the value-system making that judgement. What is perceived to be a positive functional system (say a suburban neighbourhood with amenities) or a dysfunctional system (say poorly serviced informal neighbourhoods) depends on the worldview and value-system of the individuals or collectives studying the system. In either case, resilience merely represents the capacity of a system to absorb or adapt to pressures without collapsing. This reiterates the core concept that resilience is a characteristic of a system's functionality and it is therefore value neutral.

Table 1 - Table showing examples of resilient systems in the City of Tshwane, as well as potential perceptions about its positive or negative resilience attributes .Photo's by the Author 2010. Table by the Author 2015.

EXAMPLE SET 1 - INFORMAL SETTLEMENTS AND OPEN GREEN SPACE	
	
Due to a number of conditions influencing urban development in Tshwane, informal settlements have become highly resilient subsystems in the city. Given the lack of formal housing, these self-organising settlements provide shelter close to work opportunities for many urban migrants. They persist in spite of poor living conditions and adversity. Their persistence could be seen as positive resilience in the sense that they provide shelter for the urban poor despite all odds; however, it can also be seen as negative because of safety, health, well-being and pollution issues, among others, that trap people into sub-standard living conditions and potentially degrade the natural environment.	Open green parks along river systems in the city are threatened by pollution, loss of biodiversity, and social issues like crime and homelessness. Environmentally, they often carry waste and pollution from industrial and urban areas further downstream. Given the value of green infrastructure in regulating resources and services in the urban system, seen from a positive perspective these parks bolster the resilience of the city by providing an essential function to the larger urban ecology. They also offer psychological relief from the 'concrete jungle'. However, they are also negatively resilient. For the poor they are an available resource for exploitation (water, wood, shelter); for the rich a crime and safety issue.
EXAMPLE SET 2 – TRANSPORT SYSTEM AND INFRASTRUCTURE	
	
Car-oriented design planning, development investment, and infrastructure is prevalent in Tshwane. Its urban morphology and its very large metropolitan area has made an integrated public transport system difficult to achieve. The resilience of the private car can be perceived as negative given the impact that it	The engineering solutions for infrastructural services like water, electricity and telecommunication provide efficient and robust services for standard uses. Their designs can be perceived as positively resilient in that they guarantee solutions for a range of disruptions and they provide an efficient use of resources and money.

has on sprawl, environmental pollution, traffic congestion, violent crime like hijacking, and an increase in unhealthy lifestyles. However, given the lack of an integrated public transport system throughout the metropolitan area (and perceptions about its lack of safety and reliability), private car use can be perceived as positively resilient as it is a reliable, safe and convenient form of transport between work, home and play that keeps the city functioning.	However, given the increasing social and environmental unknowns of the future, they could be seen as negatively resilient in that they do not accommodate theft, lack of maintenance or capacity for more services in future, nor can they guarantee performance in case of blackouts, flooding or sink holes. They are also highly yet negatively resilient, in that they are the preferred solution over green infrastructure services.
EXAMPLE SET 3 – GATED COMMUNITIES AND HERITAGE BUILDINGS	
 Gated communities are a resilient typology in new development in the city, perpetuated by high levels of violent crime, a thriving security industry, perceptions that government fails to deliver basic services, and lingering social, racial, class and cultural tension. Their resilience is seen as positive by large numbers of people buying into gated communities as a search for safer living conditions. However, given their effect on urban accessibility networks, their false sense of security, the duplication of service industries, and the increase in spatial and social division rather than integration, they can be perceived as negative at the scale of the larger city system.	 South African legislation protects buildings older than 60 years from demolition, and much of the architecture in the CBD is historically significant and protected. The fact that these buildings remain intact over long periods of time is evidence of their material and design resilience. It is also evidence of strong social structures that continue to preserve them. The fact that these 'old' buildings can adapt to new conditions and change function is a sign of their positive resilience. However, they may fail to remain relevant for younger populations and different cultures, and this is often perceived as a sign of their negative resilience.

As explored above, whether a system is perceived to be functional or dysfunctional depends largely on the value systems held by the citizens and professionals operating within an urban system, and the challenge remains in being able to make responsible, holistic, aesthetic, just and precise decisions in response to what resilience findings show.

A perceived dysfunctional system is not necessarily a vulnerable system, since a vulnerable system would show signs of weak resilience and could be close to collapse. Consequently, to suggest that resilience is the solution to vulnerability is to mistakenly assume that

vulnerability can be eradicated from a system. If aspects of a system's vulnerability were to be eliminated, they would manifest in other parts of the complex systemic network (Anderies 2014: 136). Hence, increasing the specific resilience in one aspect of the system does not necessarily increase the overall resilience of the entire system.

To weaken the resilience of a perceived 'dysfunctional' system while the resilience of a 'functional' system is strengthened is motivated largely by the worldview upon which decisions are made. For example, operating from the perspective that economic growth is not only good but imperative, global economic and political decisions made before the 2008 economic crisis "led the world to the brink of disaster" (Jackson 2009: 21). The resilience of this perspective continues to maintain and entrench the existing global trajectory of economic growth and crisis. Increasingly, this specific condition in the system is conserved and sustained, at the cost of the general resilience of the rest of the system (Walker & Salt 2012: 23). The perception that it is good to make vulnerable aspects of the system more resilient may actually be detrimental to the whole system.

Alternatively, operating from the perspective that cities should evolve and regenerate in response to changes over time, an urban system operated from an ecological worldview might value the ability of a city system to change and to accommodate development rather than growth. The current cocktail of crises could be seen as a rare opportunity to evolve toward greater consciousness embedded in an adaptation of investment in the general resilience, well-being, and flourishing of urban living systems. This would require a change in the perceived expectations that we hold about material success, value and ambition (Gilding 2011).

Using resilience theory to inform the study of urban systems provides insight into which subsystems are showing signs of high resilience, in the absence of which they may be showing signs of vulnerability. Informed judgements made in light of these findings may provide clues about strategies that can be applied to develop or collapse aspects of the system in order to transform the whole. In the case of rebuilding after a disaster, this perspective allows communities to interrogate the previous regime and explore more positive systems through regenerative design strategies. This occurred in Springfield in the USA, where the town's children saw a devastating tornado as their mother "who came to clean up a disaster" (Hes & Du Plessis 2015: 31). They were able to take part in a conversation to rebuild the town post-disaster, a privilege rarely afforded to children. Their input called for imagining how Springfield could be better, if it did not have to go back to what it was. This perspective underpins the regenerative design paradigm, which aims to

build the regenerative capacity (and thereby resilience and sustainability) of urban systems, architecture and communities by working with natural potential. Positive resilience in this perspective would be seen as a normative principle that aims to transform an existing system into a different scenario that builds the resilience of a 'regenerative' or 'positive' whole system. In contrast, perverse resilience would be the presence of 'negative' systems that are perpetuated within highly resilient, albeit dysfunctional practices or functions.

4.12 Conclusions

This chapter built an urban resilience understanding on the strengths of change and evolution in urban systems. It framed resilience theory in the context of its development over the past four decades. It explored resilience from three perspectives – resilience within systems, resilience as a normative position, and a hybrid form of resilience operating with aspects of both perspectives. Various fields or disciplines apply principles of resilience within their discourse; however, one of the three perspectives (systems, hybrid or normative) of resilience frames their methodology. Resilience thinking within each field might focus on resilience of specific aspects, but there is potential for general resilience strategies to inform interdisciplinary engagement in the global SES. This multi-perspective approach could form the basis of an urban resilience approach that first studies the system (the lenses), and then provides a practical path for intervention (the map).

In the case of systems-based resilience, three manifestations of resilience in response to change can be observed: to bounce back to a previous condition which existed before disturbance, to adapt the conditions of the system following disturbance, and lastly, to transform the conditions considerably in order to create a new state. In addition to framing the context of resilience theory, core concepts underpinning resilience as a property of a whole system were explored; namely, as a means of maintaining (stasis) or collapsing (dynamic) systems operating at either specific or general levels in response to particular or unknown disturbances. Lastly, the neutrality of resilience as an emergent property in a system was discussed, as well as the perceptual bias that informs notions behind 'positive' or 'perverse' resilience. The explorations of theory conducted in Part One will form the basis for the translation of ecological resilience concepts and models into the Tshwane urban system in Part Two.

CHAPTER FIVE

THE RESILIENCE LENS: UNDERSTANDING THE SYSTEM

5.1 Introduction

Part Two of this dissertation establishes the conceptual basis for urban resilience thinking by exploring examples of ecological resilience theory within the Tshwane urban system. Chapter Five forms the first in two steps that observe change through an ecologically grounded 'resilience lens' and build toward a third step for an urban resilience perspective. Since resilience is an emergent property of a system, to understand it requires comprehending the structure, patterns and relationships that give rise to the system. Consequently, Chapter Five explores the concepts and foundational thinking behind exploring a system and observing systemic change, by noting complexity across scales that makes up the panarchy of the system. It then explores how one would intervene within the panarchy by zooming into a specific scale in the panarchy known as the focal scale, which has scales above and below. Then, the variables and drivers of change are discussed, from those that emerge as rapid and infrequent disturbances in the system, to those that are more persistent and frequent. These concepts are explored using examples from the City of Tshwane, to gain insight into its unique flows and patterns of evolution.

5.2 Panarchy: applying ecological resilience within a system

> The lesson is that you cannot understand or successfully manage a system – any system, but especially a social-ecological system – by focusing on only one scale (Walker & Salt 2012: 17).

Resilience is studied at a specific scale which is impossible to separate from other scales. Since all complex adaptive cycles embody hierarchies of resilience (and vulnerability) at all scales of an interconnected and interrelated system, isolating the resilience of a system at a particular scale is useful only as an entry point for study. The linkages between the focus area and those scales above and below it need further investigation. In order to do this, the city system and all of its components (both living and non-living, tangible and intangible) need to be viewed as a holistic entity as described by a social-ecological system (SES).

A holistic view sees that a system is made up of various co-dependent (and equally essential) components operating at hierarchical scales (of subsystems comprising a system) of interaction and interrelation (Holling *et al.* 2002). These respond to various disturbances across time. However, "the panarchy model transforms hierarchies from fixed static structures to dynamic adaptive entities whose levels are sensitive to small disturbances" throughout the cycles of change that a system undergoes (Gunderson *et al.* 2002: 15). The

interplay between various press (long-term) and pulse (fast) disturbances in a system requires an understanding of where disturbances are operating from within various scales of the SES (the holarchy and panarchy).

Looking for links between press and pulse disturbances in cities is enriched by Arthur Koestler's (1990) *holarchic* understanding of the relationship between components, which themselves are whole with their own internal structure, while simultaneously being part elements in a bigger system within which they operate according to system rules and patterns that determine their behaviour (Wilber 1996; Du Plessis 2011). This notion of a single holistic system with nested subsystems that are simultaneously whole (to their subsystems) and parts of larger systems is termed the holarchy (Koestler 1990). Over the course of time, system properties emerge from the structural relationships and interactions of the components across different scales in the holarchy. These multi-scaled processes and relationships all undergo cycles of change and adaptation that in turn affect each other and inform the co-creation and evolution of the system as a whole. This creative process and the systems that take part in the adaptive cycles of co-evolution make up what Holling calls the panarchy, the theoretical framework that describes the multi-scaled dynamic relationships within an SES (Holling *et al.* 2002).

5.2.1 Setting the scene for panarchy via holarchy

The scales at which the *Kosmos* unfolds can prove extremely difficult to relate to, given the simultaneous yet contradictory states in which humans exist in relation to them. At one point, the scale of the universe is intimidating in relation to the individual, while at the other end individuals can hold immense potential for transformation within their context. Almost twenty years ago, Fritjof Capra wrote *The Web of Life* (1996) in which he used the powerful and poetic metaphor of a web to describe infinite connections between the interrelated systems that build the complexity of life across many scales. This created the awareness that actions ripple across the web in unquantifiable ways since the whole system does not equal the sum of the parts. Carl Sagan's explorations of the vast cosmos led him to realise that to the human species Earth represents everything, because it is the container of life and the driving force behind manifested existence; it is home. However, on the cosmic scale, Earth is merely "a mote of dust suspended on a sunbeam" (Sagan 1997: 12). Both Capra and Sagan described the same system; however, in one humans are capable of effecting change, while in the other their existence seems almost insignificant.

Understanding that this paradox exists requires understanding the fabric that makes up the cosmos, or rather *Kosmos*. *Kosmos* was originally used by the Pythagoreans to describe "the

patterned nature or process of all domains of existence, from matter to mind to God" and therefore contains the cosmos (or the physiosphere or the physical universe), the bios (or biosphere), the psyche or nous (noosphere) and the theos (the theosphere or divine domain) (Wilber 1996: 16). A distinction between cosmos (embedded with materialistic bias) and *Kosmos* (integrative or tangible and intangible realities) must be made in the consideration of resilience in social-ecological systems (SESs).

Kosmos represents a holistic system where its parts create patterns of connection that transcend themselves to emerge into new parts, in line with the characteristic property of the evolutionary process. The parts or wholes that make up this system are termed *holons* (Koestler 1990), and a *holon* is defined as "an entity that is itself a whole and simultaneously a part of another whole" (Wilber 1996: 17). Holons exist throughout the Kosmos and the patterns or relationships created between *holons* give rise to increasingly more complex structures, which transcend yet include all the *holons* that have contributed to their making.

In the built environment for example, a building illustrated as 'entity A' in Figure 19 is in Figure 19.2 made up of elements or *holons* like foundations, walls (made from materials like brick *holons* and mortar *holons*), floor slabs, and columns (De Kay 2011: 309). However, the building itself is a part of a whole city block, while the city block is made up of many buildings and it is one part of many city blocks that make up districts and in turn, a whole city, as shown in Figure 19.3.

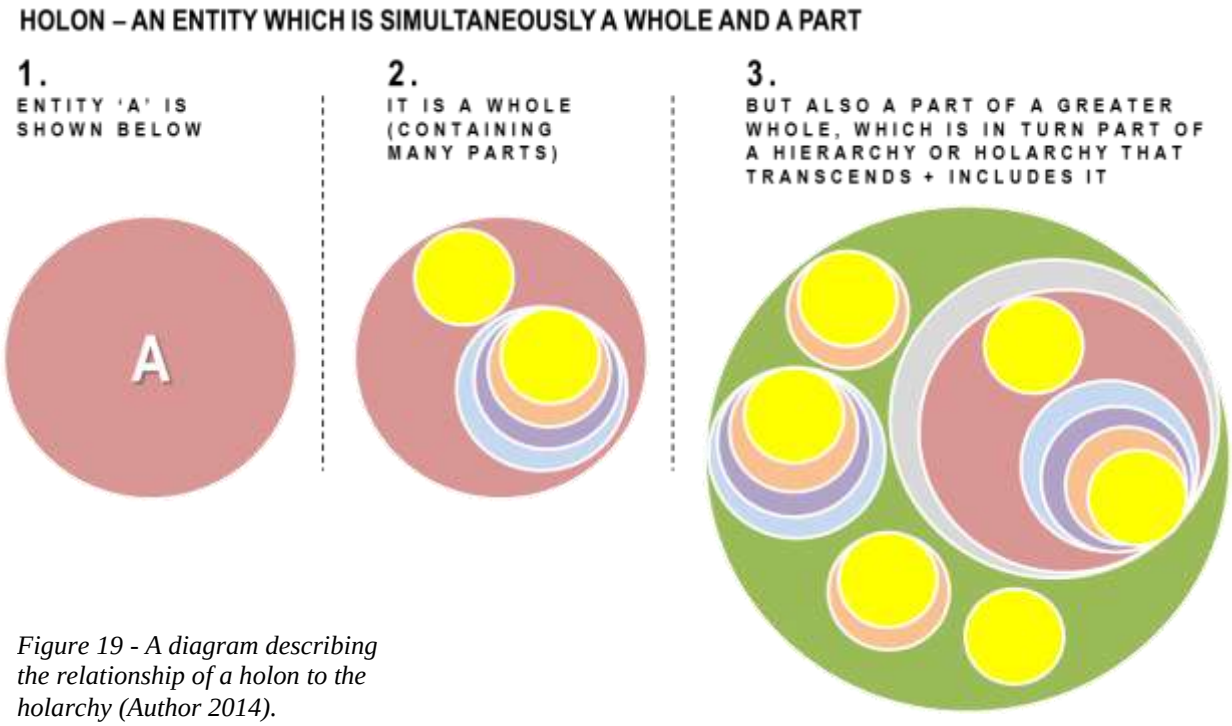


Figure 19 - A diagram describing the relationship of a holon to the holarchy (Author 2014).

Increasing levels of complexity correlate to a communion between holons that are able to transcend themselves and include what went before, to emerge as something novel. This pull toward self-transcendence and emergence in increasingly more complex ways represents the nested hierarchy of parts and wholes in a system and which is termed holarchy. When a holon can no longer creatively emerge and transcend itself, nor sustain its own agency or communion with another holon, then it has the capacity for self-dissolution and to return to a preceding state.

This hierarchy of holons, or holarchy, is fundamentally important in understanding that holons that are more complex emerge from less complex holons. However, the survival of the most complex holons is directly dependent on the health of the least complex holons from which they arise. As Meadows (2008) explains, systems have a self-organising 'structuring' property that allows for actively creating new structures by "learning, diversifying and complexifying" their existing patterns. This creates the holarchical system that evolves from the bottom up, where higher or more complex scales serve the purposes of the lower scales (Meadows 2008). Wilber describes the developmental sequence such that, if the biosphere is destroyed all life forms are destroyed however; the physiosphere could still exist. Alternatively, destroying the physiosphere would destroy the biosphere and *noosphere* that transcends it since, "where matter is favourable, life emerges; where life is favourable, mind emerges … where mind is favourable, spirit emerges" (Wilber 1996: 29-31).

This knowledge can guide a holistic response to development within our human systems, with reference to the built environment and its value and impact within the natural systems on which humans depend for survival and quality of life (De Kay 2011: 81). Valuing the intrinsic worth of all holons shifts the human value system into awareness that, as a component of our own being, destroying the biosphere is "literally suicidal for us … harming the biosphere is internal suicide, not just some sort of external problem" (Wilber 1996: 35). Furthermore, the study of urban resilience requires a holistic perspective that acknowledges that the whole system is more than the sum of the parts (Peres & Du Plessis 2014b), or "the whole is at a higher or deeper level of organization than the parts alone, and that's a hierarchy, a *holarchy*" (Wilber 1996: 25).

All life-forms possess different depths of evolutionary consciousness and are at different points within this process. While all holons hold intrinsic value, their roles are different from each other based on their trajectory and, in addition, can change along the developmental sequence that forms the evolutionary process. In the case of complex and emerging theories like that of urban resilience, holarchy and the evolutionary purpose offer

clear and useful orientating descriptions for exploring city systems. Broadly speaking, the narrative of urban evolution unfolds to increase depth, "to go beyond what went before, and yet include what went before, and thus increase its own depth" (Wilber 1996: 37). This narrative of the holarchy, along with the transcendent depth that drives existence, provides the building blocks from which to frame the panarchy.

5.2.2 Defining *panarchy*

While holarchy describes a means of structuring the *Kosmos* and its relationships, it does not provide a means of understanding how change occurs and how the system adapts to accommodate it. Holling *et al.* (2002) describe cycles of adaptation that shift systems toward greater or lesser complexity. These linked adaptive cycles operate at different scales of time and space but directly influence each other, and their linkages are very important for how the system as a whole operates. The nested and linked relationships between the various hierarchies of adaptive cycles occurring within the holarchy are what Holling describes as the panarchy (Hamilton 2008: 42).

Panarchy is a descriptive term that encompasses the unpredictable dynamics of natural and human systems at different scales, and is the key to successfully understanding a system that is self-organising and adaptive. As a term it "embodies notions that sustain the self-structuring capacity of systems (system integrity), allow adaptive evolution, and at times succumb to the gales of change" (Walker & Salt 2006: 89). The panarchy results from the self-organising patterns of processes or archetypes (Meadows 2008) that structure the system, and which in turn reinforce existing patterns. This dynamic structure is driven by a small set of key processes that affect the panarchy in a way that then governs the behaviour of the whole, so much so that "functioning of those cycles and the communication between them determines the sustainability of a system" (Hamilton 2008: 42). Within the panarchy, the lowest (or less complex) scales undergo rapid change, while in higher (or more complex) scales change occurs more slowly.

Interactions across different scales influence the adaptive cycles in the panarchy and are often more important in generating change than the actions themselves (Holland 1995: 3). Therefore hierarchies, patterns and structures of the system become important because "… the scale in which we are interested is connected to and affected by what's happening at the scales above and below, both in time and space. At each scale the system is progressing through its own adaptive cycle, and the linkages across scales play a major role in determining how the system at another (linked) scale is behaving" (Walker & Salt 2006: 88). Since disturbances create feedback loops, these adaptive cycles affect the

resilience of a system, either as balancing (or negative) feedback loops that attempt to return the system to equilibrium by resisting change, or reinforcing (or positive) feedbacks that allow for change (Meadows 2008).

5.2.3 Feedbacks

Understanding interactions between key components in a focal system provides clues as to how it can be managed for productivity, stability or resilience, as well as where the limits to resilience lie. Feedbacks form a crucial link in this understanding. Feedbacks loops are defined as "a close chain of causal connections from a stock, through a set of decisions or rules or physical laws or actions that are dependent on the level of the stock, and back again through a flow change to this stock" (Meadows 2008). In other words, a feedback loop is the change that occurs following an interaction between components of a system in response to a different signal, which in turn has an effect on the components. The time it takes for a feedback to show the consequences of a change in one part of the system elsewhere, refers to the tightness of feedback. An SES that takes longer to respond to signals of a forthcoming disturbance has less strength (Walker & Salt 2006: 95). The tighter the feedback, the better it is in managing a system, since "as feedbacks lengthen, there is an increased chance of crossing a threshold without detecting it in a timely fashion" (Walker & Salt 121).

A feedback loop is a closed "chain of causal connections", and therefore depends on the idea of a closed ecological system in which stewardship becomes important to the management of resources (Van der Ryn & Cowan 2007: 38). While this offers a useful perspective for managing known resources (especially in light of known limits to planetary resources), it is questionable whether, from a social-ecological perspective, we are functioning in a closed system, especially when we consider transcending levels of consciousness and *noospheric* development. For example, spirituality explains consciousness as the awareness or mindfulness of "a transcendent domain that resides beyond the everyday world of pain and struggle" (Chopra & Mlodinow 2011: 4) and extends to the suggestion that knowledge or consciousness of *Kosmos* rests inside the mind and is independent of space and time.

It is easy to see the relationship between cause and effect in a linear system, but the very nature of an SES with its complexity and levels of adaptation results in non-linear relationships between systems, where a cause does not produce a proportional effect. Feedbacks between consciousness and the physical world are important; however, this dissertation will focus on biophysical feedbacks touching only lightly on social or *noospheric* components.

Feedback loops have two important characteristics (Meadows 2008: 187-189). Firstly, the information delivered by a feedback loop (whether physical or non-physical) can only affect future behaviour and cannot correct past behaviour. Secondly, systems that have similar feedback structures tend to produce similar dynamic behaviours. Once interactions in a system have been affected (positively or negatively), the system will adjust in response to the changes to either stabilise or collapse the system. These adjustments occur in two ways, either as balancing feedback loops or as reinforcing feedback loops.

A balancing feedback loop is one which seeks to create stability in a system by resisting change, and is therefore called a 'negative' feedback loop because it "opposes or reverses, whatever direction of change is imposed on the system" (Meadows 187). Balancing feedbacks require enough resource reserves to ensure that they have capacity to oppose or reserve change. The critical feedback loops that keep a system in its current regime provide clues about the system's resilience. One of the reasons why pursuing efficiency in complex adaptive systems fails over the long term is because fewer resource reserves, along with limited variable capacity, eventually cannot maintain system stability. At this point, they may transform through collapse. Reinforcing feedback loops amplify or enhance the direction of change and are therefore called 'positive' – they are self-enhancing, lead to exponential growth or runaway collapses, and therefore can set in motion 'vicious or virtuous' cycles of change (Meadows 187). All systems depend on 'critical' feedbacks to direct them to stay in place or change, and if these feedbacks are weakened by not being tight enough, for example (Walker & Salt 2006: 146), the resilience of the system is weakened. In piecing together an understanding of the behaviours structuring an urban panarchy, it becomes useful to see whether interactions between physical and non-physical urban components are balancing or stabilising behaviours, and which feedbacks are critical to maintaining the identity of the system.

5.2.4 Exploring panarchy in Tshwane

Studying a city's panarchy highlights linkages and interactions between urban components that may influence development. An urban panarchy is affected by the actions of individual agents interacting through the structures of a system to effect ripple changes throughout different spheres and scales of the whole system. Usually, in a complex adaptive living system (which includes humans), individual agents interact until they figure out some workable order that allows them to survive, connect with their environment, and reproduce in never-ending adaptive cycles of growth, accumulation, restructuring and renewal (Hamilton 2008: 85).

Within a city, this can mean people interacting with the system to advance themselves, but often the effect might not be beneficial for the whole system in the long run, triggering a shift in the system. Through the exploration of criminal activity by a single agent in an urban panarchy, Du Plessis illustrates how individual actions can cascade through a system, fundamentally shifting its structure and identity (Du Plessis 2008). Initially at the scale of the individual, change occurs quickly and reaches far, while at higher scales of the system, this is not the case. The following imaginary narrative builds on the exploration by Du Plessis to illustrate how a peripheral agent to criminal activity in the Tshwane panarchy can have ripple effects on the physical structure of the city in response to his activities.

Listening to the radio on the morning of Nelson Mandela's release from prison in February 1990, 15-year-old Wonga[6] decided he would join his eldest brother in Mamelodi as soon as possible. He would trade the stifling conditions of rural life in the Transkei[7] for freedom in the capital city where he was sure the ANC would be in government very soon to improve life for black South Africans. His excitement increased as the years followed, tales of opportunities in a new South Africa reached him and gave him the courage to quit school at the end of Standard 9 and go to Pretoria to be a part of the first national democratic elections.

He believed his life would improve in Pretoria and that he could make the most of being a citizen in a democratic South Africa. However, after almost a year in the capital, Wonga had no permanent employment as competition for jobs increased with many qualified people moving to cities from the former homelands or following exile. Employers wanted workers with a Senior certificate or a driver's licence at least, and he had neither. He lived in a room in a small house his brother was renting, but the rental increased due to high demands for housing in Mamelodi. His brother had to rent Wonga's room out to someone who could pay. Wonga found cheap accommodation in a shack in an informal settlement just outside of Mamelodi, which he hated. Wonga worked as an 'informal' inner city car guard after car theft escalated. He 'watched' people's cars while they shopped or worked in exchange for tips. He bought a bucket and started washing cars while he looked after them, to make more money.

Soon more people were guarding and washing cars in his street. He earned a few good tips a day, but income was irregular and it was tough to be out in the sun, wind and rain every day. He was verbally abused by irritated drivers, and intimidated by other car

[6] Wonga is an imaginary character. His name means 'status' in Xhosa.
[7] Transkei was a former homeland in South Africa, and was assimilated into the Eastern Cape in 1994.

guards and police. One late afternoon, he was beaten by three men who stole all his tips. He then began paying a portion of his daily earnings to a local 'thug' in exchange for protection. Police presence in the inner city diminished and buildings remained vacated after offices closed down or relocated to suburban office parks. Petrol and food prices increased and he couldn't afford the daily train and taxi[8] ride home, so he began sleeping in the entrances to vacant buildings to save money, returning 'home' on weekends.

One afternoon he was told by a gang of men to 'get lost' for twenty minutes or they would kill him. When he returned they had stolen three cars from his street and the vehicle owners were talking to the police. They saw Wonga and he was arrested on suspicion of being involved in the thefts. He spent almost two weeks in an overcrowded holding cell before his release. When he returned home, he discovered his shack along with all his few possessions had been razed in a 'clean-up' operation. He felt the new South Africa had failed him. He worked hard, but got nowhere. Meanwhile the government did nothing to help him, while the 'white' people still had money, cars and houses.

Desperate, he went to an address that a person he met in prison gave him to look for help. There, Wonga befriended a local gang of car thieves and house burglars. For the first time after having lived in the capital for 7 years, he felt he was closer to achieving the lifestyle he deserved in the new South Africa. He lived with the gang in a 'real' house in Mamelodi and he had a cell phone so he could call his mother regularly. He made friends easily, was invited to many social gatherings and was popular with local girls.

He became increasingly involved in gang activities. Initially he drove around Lynnwood and Garsfontein[9] waiting to pick up his friends who were burgling houses without alarm systems or electric fences. Suburban streets were dead day or night, and it was easy to break into houses unseen by neighbours who hid behind their high walls in a perceived sense of safety. As crime increased, suburbs became fenced off with controlled access points, neighbourhood policing began and new developments were only in the form of security complexes. The gang had to adapt their strategy. Wonga learned to deactivate car alarm systems and satellite tracking devices, remove electric gates from tracks, break through palisade fences and place thick blankets over electric fences.

As crime prevention technology became more sophisticated, so did the gang's approach to crime. Wonga befriended local security guards and domestic workers to find out about the habits of the families they were targeting. With this information, his friends

[8] Taxis in South Africa are 16-seater commuter minibuses operated by individuals working for taxi associations.
[9] Lynnwood and Garsfontein are two suburbs in Tshwane about 20 kms south-west of Mamelodi.

were better able to execute hits, hijackings of luxury vehicles for car syndicates, and armed robberies. It was easy to silence witnesses, security patrol guards and corrupt police since people were desperate for money, or scared to speak out. Wonga tried not to think about what he was doing too much. After all, he was not pulling the trigger himself…

What this narrative and Table 2 illustrate is that a social-ecological entity is made up of many different parts that interact to make up and feed back into the whole. Because of this, the actions of a single agent can have far-reaching and powerful effects on the larger system and future trajectories long after that agent ceases to exist. By understanding the key components that make up the system as well as how they contribute to the dynamics of the whole, it is possible to see whether they are triggering feedbacks that "amplify change in the whole system or have a stabilising effect" through self-organising interactions that adapt and make novel configurations possible (Resilience Alliance 2010: 6).

The panarchy includes the notion that the self-organising capacity of a system to maintain its integrity allows for adaptive evolution while sometimes succumbing to forces of change (Walker & Salt 2006: 89). Understanding the system across multiple scales, along with its dynamics and the components that make up the whole, helps to reveal factors that "may be eroding or enhancing resilience in the system" (Resilience Alliance 2010: 6), and this is then the first and most important step in exploring a system through a resilience lens.

Table 2 - An exploration of the ripple effects of actions in the Tshwane panarchy (Author 2015).

WONGA'S ACTIONS RIPPLING THROUGH THE PANARCHY TO CHANGE THE 'LOOK' OF TSHWANE				
Less complex individual actions			More complex systemic interactions	
Progression of time creates feedbacks rippling through the larger system that increase complexity and the number of agents	**Actions**	**Localised effect**	**Intermediate effect**	**Distant effect**
	Decides to leave home	Inspires other youths to leave in search of a better life	Decrease in local traditions and community development	Flight from rural to urban
	Quits high school	Demotivates local teachers and pushes students to follow suit	Dropping student numbers reflect in budget and supply cuts	Fewer students and teachers lead to collapse of rural school systems
	Arrives in Mamelodi without a job or a place to stay	Puts pressure on his brother to provide accommodation and food	Increases the demand for affordable housing and jobs in urban areas	Pressures city infrastructure – housing, amenities, resources and civic services
	Cannot find a 'formal' job	Cannot open a bank account, or rent a place in his name – relies on informal systems	Impossible to get into the formal market – too many hurdles	Creates the conditions for a thriving informal sector and syndicates within it
	Moves to an informal settlement	Uncomfortable living conditions and demoralising environment, but cheaper than Mamelodi and no paper work necessary	Issues arise around ownership, health, safety and services. Policing is non-existent – self-organised policing where possible	Increase in informal settlements puts pressure on the municipality. Forced land removals and legal battles halt housing delivery
	Takes initiative to start working as a car guard and car washer in response to vehicle thefts and criminal activity in CBD	Attracts others to do the same (some as a cover for theft from vehicles or petty crime); this results in annoyance to drivers	Deters patrons from going to the CBD. Businesses suffer, creating demand to relocate to malls	Creates pressure to build formal paid parking lots and strip malls and relocate business away from the CBD
	Interactions with criminal activity in the CBD	Begins paying for protection and works with local car syndicates which leads to his eventual arrest	Funds criminal activity in the area and perpetuates local syndicates. Perceptions increase that the CBD is unsafe to walk in, or to operate formal businesses in. Informal businesses increase	Increased criminal networks grow organically with individual support and become impossible to police. Surveillance cameras, security guards, burglar bars, barbed wire and alarm systems installed
	Begins sleeping on the streets	Saves money on transport costs, saves time, uses saving to eat and drink at a local shebeen until late and sleeps in a vacant shop front in a derelict side street	Increases the demand for affordable shelter in the CBD, increases the perception of inner city decline, government departments move to peripheral suburbs	Pressure for the municipality to conduct 'clean-up' operations while a number of urban poor become 'trapped' in the CBD. Open spaces become fenced off and locked up at night
	Assists a gang in exchange for money, support system and protection: he is quick to learn about latest security advances and uses his charm to network the broader community. Assists the group in adapting their activities to feedbacks from the security sector	Decrease in policing, lack of investment in municipal infrastructure, higher burden on individual home owners facilitates criminal activity	Homeowners respond by increasing security in their homes, giving rise to security oriented businesses and private armed response companies	Increase in gated settlement developments on greenfield sites, densification of old suburban erven and plots into security complexes, lack of ownership over the street edge and public space, deterioration of the public environment

5.3 Understanding the focal system and its drivers of change

> How the system can and will respond, strongly depends on the states and dynamics of the system at the scales above and below (Walker & Salt 2006: 91).

A major challenge in trying to understand the panarchy is that the scale and complexity of such a system is impossible to replicate, therefore a full analysis of its components, drivers and feedbacks in both tangible and intangible spheres of the system is unrealistic. For this reason, resilience assessments of social-ecological systems (SESs), as promoted by the Resilience Alliance (Resilience Alliance 2010) and Stockholm Resilience Centre (Barthel *et al.* 2013), have been criticised (Davoudi 2012: 305-6) for being exclusionary of multi-dimensional systems and, by default, of inaccurate representations of the panarchy.

The world is a continuum in which there are no separate systems, yet an understanding of the forces driving the issues framing the context of the resilience of the system need to be explored by drawing a soft boundary around a focal system (Meadows 2008). Soft boundaries are not seen as hard limits, but rather as issues of concern that are investigated; these flexible soft boundaries adjust as more information is collected about the focal system. The purpose is not to replicate or understand an entire system, but rather to look for structuring patterns that might inform systemic interventions.

The focus is to observe the issues as they fit within the system by directing the investigation around soft boundaries. These soft boundaries are set within spatial (physical environment) and temporal (timeline) boundaries to create what is termed the focal system (Resilience Alliance 2010: 10). In addition to developing an understanding of spatial and temporal boundaries, the focal system is explored in relation to interactions with scales above and below the focal scale of the focal system. Last in the process comes the consideration of intangible aspects pertaining to belief systems and cultural norms that affect the focal scale and interactions within the larger system, but these will not be explored further.

5.4 The focal scale, with scales above and below

> … [U]nderstanding organisms as ecological entities is impossible without examining their linkages to some larger system of which they are a part (Pickett et al. 2013: 8).

Studying a system and its resilience depends largely on a clear idea of the focus area of study and the issue of concern within. Defining a focal system with spatial and temporal boundaries provides a good starting point for investigation from which a conceptual model of the focal system can emerge. This model gathers information about key drivers of change within and external to the focal system that influence its behaviour, its buffers, its interactions with multi-scaled disturbances, as well as the responses and interactions to

these changes at many scales. While the focal *system* forms the basis of investigation for systemic change, the focal *scale* is the scale within the panarchy at which the focal system predominantly operates. The focal scale is the entry point into the panarchy and provides a snapshot of the issue embedded within a larger complex system, shown in Figure 20-21.

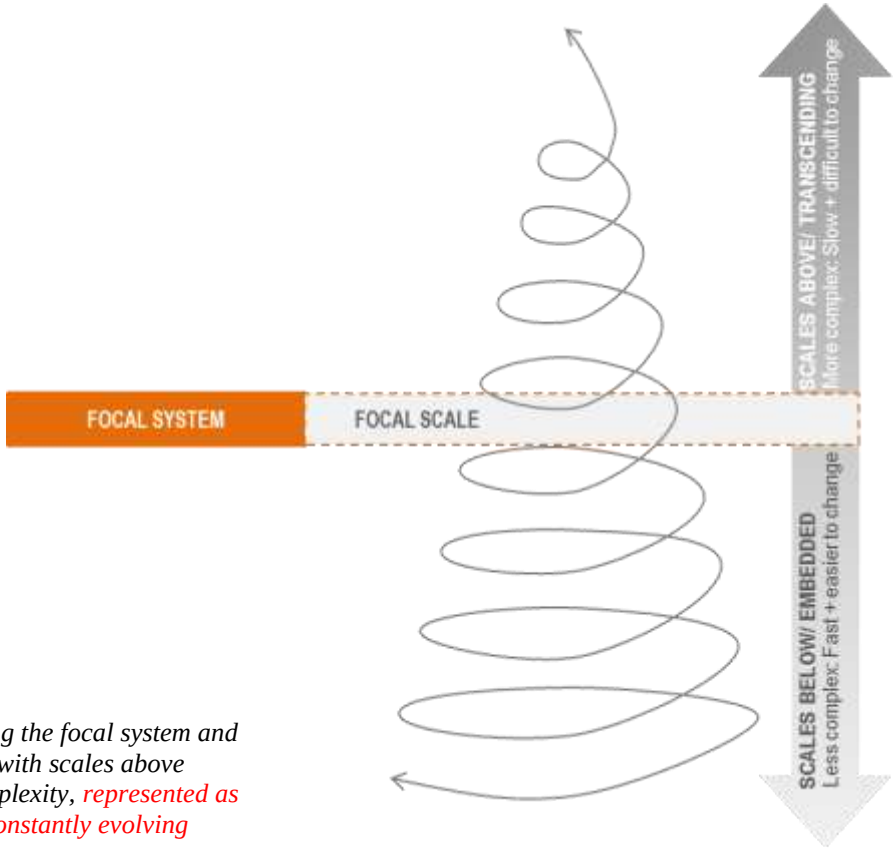


Figure 20 - Diagram showing the focal system and focal scale in the panarchy, with scales above increasing in depth and complexity, represented as a dynamic spiral, which is constantly evolving (Author 2015).

Studying the focal system does not entail a comprehensive replication or analysis of the system as a whole, but rather an investigation into systemic patterns that emerge within the focal scale (defined by the boundaries of time and space of the issues of concern), and may inform patterns or behaviours at higher or lower scales of the system. These issues manifest drivers or variables that set the focal system on a perpetual path of change that, in turn, influences the whole system through feedbacks. Studying the relationships between drivers of change in the focal system requires observing the systems below and above it.

Regardless of which position the focal system has within the panarchy, there will always be scales above it, comprising greater complexity in *depth* where change occurs more slowly, as well as finer scales below it in which less complexity in *depth* allows for faster change. Allowing disturbances to occur at lower scales in the system can mean that at higher scales, dynamic stability is experienced. This develops increasing clarity around critical system components that are "connected to and affected by what's happening at the scales above and below, both in time and space" (Walker & Salt 2006: 88) (see Figure 21).

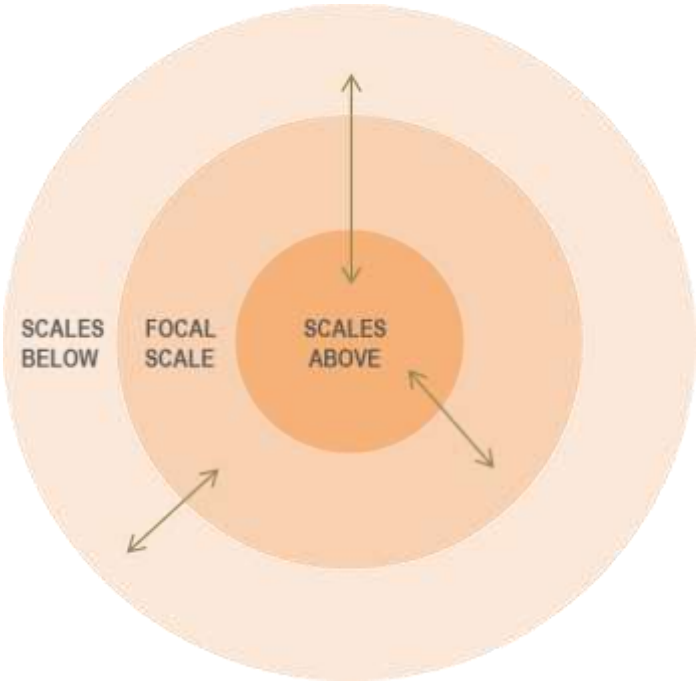


Figure 21- The focal system of a particular issue in relation to scales above and below in the panarchy that are undergoing interrelated change (Author 2015).

5.5 Variables

Variables are those elements that show evidence of change within the system and create its dynamic character as well as describe its characteristics. Variables can be internal components within the system that give it its character, but they can also be external forces that disrupt the system. Ecological resilience theory describes system variables in three areas. Firstly, *state variables* describe the important aspects or components of the system that define the current state of a system. The number of variables in a system can be unlimited, but their particular combination is what defines the current state of the system. Secondly, *controlling variables* are those key variables in a system that control the levels of the other variables and keep the system within certain margins. Thirdly, *drivers of change* are external variables that can create slow or fast change in the system components. Slow variables determine the dynamics of fast variables, but change in slow variables is instigated through change in fast variables (Walker & Salt 2006).

In a panarchy undergoing constant change, the ability of a focal system to recover or adapt to change depends on many changes in variables at lower, less-complex scales, cascading up to higher, more complex scales. At this point, it becomes important for the higher scales to have memory regarding how they should respond. Different scales influence each other permanently, either as large-scale, slow variables affecting the trajectory of smaller scale cycles, encouraging them to repeat (memory), or smaller scales combining to initiate a revolt in the scales above, precipitating change and reorganisation at the higher scales (Walker & Salt 2006: 93).

5.5.1 State variables

The key variables or components that make up a focal system do so with various amounts of each combining to create a particular state in which the system finds itself. This multi-dimensional space arises from all possible combinations of amounts of these variables (Walker & Salt 2006: 54). It is therefore a dynamic space that is constantly morphing between the different values of the variables, and always attempting to remain within their range. Variables or components in an SES that are relevant to the key issue being investigated can be found by asking the question, 'resilience of what?' (Resilience Alliance 2010). For example, if we look at the issue of a lack of affordable housing in Tshwane's eastern suburbs, we could identify the affordable housing state space as consisting of affordable units, people (users, government and third-parties), available land, amenities and job opportunities as variables that define this system. The values of these variables are what constitute the system, where the state space is the five-dimensional space that unfolds from all possible combinations of these variables in different proportions. The system dynamics result from shifts in this state space through changes within, as well as changes resulting from external variables that disturb or disrupt aspects of the system (but do not collapse the state space).

5.5.2 Controlling variables

Controlling variables are those that determine the levels of other variables (Walker & Salt 2006). In other words, they form a key role as components of the system and are usually also those that change slowly and appear to be most conserved. Shifts or changes to them will ripple significantly throughout the rest of the system, because control variables determine the levels of the other state system variables. Based on the previous example, control variables in affordable housing in the east of Tshwane scenario would be people – predominantly the demand from users (numbers) and the people implementing regulations in local government (capacity) – and available land size, restrictions and opportunities. These two key controlling variables will have an effect on the quantity and quality of affordable units available, the reaction from third parties to the unit typologies and target market, amenities, and job opportunities in the area.

5.5.3 Change variables (or drivers of change)

Change variables or drivers of change within an SES are the consequences of disturbances that occur slowly over long periods of time, or abruptly over a short period of time. Apart from being characterised by time, change variables are also divided into those that are characteristic (known or expected), large and infrequent (catastrophic but rare) and

unknown (cannot be predicted or prepared for) (Walker & Salt 2012: 49). In living systems, the complexity of interactions and relationships between components in a system increases after a disturbance, and as time passes they become more diverse and well-connected internally (Pickett *et al.* 2014: 148).

Change variables therefore generate conditions from which the system can regenerate and create complexity, and disturbances create the force with which this can happen. Walker and Salt (2006) refer to these change variables predominantly from the perspective of slow variables, while the Resilience Alliance refers to press (fast) and pulse (slow) disturbances (Resilience Alliance 2010). While there is a level of overlap between both terminologies, there is a slight distinction. Variables are seen more as those components within a focal system that are dynamic and changing, while disturbances infer something that is external to but affecting the focal system. While this distinction is useful only in identifying the source of variables and disturbances, the importance lies in seeing that both are referring to components of a system that undergo change and therefore add to system dynamics. This dissertation uses change variables and disturbances interchangeably, as a disturbance might have become a variable component of the focal system over time.

Change variables or disturbances are important components within a focal system and have a direct bearing on understanding a system's resilience. They can be characterised according to their frequency, duration, severity and predictability, and can be pieced together to better understand the variables of a focal system. Often press and pulse disturbances with similar characteristics occur in combination, with a series of disturbances impacting on a system without giving it time to recover (Resilience Alliance 2010).

While most research conducted on the subject of urban resilience tackles issues relating to short-term (pulse) disturbances like flooding, earthquakes or terrorist attacks, relationships between persistent (press) disturbances or slow variables that occur over long periods of time are ignored, even though their structures often lead to pulse disturbances. Examples include resource exploitation, natural disasters, rapid urbanisation and urban poverty, informal settlements, policy implementation, and environmental degradation, as well as social concerns including population growth, unbridled capitalism, political dictatorships, intolerance, sexism, racism and censorship, materialism and reductionism, health and safety, crime and education. Press disturbances tend to become key variables in an SES, occurring in both the biophysical world as well as the noospheric world. However, they are rarely integrated as mutually informing components. Ignoring underlying press disturbances or slow variables results in compounded future problems.

5.5.3.1 Press disturbances – large-scale disturbances or slow variables

Socio-ecological systems consist of many variables reaching across scales. SES trajectories are governed by only a handful of key interacting, slow-moving variables which also form the controlling variables of the focal system. Slow moving variables drive change slowly over decades, centuries or millennia; sometimes their effects can be traced, but often in the case of natural systems (and even social systems) they are not obvious until it is too late. The erosion of key slow variables and processes in a system create press disturbances that can lead to irreversible collapse (Gunderson *et al.* 2002: 7). The most significant press disturbances in the urban condition are those that humans have some influence over. Societal beliefs and policies are slow variables that have significant effects on the structures of SESs. As human populations and especially consumption levels grow, they will intensify press disturbances and influence the system's general resilience.

Many variables are driven by the politics of economy – the underlying driver of growth, development and societal goals within cities and their regions. Press disturbances like informal settlements, environmental degradation and urban poverty impact all countries to some extent, but the assumption is that Africa is most at risk since it is experiencing high rates of urbanisation in the context of pervasive poverty and inequality. These city environments may also not have the adaptive capacity to leverage change or steer socio-economic and environmental systems beyond survivalist conditions.

In these systems it proves useful to see that slow variables are often the source of vulnerability within a system when they are managed in a way that forces them to resist change. For example, increasing numbers of people sleeping in the streets of the CBD due to urban poverty, might result in food and shelter support from local charity organisations that reinforce the press disturbance, combined with a lack of governance to address the drivers beyond the focal system perpetuating the problem (remedy versus cure approach). As these managed responses persist, the slow variable of urban poverty becomes entrenched in the focal system, thereby increasing the vulnerability of the other state variables.

5.5.3.2 Pulse disturbances – small-scale disturbances or fast variables

Pulse disturbances usually occur as discrete events and do so fairly rapidly in relation to press disturbances which exert more gradual pressure. In addition, pulse disturbances occur unpredictably in terms of timing and magnitude, leading to disruptions to the system that cannot always be forecast or planned. However, gathering as much knowledge as possible about the focal system and its disturbances can reduce uncertainty about individual events

and known risks, while attempting to reach certain goals. Pulse disruptions can be droughts, fire, disease, flooding or even riots and large-scale events like the FIFA World Cup held in South Africa in 2010. Furthermore, what might appear to be a pulse disturbance in a short time frame might actually be a regularly occurring incident over time, which may turn into a press disturbance and a slow variable in the focal system.

In the case of physical disasters and flooding, pulse disturbances generally lead to the response of protecting the system from the disaster. Over time, the efforts invested in making protection systems more efficient (by removing variability and redundancy) proportionally increase their vulnerability to smaller disasters that were previously easily accommodated, and reduce their capacity to cope with compounded press and pulse disturbances affecting the system. Pulse disturbances are often symptoms of much larger issues placing pressure on the panarchy; however, they are the first to receive a lot of attention in a focal system. Being able to identify changes to the frequency, magnitude, duration and predictability of pulse disturbances can provide vital clues about slow variables that might be driving these changes.

5.5.3.3 An example of a pulse disturbance turned press in the City of Tshwane

Tshwane's connection to water was integral to its establishment as the town of Pretoria in1855 (Dippenaar 2013: 6). The abundance of water and game drew communities such as the Bakwena in the 1600s and the Matabele in 1825 (evicted by Zulu impis around 1832) (Andrews & Ploeger 1989: 2) to settle in the area between the Apies River and the Steenhovenspruit. British and Boer settlers began to arrive soon thereafter and in 1853, portions of the newly established Daspoort and Elandspoort farms were consolidated to form the town. The Apies River system is one of three prominent streams in the inner city, with the other two being the Steenhovenspruit and Skinnerpruit. The original 1855 grid plan of Pretoria, with a centre-point at the axis of two prominent avenues, connected closely to the streams upon which the town depended (Peres, Barker & Du Plessis 2015).

As Pretoria evolved from settlement to city, the built environment encroached onto the floodplains. Water was sourced from the Apies River, illustrated in Figure 22 (Le Roux, 1991: 64), but the river would often burst its banks, damaging buildings and endangering humans (Engelbrecht, Agar-Hamilton, Pelzer, Behrens *et al.* 1952: 66). The 1880 floods (Engelbrecht *et al.* 1952: 100) led to the decision to canalise the seasonal Apies, Steenhoven- and Walkerspruit streams, thus obscuring and eroding the natural flow of the original arteries and reducing rivers to storm water channels (Jordaan 1989: 28).

Figure 22 - Pretoria in 1886 as seen from Daspoort Ridge. In the foreground is the confluence of the Apies River and Steenhovenspruit (Le Roux 1991: 64).

Decision-making at that time was deeply entrenched in a reductionist worldview that sought control over the natural forces of destruction affecting the optimal functionality of the city. The short but destructive pulse disturbance of seasonal flooding led to a response that has itself created a long-term press disturbance in the greater urban ecology. As flood mitigation, the channels are a huge success. When there are heavy rains, the well-engineered (or over-engineered) and structurally robust channels fill up to capacity and carry storm water away from the city, and then return to their usual slow trickle. It is a highly resilient element in the urban system that bounds the inner city and has defined its urban character for over a century. At its own focal scale it is highly resilient, but it may not be building structures of overall resilience required at higher or lower scales of the Tshwane SES.

5.6 Understanding the system: exploring a focal system in Tshwane

> … [C]ities are networks (McInroy 2014: 209).

This section aims to understand the relationship between the various levels of press disturbances in the Tshwane panarchy from the perspective of an informal settlement known as Woodlane Village. The panarchy is derived from a desktop study of newspaper articles sourced over the last fifteen years, a time during which informal settlements have persisted in the city despite efforts to remove them. It is also based on observations of the

focal area of Woodlane Village in order to build an awareness of the complexity of the phenomenon of self-organised informal settlements in established suburbs east of Tshwane.

5.6.1 Informal development, the other face of life in the city

Since the establishment of a democratic South Africa in 1994, the country's major cities have experienced an influx of migrants from rural areas and neighbouring African countries into 'townships' and informal settlements on municipal lands (Soggot & Amupadhi 1997). Rural areas have also experienced high levels of 'rural urbanisation' (McHale *et al.* 2013). In the Apartheid City plan, racial segregation was achieved by deliberately separating white, coloured and black neighbourhoods using natural features, industrial 'buffers', or distance. In South Africa, the terms 'township' or 'location' referred to 'non-white' neighbourhoods located on the city periphery. Designed to be controlled self-contained areas that functioned separately from the 'white' city, 'townships' played a crucial role in the Apartheid City plan and embodied the complex process characterised as functional inclusion, spatial separation and political exclusion (Chipkin 1998).

After the system of control collapsed, South Africans of all races were drawn to city life; however, these urban areas are not always able to meet their needs for housing, employment and health within formal infrastructure frameworks – a trend prevalent the world over (Burdett & Sudjic 2007). As the number of urban poor increases, so does the gap between the rich and the poor. Despite being dominated by strong African and global cosmopolitan influences, the *Afropolitan* (Nuttall & Mbembe 2008) nature of contemporary South African cities has been slow to bridge the social disconnect that continues in forms like informal housing and trade, up-market security estates, car-dominant planning, increased crime and dwindling public amenities. Government investment in the 'townships' continues, with little affordable or alternative subsidised housing being provided in areas of the city where poorer residents want and need to be in order to sustain livelihoods. In twenty years of democracy, a high quality integrated housing scheme is yet to be realised in the eastern suburbs of Tshwane.

Over the last fifteen years commercial and residential development and investment in Tshwane has shifted eastward, due to the perceived decline of the inner city and the higher-profit development opportunities in the suburbs east of the CBD, as shown in Figure 23. The gated estate typology has been a dominant response to the perceived security risk of living in the older suburbs (Landman 2007), as well as the need for affordable medium density housing for middle-income markets. A number of golf and equestrian-themed estates characterised by large, physically cut-off and privately serviced and managed

landholdings have drawn high-income earners. Movement around them is confined to car-dominated roads poorly serviced by public transport, save for the private mini-bus industry. These areas rely on malls, private schools and hospitals for their social service infrastructure, with little or no council-led investment in amenities, infrastructure or public spaces. The typology results in pockets of leftover land consisting of neglected municipal sites, servitudes and natural areas (Peres & Du Plessis 2013).

Figure 23 - Aerial view of the Tshwane CBD and Mamelodi in relation to a few eastern suburbs. Base image courtesy of Google Earth. (Author 2015).

The formation of at least ten fast-growing informal settlements in these 'left over spaces' frustrate local communities who require clarity about the future decision on whether these informal settlements will be removed, upgraded or left as they are. However, these settlements have not emerged in isolation from the rest of the system. Most upmarket estates and households rely on a number of low-income workers to provide services as security guards, cleaners, domestic workers, gardeners, child minders, retail and construction workers and handymen. However, residential estates offer no housing options for these marginal workers to live close to work, nor has council provided affordable housing in the areas; to make their livelihoods, workers are left to commute long distances at high cost to areas badly serviced by public transport (Turok *et al.* 2011). Over time, marginal

workers save on transport and accommodation costs by uncomfortably 'squatting' close to work opportunities.

High transportation costs, lack of affordable housing, ad hoc work opportunities and commercial and residential development opportunities in the east have resulted in the emergence of informal settlements in tracts of well located, yet unmaintained, un-used, and 'out-of-sight' land. The situation remains unresolved, since informal settlers cannot be evicted from the land without suitable alternative housing options being provided by the municipality (Department of Housing 1998).

Woodlane Village, illustrated in Figure 24, is the result of the systemic processes described above. Situated just east of Moreleta Park, its emergence has led to tension between the Moreleta Park community and the growing number of 'vagrants'. The 'formal' community links criminal activity to the informal settlement, and cites the over-crowding and unsightly, unhealthy living conditions as reasons for the declining value of their property investment (Roux 2012). It is often referred to as 'Plastic View', because it appears to be made largely from salvaged plastic (Venter 2012). It was 'organised' by some of the informal settlers in 2008, with the support of a local non-government organisation (NGO) and under prescribed conditions from the municipality; it comprises 856 households and roughly 3000 residents. Its physical characteristics and location inform its emergence and resilience.

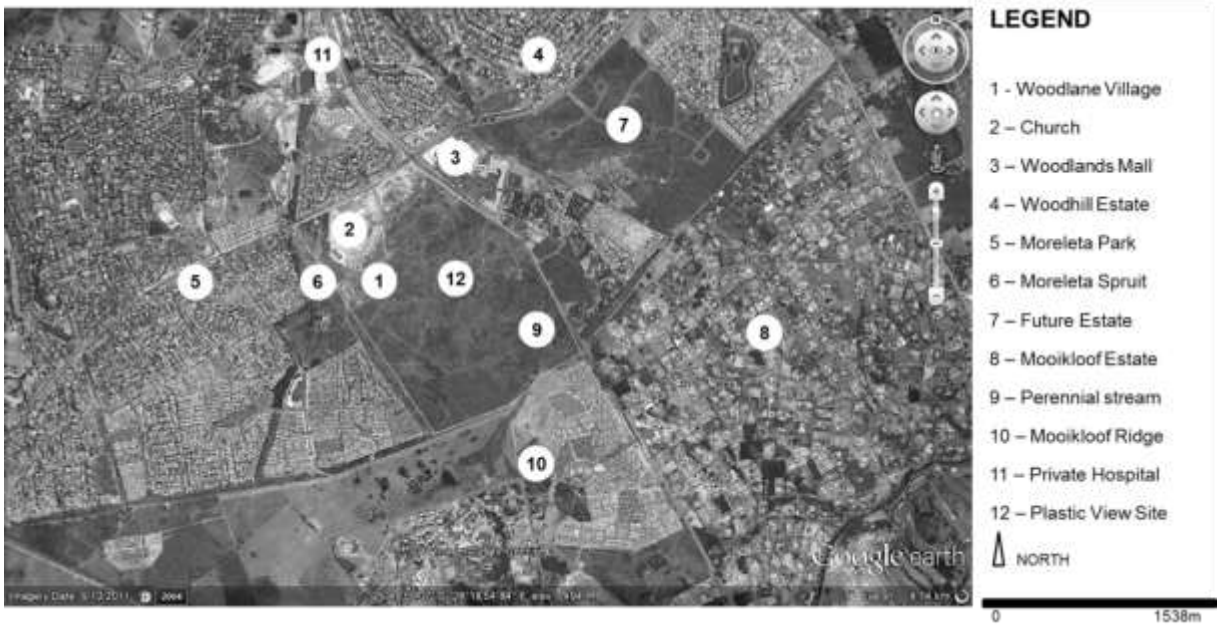


Figure 24 - Aerial photo of Plastic View and its surrounding context. Base image courtesy of Google Earth (Peres & Du Plessis 2013).

Residents of Woodlane Village say they have been living on this municipal land since 2001, because of the need to be closer to job opportunities (Hlahla 2010). It is conveniently located next to wealthy estates, a large local church, a mall, as well as a Christian faith-based community outreach NGO. In mid-2012, the municipal land was allocated for subsidised housing by court order. This was the result of persistent objections from the greater community against a) the rising number of informal settlements in the area, b) the effect on investment (Roux 2012), c) the risk of poor quality RDP housing being built on the land, and d) human rights organisations protecting the settlers from eviction without suitable relocation options as required by law (Department of Housing 1998). The court order set a precedent for the city; its response to informal settlements, alternative subsidised and affordable housing integration, and transformations to housing or planning policy are all consequently affected. However, the municipality has not yet realised any visible action with regard to this court order.

Given the increasing demand versus lack of housing in areas of high economic activity, the court order creates an adaptation within the city system that allows for alternative responses to housing and development in the area, if the municipality follows through. This creates a window of opportunity, a threshold between an existing system state and, possibly, a new improved one. In addition, the resilience of the community to find and create shelter on the land despite eviction efforts shows high levels of adaptive resilience. Similarly, the resilience of the greater community in either fighting to have the settlement removed, or assisting in developing long-term solutions through collaboration with the Woodlane Village residents, has been high. Both communities are showing signs of resilience through adaptation of their networks, physical responses and system relationships, and both are evolving the city form.

5.6.2 The Tshwane panarchy from the perspective of Woodlane Village

Insight into patterns of change and adaptation in the Woodlane Village focal system and the panarchy in which it sits, highlights the linkages between press and pulse disturbances, as illustrated in Figure 25. This knowledge shapes awareness that settlements like Woodlane Village are not isolated from bigger forces, but are connected to both large-scale issues pressuring the city, and small-scale needs and responses of its citizens.

To achieve this understanding, the Tshwane panarchy is broadly divided into three scales. First, Woodlane Village forms the focal scale along with surrounding suburbs like Woodhill, Mooikloof and Moreleta Park. Secondly, finer scales comprising the residents, community support units, natural features and Woodlane's own features form the second scale. Thirdly, higher scales comprise the Tshwane City Region and beyond. Within each scale, a variable

may respond to a disturbance and simultaneously exert pressure on the system that cascades through the panarchy. Therefore, Woodlane Village may have emerged out of press disturbances from the City region scale, but it has also pressured the intermediate scale of the surrounding neighbourhoods.

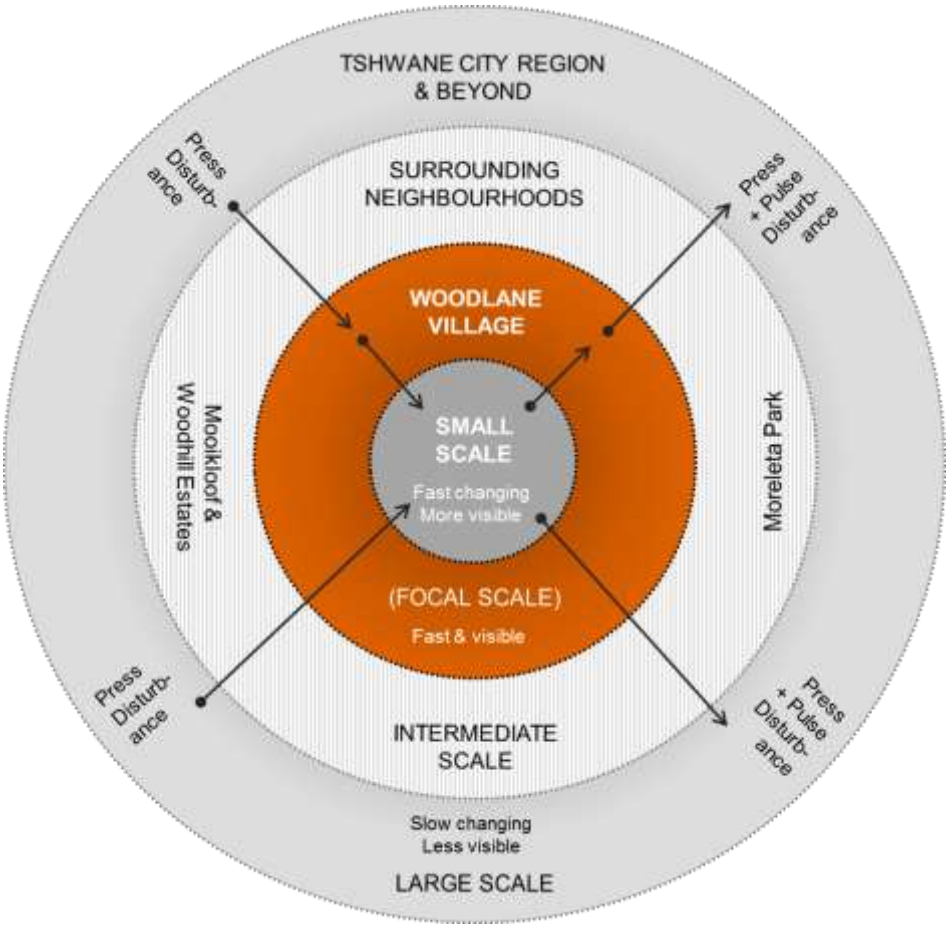


Figure 25 - A diagrammatic representation of the Tshwane panarchy, with Woodlane Village as the focal scale: scales above show higher complexity and slow change, with finer scales below (or within) showing more linear relationships that can change quickly (Peres & Du Plessis 2013).

5.6.3 Understanding multi-scale disturbances in the panarchy

Woodlane Village demonstrates the interaction and relationship between change variables and their influence on state variables across the focal system. Strong connections between seemingly unrelated components emerge, such as informal settlements developing close to middle to high income suburbs in Tshwane. Awareness of these intertwined issues may help inform the community as a whole about their responsibilities to each other, and to the natural ecosystem of which they are a connected and integral part. Understanding of the multi-scale disturbances in the focal system is built on the press disturbances impacting upon Woodlane Village over the three scales of the panarchy discussed previously – the

focal scale, the scales above and the scales below. A few of the most prominent disturbances will be unpacked to understand their multi-scale system dynamics (Resilience Alliance 2010).

5.6.3.1 Large-scale press disturbances that created Woodlane Village

Understanding the multi-scale dynamics of this panarchy begins with the forces driving the city and national system, leading to gaps in the urban tissue that are points of vulnerability and opportunity. Many press disturbances have caused the conditions under which Woodlane Village could emerge; a desktop review of newspaper articles narrowed the list down to three main issues (Peres & Du Plessis 2013).

The first relates to the Apartheid City plan and its structural legacy affecting the contemporary functioning of Tshwane (Herve 2009). Its major effects are visible in the extensive distances between affordable housing located in former 'townships' and work opportunities within the wealthy suburbs; Tshwane is the metropolitan region with the longest commuting time (SACN 2011).

The second is linked to the first, and deals with the lack of alternative affordable housing options for unskilled and semi-skilled workers in newer suburbs. Many security estates or residential complexes do not provide on-site staff accommodation, while previously most homes in South Africa had staff quarters on the property. There are limited facilities for 'temporary' workers working a few days a week in an area. This is combined with the lack of council investment in integrated housing outside of the peripheral 'townships' (Herve 2009).

The third comprises policy, which has created loopholes in the allocation of housing. The allocation of housing subsidies and legislation that prohibits the removal of settlers without providing alternative accommodation, offers an opportunity for informal settlers to 'jump the queue' and get RDP housing after invading municipal land from which they cannot be evicted without receiving alternative housing (Department of Housing 1994).

5.6.3.2 Press disturbances created by Woodlane Village and disturbing the larger system

An analysis of the pressures exerted by the focal system on the intermediate scale and the larger city scale shows that Woodlane Village has grown and persisted despite a number of disturbances (Roux 2012). Concurrently, articles refer to the pressure that its presence is placing on surrounding communities and the overall system. Local communities have been concerned with an uncertain future: will Woodlane Village be removed, maintained or formalised?

Uncertainty has been one of the forces behind fragile market perceptions that adversely affect (pre-recession) property prices in the area and alienate local communities (Roux 2012). Another has been the perception that the informal settlements link to criminal activity in the surrounding neighbourhoods, triggering higher security measures as responses and subsequently higher criminal violence. The third force has been the loss of ecosystem services and reduced quality of the natural environment. Lack of sanitation and dumping has led to pollution of water courses and has negatively affected the overall environmental quality on site, including the open space systems to which these streams connect on the intermediate and city-wide scale. Lastly, the recent court decision to formalise the settlement creates a precedent for the city regarding its response to other informal areas within the region (Venter 2012).

5.6.3.3 Press disturbances that created pulse disturbances within Woodlane Village

The last step looks at pressures that have led to pulse disturbances occurring within Woodlane Village that have thus far been overcome by the community. The first pulse disturbance deals with seasonal risks and natural disasters. Winter shack fires are a reality. Due to a lack of building controls, shacks are built too close to each other without fire breaks or insulation; and due to a lack of municipal investment in clean or alternative energy for poorer communities, paraffin lamps and open fires are sources of heat in winter (SAPA 2012). In summer, floods are raising concern. Woodlane Village is located on a small portion of a large site containing a flood plain, with two streams running through part of the site. During heavy rains the site is saturated by water from the Rietvlei Dam upstream and storm water runoff from surrounding expanses of hard surfaces (Mail & Guardian 2008). Eviction attempts by the local authorities have been a source of pulse disturbances; rising tensions from the local community propelled forced removals of a number of informal settlements in the area. In 2006 a clean-up project carried out by Metro Police resulted in shacks and their belongings being burnt, in an effort to remove the informal settlement and the homeless without providing alternative accommodation (Venter 2012).

In turn, this resulted in another pulse disturbance – that of local non-government organisations intervening in forced removals by organising and offering legal and social assistance to the affected community. Through this assistance, the various informal settlements scattered through the site were organised in 2008 into a single organised and regulated informal settlement within a controlled and demarcated area managed by the local authority. This response was a balancing feedback that aimed to counter the change. But while successful on this site, the confinement of the growth of Woodlane Village has resulted in similar 'land invasions' on other 'empty' sites in the east, thereby reinforcing the

phenomena. In close proximity, 'Cemetery View' is emerging as a fast-growing settlement next to an existing cemetery, which has begun to encroach into the burial grounds (Martins 2014). More recently, politically motivated 'land-invasions' by the Economic Freedom Fighters have occurred in land further away which they coined 'Malemaville' (Masombuka 2014). This settlement was created as a result of a court case to secure the informal settlers on site until alternative housing could be provided.

The last pulse disturbance identified in the desktop study was the court decision to formalise Woodlane Village, leaving the informal community excited to have 'real homes at last' (du Preez 2012). However, over three years later, the area has not yet been formalised and the issues persist. The internal resilience of the informal community has been strong thus far, showing high degrees of adaptability, one of the positive characteristics of informal settlements that is often ignored (Huchzermeyer 2008). The eventual formalisation of the suburb (and the time it takes for this to happen) will have an impact on the community's resilience – changes to the physical environment, to the NGO support structures and to the governance system will have a positive or negative effect on the resilience of this settlement.

5.6.4 Multi-scale disturbance relationships

Having found press and pulse disturbances that have affected and continue to affect the Woodlane Village focal system, the study continues toward building an understanding of the multi-scale relationships that exist between them. As pressure on the system intensifies over a long period, a release or collapse is usually an opportunity for reinvention, but only if a deeper consideration of the interplay between forces is understood. The following section describes relationships between disturbances in narrative form, shown in Figure 26.

The Apartheid City plan continues to influence the functionality of the South African urban landscape (Issue 1), most prominently through access; the 'townships' remain disconnected from other city areas. The nearest formal 'township' where many marginal workers live is called Mamelodi and is located at least 20km away, too far to walk and too expensive to drive. The cost and time required to use public transport consumes a large percentage of disposable incomes, especially when many only have temporary jobs in Moreleta Park and need to be in the area in order to get more work or to cut their travel expenses (Hlahla 2010). In addition, despite investment by most tiers of government from national to local to provide affordable housing (Issue 2) for the poor, it has largely been located in the traditionally 'black townships'. This adds to inaccessibility, where poorer people struggle to get to places of employment to generate livelihoods (Herve 2009). With current policy

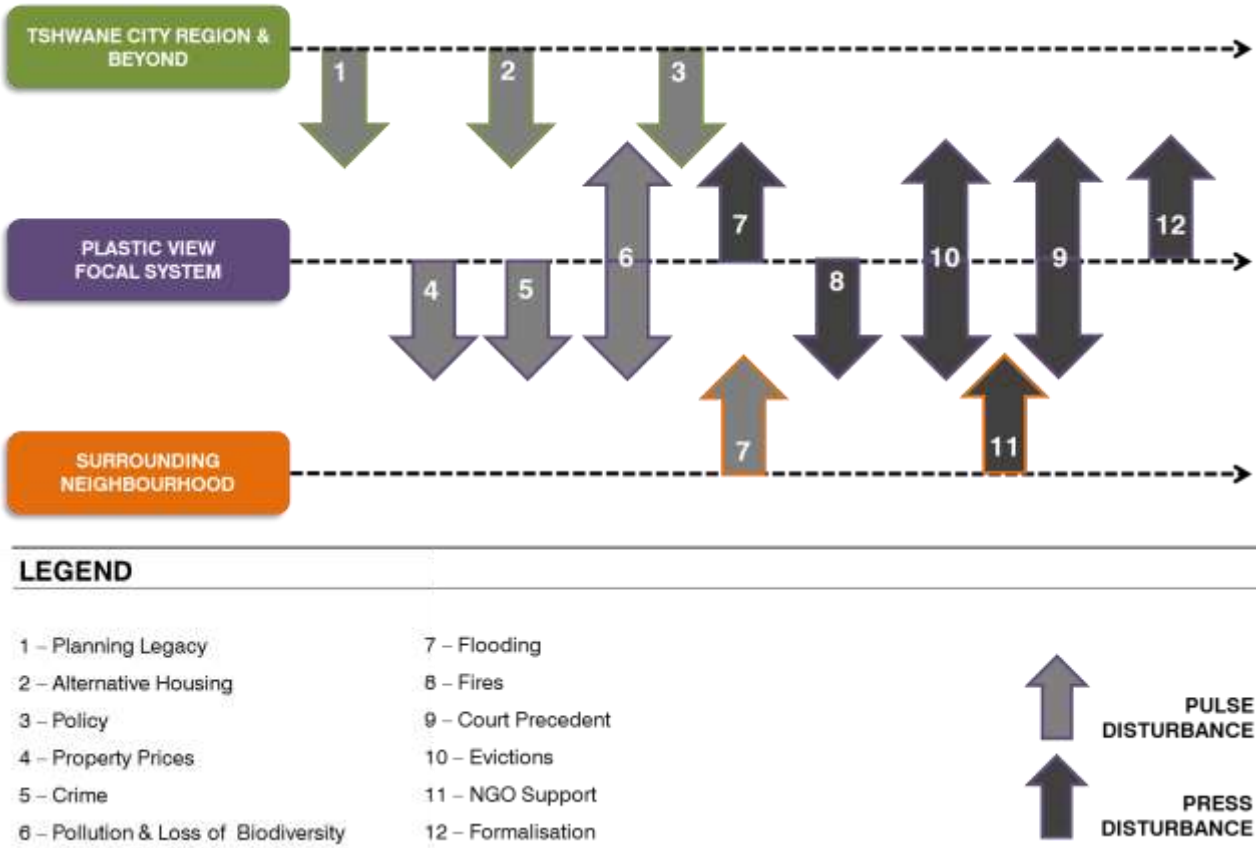


Figure 26 - A diagrammatic representation of the relationships between press and pulse disturbances across the Tshwane panarchy, as seen from the Plastic View/ Woodlane Village focal system (Peres & Du Plessis 2013).

promoting subsidised housing and laws protecting tenants and squatters alike from eviction (Issue 3), the informal market has filled an essential gap in the city: flexible housing close to work opportunities. Unless there is a revision of planning schemes, and potentially the subsidised housing and eviction policy, innovative solutions for alternative quality housing for marginal urban South Africans would remain limited.

As general press disturbances intensify, they create conditions that make settlements like Woodlane Village possible. The presence of informal settlements next to high-income residential suburbs links back to Issues 1-3; these suburbs offer places of employment and livelihood opportunities, as well as the possibility of 'jumping the queue' to access subsidised housing. As a consequence of its emergence, Woodlane Village has started placing press disturbances of its own on the surrounding community: property prices have become fragile (Issue 4), perceptions have arisen that crime in the area emanates from the informal settlement (Issue 5), and there has been an increase in pollution and degradation of city-scale watercourses and their biodiversity (Issue 6).

The ripple effects of built-up press issues are felt up to the city-region scale. Tension in the surrounding community has led the council to disrupt Woodlane Village on a few occasions through attempted land evictions (Issue 10). However, eviction policy (Issue 3) and the assistance of local NGOs protecting and supporting the settlers (Issue 11), has meant that there has been little change to the growth and longevity of the informal settlement. Fires and natural disasters like seasonal flooding (Issues 7 & 8) have not collapsed the settlement. Instead, they emphasise the connection to Issues 1-3, since estate typologies and the commercial boom resulted in developments with expanses of hard surfaces, increasing storm water runoff and putting pressure on natural streams and storm water systems.

As press and pulse disturbances continue to impact on the panarchy, a recent pulse disturbance may have the greatest effect on the focal system: the court decision to formalise Woodlane Village (Issue 9) and permanently locate its legal residents in the area sets a precedent for other similar instances of informality in the city (Issue 12). This will have consequences for Issues 1-3: a) it is an opportunity to integrate lost spaces in the disjointed city (Issue 1) by locating marginal workers closer to places of employment and spatially stitching communities together; b) it offers the low-skilled workers housing close to where they need to be to generate livelihoods (Issue 2) and c), it offers an opportunity to revisit current policy and find innovative ways to build adaptability and resilience into housing and planning strategies (Issue 3). Issue 9 also affects the Woodlane Village community; it offers an opportunity to build resilience against natural disasters by applying methods that integrate natural processes and alternative planning, and also to build social resilience and strengthen the quality of educational, health, food security and recreational amenities for the informal settlement. Lastly, pulse Issue 9 has consequences for the surrounding neighbourhoods: it offers the certainty of a workforce close to home and the possibility to build symbiotic networks of livelihoods that not only benefit workers in the informal settlement, but also most of the neighbourhoods around it.

Narrating these multi-scale relationships highlights the interconnectivity of disturbances in the panarchy and offers the insight that most events have an effect on the system as a whole, that filters through to other scales of the system suddenly or slowly (Capra 1996). The systemic pressures affecting the Tshwane city panarchy, from the perspective of an informal settlement called Woodlane Village, show that not only are pressures exerted on the system multi-scaled, but also highly interconnected and interrelated. This leads to the conclusion that current models of development are insufficient for dealing with press disturbances placed on transitioning urban systems in South Africa, while trying to cater for the needs and aspirations of its society.

The above stems from lack of awareness about the interplay between press and pulse disturbances and their effects in the city. This understanding could assist in building resilience across the panarchy. Woodlane Village has demonstrated high levels of internal resilience, while the surrounding neighbourhoods have demonstrated weaker levels of resilience, partly due to the uncertainty regarding the future of Woodlane Village. At city scale, out-dated policies have also shown high signs of resilience. However, given the recent court decision to make it permanent, the integration of lower income groups into wealthy suburbs may build diversity and capacity for overall system resilience, because cross-scale networks would be strengthened.

Further investigation into the relationships discussed above may enrich the research into mapping the urban resilience of the City of Tshwane and highlight that a necessary change is required in the way we think about development and planning for the future of South African cities. It shows that professionals, practitioners, academics and government officials involved in the built environment need to rethink how we view change (Wilkinson, Porter & Colding 2010) and identify potential therein for positive growth of urban systems in aspirational cities. This offers an adaptable, dynamic and robust approach for assimilating changes into regenerative processes in the urban SES. Change in a panarchy cannot be viewed as a linear concept, but rather as a dynamic framework (Wilkinson, Porter & Colding 2010) of interconnected and interdependent processes that collectively increase or decrease resilience.

5.7 Conclusions

Understanding the relationship between multi-scale press disturbances offers an opportunity to open thinking about city planning in the City of Tshwane into a holistic, long-term and less efficiency driven approach – one that strives for constant evaluation and evolution of the city since "resilience is the great moral quest of our age" (Zolli & Healy 2012). The effects and consequences of changes and interactions with the panarchy also have the potential to completely transform or collapse a system. These were the bases of exploration in Chapter Five, using the narrative of an individual in the city, as well as the focal system of Woodlane Village.

CHAPTER SIX

THE RESILIENCE LENS: OBSERVING CHANGE OVER TIME

6.1 Introduction

From a holistic ecological perspective, "resilience is not about the speed of the bounce back, as much as the ability to get back" or in other words, to recover in the direction of something like it was before a disturbance (Walker & Salt 2006: 37). However, as discussed previously, resilience is not automatically desirable – some changes or regimes are negative to the overall quality of a system and could be allowed to collapse (if they are not too resilient) in order for the system to regenerate (Walker & Salt 37). Attempting to change the resilience of a system (whether perceived to be negative or positive) can have significant irreversible consequences for societies. A deeper awareness and understanding of the resilience of a focal system over a period of time needs to be acquired. Humans are able to adapt to fast changes because they are more visible, but they are not as capable of understanding the long-term consequences of actions and the negative changes they may bring. Examining change over time is important since, as long-term environments, cities suffer or benefit from the long-term effects of changes.

The previous section discussed systems components and their relationships in order to understand the focal scale. This section explores how to understand change over time in these systems through two approaches. In one approach, SESs are seen to contain a number of simultaneously occurring regimes or stable states that are separated by thresholds. In the other, the behaviour of SESs over time is viewed through cycles of adaptation, namely a slow cumulative capital growth and conservation phase (fore-loop) and a collapse into an uncertain, novel, experimental release and reorganisation phase (back-loop). Together, these concepts work to paint a picture of the focal system, by highlighting the characteristics that influence how much change and disturbance it can accommodate without losing its identity.

6.2 Regimes and thresholds

> Managing for resilience is all about understanding a social-ecological system with particular attention to the drivers that cause it to cross thresholds between alternate regimes, knowing where the thresholds might lie, and enhancing aspects of the system that enable it to maintain its resilience (Walker & Salt 2006: 59).

In a system, a regime consists of those rules that inform the relationships between variables and give rise to its character, behaviour and integrity. A regime, also called an 'attractor'

(Folke 2006: 257), is a dynamic space made up of a number of variables and relationships that form part of it; whichever regime or state the system is in, it will retain its identity (basic structure and function) and therefore keep behaving in the same way (Walker & Salt 2006: 164). A change to most of the state variables could cause the system to shift from one regime of behaviour to another, since the relationships that defined the limits of that regime had changed and a critical threshold had been passed (Walker & Salt 57). An increase in one of the variables makes the system less resilient toward it and vice versa.

The manner in which a system responds to the shocks and disturbances targeting it depends greatly on the particular context that the system is in, its own scale and its various connections across scales, and lastly, its current state. For example, within a city, one could say that a residential neighbourhood could have various states differentiated by the housing typology, where the mix between typology, amenities and infrastructure changes might alter, but it still forms an identifiable neighbourhood regime. However, if the mix begins to shift and one of the variables begins to accumulate, then potential for a new regime develops; say all housing typologies are replaced by offices and retail, then it will no longer be a neighbourhood regime, but will slip into a business district regime. Whether as a neighbourhood or a new business district, changes taking place in this focal system will not be massive in the larger city system, but they may have lasting ripple effects on the larger system. For the larger system, the implications are not severe save for the potential loss of memory and reserves, since most SESs contain multiple regimes. A regime depends on its feedbacks and thresholds, and it follows that understanding the resilience of a system depends on understanding where the thresholds in a particular regime lie.

6.2.1 Thresholds

Before a system tips from one regime into another, the levels of controlling variables begin to change, which in turn create feedbacks to the rest of the system. The levels at which these feedbacks change the system are called thresholds. In other words, the threshold is the point where one system changes into another that has different rules. Finding slow-moving variables in a system, and where their desirable thresholds lie, offers a chance to manage resilience. Moving beyond thresholds will cause the system to behave in a different way that may not be reversible. Continuing past a threshold leads to tipping points in the structure and function of the system that ripple through and can permanently alter many systems linked to it. These tipping points are called *critical* thresholds, because, if crossed, other systems may also collapse. There are no obvious signals before crossing a critical system threshold. However, complex adaptive systems are said to show system behaviour

changes such as increased variance or 'stuttering' at multiple scales before a regime shift, and these could function as warning signals (Folke 2006: 262).

Walker and Salt (2006: 59) suggest that knowledge of the thresholds of a regime are critical in achieving the resilience of a sustainable ecological system; knowing what drivers cause variables to cross thresholds, where those thresholds lie, and enhancing variables that allow for its resilience. They further suggest that resilience can be built into a system in three ways: by moving thresholds, by moving the current system away from a threshold, or by making a threshold more difficult to reach. Intentional changes to transform a system between different system states within a regime may be triggered, when it has become too expensive or impossible to manage, by introducing new variables (Walker & Salt 62).

Finding thresholds begins by describing the focal system and its variables, as in Chapter Five. Different regimes applicable to the system are then listed. Together these describe the current state of the focal system and what it might be shifting toward. Then, the slow variables or press disturbances are addressed to identify which hidden variables are pressuring the system to force it to cross a critical threshold. Understanding where these critical thresholds lie comes from understanding their cycles of change (this will be detailed in section 6.3). While a system lies within a conservation phase, its thresholds are in place to maintain the resilience of the focal system and prevent its collapse. However, the longer the system lies in the conservation phase without a continuous measure of revitalisation or regeneration in the system, it will cause critical thresholds to move closer, causing a regime shift or a collapse (Walker & Salt 2006).

There are three types of thresholds which can be identified in a focal system: known, potential and conceptual (Walker & Salt 2012: 74). Known thresholds are those that have already been crossed. They can also be known thresholds in other sub-systems; these are however highly contextual responses to a system and should not automatically be inferred, especially within complex SESs. Known thresholds are useful in the study of engineering resilience where equilibrium is desired.

Potential concern thresholds are derived from a set of operational goals which, if the levels of their variables were dropped, require an intervention. They are measured by the rate at which a system is moving toward what has been identified as an undesirable change. Setting the targets for these thresholds can be particularly useful in the practice of transformative resilience, where the system is managed toward or away from a set of goals.

Lastly, conceptual thresholds are derived from agreed conceptual models that explore the different states that a system can be in at any time. From these, the transitions between possible states and how they unfold are explored conceptually in order to build the specific resilience of an aspect of the system toward unwanted change. Once again, this type of threshold modelling is useful in developing engineering resilience and transformative resilience. In order to understand the resilience of a system and manage responses appropriately, it becomes important to know where thresholds lie in a focal system.

6.2.2 Stable states

When a regime is in a stable state, it is in a state of dynamic equilibrium that does not change unless it is disturbed. A system can consist of a variety of stable states or 'multi-stable states' (Folke 2006: 254) or 'regimes' (Walker & Salt 2012) in which dynamic change occurs without destroying the nature and functionality of the system. In resilient systems, the system state variables are far from a threshold; however, as resilience decreases, the system state moves closer to a threshold, making it easier to cross into a new state (Walker & Salt 2006: 54) or regime.

The capacity of a system state to accommodate change in its key variables also determines the stability of the regime by maintaining a system far from a threshold. The distance to the threshold in a stable state is called a buffer (Walker & Salt 57), and the larger the buffer, the larger the resilience of the system to remain within a regime. In its translation to an urban system, maintaining a system in a specific stable state is a method of maintaining engineering resilience. Allowing a regime to flow between stable states is a means of allowing for evolutionary resilience, and managing the buffers or thresholds between states is a means of transforming away from one regime into another through transformative resilience.

6.2.3 Regime shifts

A regime shift occurs when variables in a focal system accumulate and cross beyond a critical threshold toward another, different regime. In sustainability, a system is considered resilient if it does not undergo a regime shift, but rather holds the capacity to absorb disturbances. Regime shifts result from the relationships between a few interacting variables. Too many variables result in a mode of constant regime shifts with losses of resources (like organisms, nutrients and species in an ecological system, or skills, knowledge and experience in a social system) at each shift (Walker & Salt 2006). In the long term, constant regime shifts cannot be sustained.

Constant regime shifts also affect the resilience of the focal system and the larger system, where maintaining the resilience of a specific regime comes at an initial cost. However, the loss of resilience of a focal system over time leads to much higher costs in the overall system due to the loss of resources at each regime shift. This knowledge could be used to either weaken an overall system perceived to be 'negative' through a number of regime shifts, or to maintain the resilience of a regime that is perceived to be 'positive'.

6.3 Applying the regimes and thresholds model within the Tshwane urban context

Applying the concepts of resilience regimes and thresholds discussed in section 6.2 to the Tshwane urban system takes place in an area east of the city, broadly referred to as Menlyn, which is undergoing high levels of transformation and development. This area is drawing and concentrating financial investment and business energy. It feeds off the energy of the established Menlyn Centre, along with a number of other retail nodes, as well as increasing levels of redevelopment of residential areas along the major vehicular arterials in the area. It services the fast-growing eastern suburbs of the metro, and accommodates their economic interests. The changes within this area have been the result of a number of thresholds being crossed across scales. Again, this shows the importance of the effects of the decisions of individuals and agents in the system effecting changes that ripple through the system. A number of key thresholds were crossed before what was for a long time a predominantly residential mixed-use suburb became a predominantly commercial business hub.

The following exploration examines the physical changes that have occurred in a portion of the Menlyn node, i.e. Waterkloof Glen Ext 4, over a period of seven decades focusing on recent physical change occurring during 13 years, between 2001 and 2014. While the decisions of individuals and groups obviously influenced these changes, they will only be discussed as far as they led to the physical changes. It further examines the ripple effects of these changes through the immediate surroundings of the node. It looks at the key variables that defined the regimes of the study area and how their thresholds were crossed, leading to their eventual collapse and the focal system assuming a different regime. It then looks at the scale above by addressing changes in the immediate environment, and again identifying the key variables and their thresholds. Together these 'small' regime shifts have coalesced to flip the regime of the larger area.

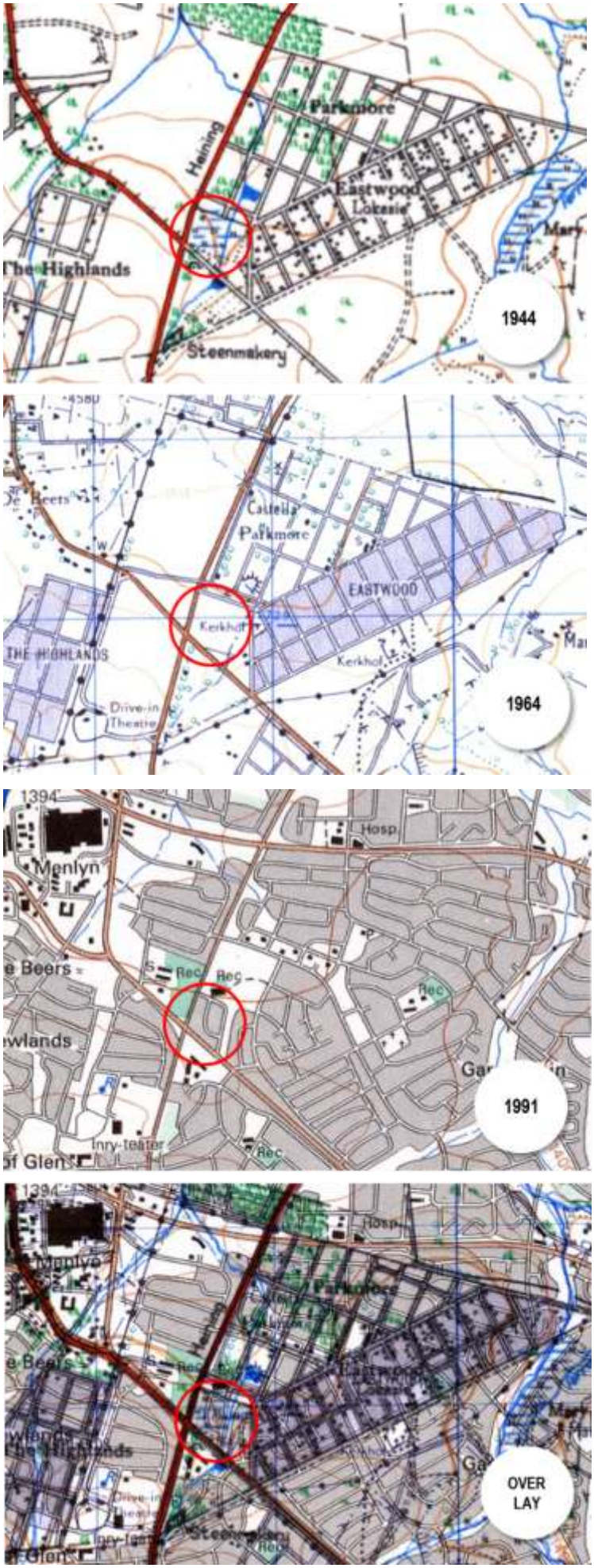


Figure 27 - Survey maps of the focal system between 1944 & 1991, with an overlay map showing the 'lost' fabric of the broader area. The red circle marks the focal system, Waterkloof Glen Ext 4.

6.3.1 Describing the focal system – area and scale

Waterkloof Glen Ext 4, the focal system and scale (from now on referred to as 'the site') of this investigation, was established on a portion of land that was used for agriculture in the earlier part of the previous century. The fields benefitted from the stream that runs along its eastern edge. In 1944, a nearby quarry and a few indigenous huts inside its boundary, shown in Figure 27, were the only activities immediately south of the site. To the northeast, the township of Eastwood was located (Trigonometrical Survey Office 1944), which in many ways resembled the multicultural atmosphere that characterised Sophia Town's fame in Johannesburg. In spite of increasingly oppressive conditions facing black South Africans in the 1940s, Eastwood's vibrancy attracted artist Gerard Sekoto to document in colourful strokes the scenes of daily life in the area at the time. The open farmlands and veld surrounding the site were probably used for agriculture and cattle grazing. Twenty years later, extensions of new residential fabric (Trigonometrical Survey Office 1964) marked the need and pressure for housing in the capital. At this time, the site was open and unutilised, Eastwood was still in existence, and one of its access roads ran along the northern edge of the site. Between 1944 and 1964, this area was characterised by pockets of dwelling areas in-between extensive farmlands and veld. This was its first regime.

6.3.2 The first regime shift circa 1980 – exploring thresholds and tipping points

By the late 1970s many of the areas surrounding the site were under pressure for residential development. In 1978/1979 the site was established as a residential suburb named Waterkloof Glen Ext 4, and consisted of 24 stands which were sold to individuals and developed 'on spec' (Re: Celeste Street 2015). The site was sparsely populated with blue gums, and contained a Municipal Garden Services depot. The Glen high school was located opposite and, with its exception, there was veld and blue gum trees adjacent to the site. The larger stands averaged around 1 756 m^2. An abandoned blue-slate quarry populated with large established blue gums was located across Garsfontein Road. Expansion of the city saw the existing key variables of agricultural land, open veld, and spare pockets of dwellings decreasing against the suburban residential variable, as well as the commercial, community, recreational and amenity variables. Around 1978/1979, the site experienced its first threshold, shifting from its use as an agricultural/ open space to a residential suburb. Construction occurred quickly during 1979/1980, with a large portion of houses built in 1980, therefore forming the tipping point from regime 1 – agricultural open space, into regime 2 – suburban residential. From 1978 onwards, the area became built up with the last two stands developed in the early 1990s.

The scales above (context) – threshold period A

The surrounding area (scales above) also experienced transformation in response to urban growth. Between 1964 and 1978, Eastwood and Parkmore were demolished to build Garsfontein, a suburb based on the modernist American suburban model that focused on a high dependence on the car and commuting to work places in the CBD. The expansion also meant the relocation of citizens living in Eastwood (according to their race) into segregated townships (the iconic urban signature of *apartheid*) like Mamelodi. This created a threshold period during which time the new regime could still be adapted into a number of different trajectories. However, the chosen trajectory was car-dominated American-model suburbia.

With middle-class white suburbia becoming a key variable in the area, there was pressure for supporting services, and this led to an increase in other variables like commercial (saving a trip into the CBD), schools (The Glen, Garsfontein Primary), recreational amenities, and other services (library, police, postal, petrol stations, churches). The blue-slate quarry adjacent to the site was developed into the Waterglen shopping centre in the 1980s, after the blue gums in the quarry (some up to 2m in diameter) were cut down, heaped together, and burned for weeks. During this time, the surrounding area developed further: the Atterbury Road bridge over the N1 was built in 1979, Menlyn Mall was opened to the public in 1980, and the surrounding open areas were developed into residential suburbs (Re: Celeste Street 2015). As these variables increased, the context of the site also tipped from agricultural open space into a car-dominated residential suburb with pockets of convenience commercial amenities (Chief Directorate: Surveys and Land Information 1991) around the early 1990s (see Figure 27).

6.3.3 The second regime shift circa 2002 – exploring thresholds and tipping points

The threshold period for the second regime flip on the site occurred around 1997. High levels of residential (expanding further east), and increasing levels of densification in the form of townhouse developments and security estates, increased the pressure for more amenities and commercial activities within close proximity to residential areas. Potentially compounded by traffic congestion, a decline in perceived security and investment in the CBD, and new potential for development outside of the confines of the strictly regulated municipal town planning regulations, resulted in a release of development energy (and pressure) in the areas surrounding the site and the site itself. As a relatively small suburb on the edge of a main arterial road, the site provided a good opportunity to test the ease and possibilities of redevelopment.

Residents of the site were invited to a public meeting hosted by the developers. A former resident describes the first round of discussions as unsuccessful: "[They] handled the [whole] venture as one big buy out and … there were disagreements because some of the residents wanted not less than a million Rand for their property when the highest valuation of all the 24 dwellings in the suburb was R 580 000 for the biggest and best dwelling" (Re: Celeste Street 2015). This public meeting held at that point in time formed a critical threshold for a possible regime shift of the site itself (and as will be shown later, also of the surrounding context).

A year later, a private investor represented by an estate agency once again approached the property owners in the area, but this time adapted the strategy from group meetings, to approaching individual owners secretly. Individual owners were approached persistently: "the insistence was so strong that although we had no intention of selling (never passed our minds) we eventually were pushed into it and sold. (We just asked what we [thought] was a "mad" price, to scare them away and they just took it and within an hour the agent came back with the full contract ready for us to sign)" (Re: Celeste Street 2015). Buyout activities were swift and covert – perhaps in an attempt to prevent the community from self-organising to resist the redevelopment at a cost to their profits and existing quality of life. Owners were not told what the redevelopment would be for, with agents vaguely drawing "the picture of a modern and new concept of a self-sustained residential area … Not what the end result was and will be in any of the rezoning in this area" (Re: Celeste Street 2015).

By 2001, most of the properties had been bought up and rented out (for residential and business uses, explored for maximum profit), while the developer obtained the rights to rezone. The properties were vacated in 2001 in preparation for demolition work, illustrated in Figure 28. By 2002, only one of the properties still held out against the developers after building works began, eventually succumbing to sell well before 2005. In 2002, the key variables defining Regime 1 of Waterkloof Glen Ext 1 had decreased from 24 residential units to 1 (see Figure 28), from established trees and vegetation to none, and from 2 narrow residential roads connecting the suburb, to 3 large unconnected access routes to large individual stands. With the collapse of its key variables, Regime 1 had flipped into another regime … emerging first as a construction site and in 2005-2006, as a 'big-box' commercial node fronting the edges of the main arterial roads (shown in Figure 29). This marked the second regime shift.

FOCAL AREA + SCALE: Waterkloof Glen Ext 4 - 2001

DESCRIPTION
Residential freehold suburb regime was established in 1978-9 in what used to be a Municipal Garden Services depot. Initially the site functioned as agricultural lands in 1944 near the Eastwood location with a *spruit* on its eastern edge. Surroundings were sparsely built up with only The Glen high school (2) creating a feature in the area and a quarry at the Water Glen centre (1). The open space was filled with pockets of established blue gum trees (8).

KEY VARIABLES
Internal - 24 freehold stands with a single unit per stand.
Street trees on narrow streets

External – Two small shopping centres (1), (6)
Community recreational facilities (3), (4), (5)
Surrounded by residential suburbs (7), (9) and arterial roads
The Glen High School (2)

FOCAL AREA + SCALE: Waterkloof Glen Ext 4 - 2002

KEY VARIABLES
Internal - 24 freehold stands demolished
Street trees on narrow streets and existing vegetation removed

External - Community recreational facilities (3) taken over by business
Surrounded by residential suburbs and small arterial roads
The Glen High School

THRESHOLD
Within a period of 5 months, the physical fabric of the focal area has been transformed from a suburban residential regime into a construction site regime.

Visible change in scale and typology of the built fabric, with changes made to the internal road layout and stand consolidation.

TIPPING POINT Demolition

FOCAL AREA + SCALE: Waterkloof Glen Ext 4 - 2005

KEY VARIABLES
Internal – 7 business warehouses built on the arterial road edge with 3 high-rise sectional title apartment buildings built in the centre of the focal area fronting the *spruit* and park to the east.
Complete loss of biodiversity with no new vegetation introduced.

External - Community recreational facilities (3) under pressure for development
New road built linking the site to Garsfontein suburb (arrow)
No change to surrounding residential suburbs and arterial roads
The Glen High School remains the same

THRESHOLD
Pressure between residential and business uses on traffic – road upgrading
Successful redevelopment of the focal area puts pressure on the surrounding residential areas for redevelopment into business uses.

FOCAL AREA + SCALE: Waterkloof Glen Ext 4 - 2006

KEY VARIABLES
Internal regime remains static. No major changes occur until 2014

External - Community recreational facilities under increased pressure for development – land cleared of bluegum trees (8) indicates a potential relocation site (arrow) for the sports facilities (3).
Demolition of a potion of surrounding residential suburbs (9) along the main arterial road opposite The Glen High School (arrow).
The Glen High School remains the same.

THRESHOLD
Pressure (and previous success) increases to rezone and develop the edges of the main arterial roads. Community facilities (3) are blocking this move.

TIPPING POINT
Residential properties bought, consolidated and rezoned for commercial uses.

Figure 28 - An aerial photo timeline of changes in the focal system, with thresholds & variables between 2001 & 2006. Base aerial images sourced from Google Earth in January 2015

The scales above (context) – threshold period B

The regime shift that occurred on the site was to have an influence on the increase in commercial development in the broader area. The period between 2002 and 2008 marked a threshold period B, in which the suburban scale and character of the area was under pressure to shift regimes (perhaps also due to municipal zoning relaxations). The success of the rezoning and commercial development on the site, greatly assisted by the property boom of the time, created the fertile conditions from which further development opportunities were explored in the area. By 2005 access to the high-rise residential portion of the site was created along the spruit edge, as shown in Figure 28, thereby furthering the distinction between commercial activities on the hard street edge. Pressure to continue developing the commercial corridor on the northern edge was realised with the relocation of the existing sports facilities in 2006, thereby enabling the construction of a large commercial venture and creating a commercial activity spine in 2008 (see Figure 30).

During the years preceding 2006, the residential properties bordering Garsfontein Road and Waterkloof Glen Extensions 1, 2 and 3 must have undergone a process similar to the buyouts that occurred on the site, resulting in the commencement of a commercial strip development in 2006 along Garsfontein Road, and the first demolitions of properties in Waterkloof Glen Extensions 1 to 3 in 2008. By 2009, two multi-storey office blocks were being developed opposite The Glen high school, shown in Figure 30, under new rights different to those of the commercial strip developments (See Addendum A).

Figure 29 - The main road into the site photographed 23 years apart: in a) 1992 as a residential suburb with a sports park, and b) 2015 as a big box commercial area with high-density residential (Author 1992; 2015).

The new commercial strip typology forms a clear shift in scale, material, character and fabric in the area, as shown in Figure 29. It marks a tipping point at the threshold between a suburban regime and a new commercial regime, with business activity forming a new key variable along with pavilion developments, car-dominated streets, lack of community

amenities (paid recreation and malls not included), lack of green infrastructure, and loss of historical memory. These new variables have changed the character of development in the area and define the new regime, which persists up until 2014, as illustrated in Figure 30.

Figure 30 - An aerial photo timeline of changes in the focal system, thresholds & variables between 2008 & 2014. Base aerial images sourced from Google Earth in January 2015 (Author 2015).

6.3.4 Conclusion

This exploration of regimes and thresholds shows that within an urban setting, there are critical thresholds that can be short or long, physical or intangible, but which together can decisively alter the trajectory of a city. Key variables that make up the core physical character and behaviour of the focal system increase or decrease over time, thereby altering the appearance of the regime. However, when more than one of these key variables are removed, then the entire regime collapses into another system with a different identity, behaviour, character and pattern in the city fabric, and its own key variables.

The ability to identify when an area is in a threshold period can provide two main benefits to the urban built environment professional – either to understand the changes occurring in the system and to create adaptive designs that reflect these changes, or to attempt to intervene and change the potential trajectory through transformative resilience actions. These transformative changes can be brought about either by moving thresholds, by moving the current system away from a threshold, or by making a threshold more difficult to reach (Walker & Salt 2006: 62), and are facilitated by changing, removing or adding variables.

6.4 Adaptive cycles

> The manner in which the system behaves is different from one phase to the next with changes in the strength of the system's internal connections, its flexibility and its resilience (Walker & Salt 2006).

All living systems, which include social-ecological systems (SESs), undergo phases of change and adaptation through which they consistently and progressively move. Joseph Schumpeter developed the initial idea of an adaptive cycle after analysing economic boom and bust cycles and the 'creative destruction' they usually went through (Schumpeter 1942). In this model, the system appears relatively stable while actually it is experiencing gradual (or sometimes severe) change between different states. Over time, the system may appear to undergo periods of "sudden instability and rapid change over a short period of time" (Resilience Alliance 2010: 27) in between stable states. The period of sudden disturbance and rapid change, called "creative destruction", offers the greatest leverage for transformative change within the cycle, and also highlights the fact that there are phases of the cycle in which stability is no longer possible. Understanding of the cycle a system follows to adapt to change provides explanations regarding when drivers change, where thresholds lie, how to build capacity for resilience within the system (if desired) or how

to break it down, and indicates where interventions are possible in the cycle to leverage the greatest potential in the system.

In an ecological system, the amount of capital available or utilized, the systemic connectedness represented by system flexibility versus lock-in, and influences exerted on it all change; and the product of these is the degree of adaptiveness embodied by the system (Pickett *et al.* 2014: 149). In other words, a system absorbs disturbances while maintaining its core structure and function in different ways at different phases of the adaptive cycle. Within each phase in the system things happen differently, shifting between slow or quick, and unpredictable or ordered states. The adaptive cycle recurs continuously and links up to cycles at scales above and below to form the panarchy. This process is represented by four phases: Rapid Growth, Conservation, Release and Reorganisation (Walker & Salt 2006: 75). The conceptual model of an adaptive cycle is represented through a figure of 8 which continues infinitely, highlighting the "core meaning of resilience that parallels metaphors of adjustment of complex systems with open-ended dynamics" (Pickett *et al.* 2014: 150). This means that a system can manifest different stable states (while remaining the same system) and secondly, that systems move through linked scales of adaptive cycles.

The adaptive cycle does not guarantee resilience; rather, it provides a conceptual understanding of how resilience emerges in a system where resources change and disturbances occur. The amount of resilience that a city is able to demonstrate in response to disturbances is determined by the severity of shocks, and the changing capacity of the system to absorb them at different phases of the adaptive cycle (Walker & Salt 2006). The four phases of the adaptive cycle concept represented in Figure 31 are described in detail by Walker & Salt (2006) and the Resilience Alliance (2010) as:

The Rapid Growth Phase – *the "r" phase in the conservative fore-loop*

The Rapid Growth Phase is a period in the system when opportunities and resources within the system are exploited, resulting in a maximum growth rate known as "r". During this time, the system is very flexible, because the system components are still weakly connected and the internal state is weakly regulated. At the same time, a high amount of capital is available. Because of this the system begins to prosper in a very short time frame and within very high environmental variation. The variables that exploit and create growth are known as the "r-strategists".

The Conservation Phase – *the K Phase in the conservative fore-loop*

Incrementally, the Rapid Growth Phase begins to slow down into a state of conservation and accumulation of energy, material and capital, wherein the connections between variables increase and the variables may change or diminish due to competitiveness. The number of adaptive opportunists begins to decrease once specialists emerge who build mutually reinforcing relationships that reduce variability, but are strongly regulated internally to exclude new ways of doing things. Over time, the whole system slows down and becomes more rigid as efficiency increases (at the loss of flexibility and redundancy). An intervention can be made at the potential point where a Conservation Phase usually moves directly into a Release Phase, but it can also move back into a growth phase through some small and well directed perturbations. So to keep a system from entering into a late Conservation Phase for a long period, disturbances created at lower scales can be used to ripple through to the higher scales (Walker & Salt 88).

For example, the global energy market is dominated by fossil fuels, despite scientists and economists warning of the need to move to alternative, renewable energy sources. The lack of shift is due to the system being trapped in the fore-loop of the cycle, most probably in a late Conservation Phase. Resources are locked up in slow, predictable conservative growth of the fossil fuel industry in the most efficient way possible, without increasing the diversity of sources. This loss of adaptability has resulted in a loss of innovation and resilience. At some point, a shock will result in a collapse, wherein the captured energy and resources will be released; the later the collapse occurs, the bigger the losses that will be incurred, and the next forward loop will be different from what it may have been had the collapse happened earlier (Walker & Salt 84). This might have been avoided if alternatives at lower scales of the system, perhaps smaller service providers or individuals being allowed to supply off-the-grid solutions, had been provided.

The Release Phase – *the Ω Phase (Omega Phase) in the reorganizational back-loop*

The longer a system sits in the Conservation Phase, the easier for a smaller shock to propel it into the Release Phase because of the rigidity of the mutually reinforcing relationships in the previous phase. As the system collapses, energy and resources are released and the existing structure crumbles because optimisation and efficiency no longer work. A new trigger or disturbance can collapse or derail a deeply entrenched practice or state, releasing its capital in the process of "creative destruction". The shock creates a crisis

followed by a period of "denial, resistance, and reformation" in which "institutions and the connections between them are most open to transformation" (Gunderson *et al.* 2002: 4).

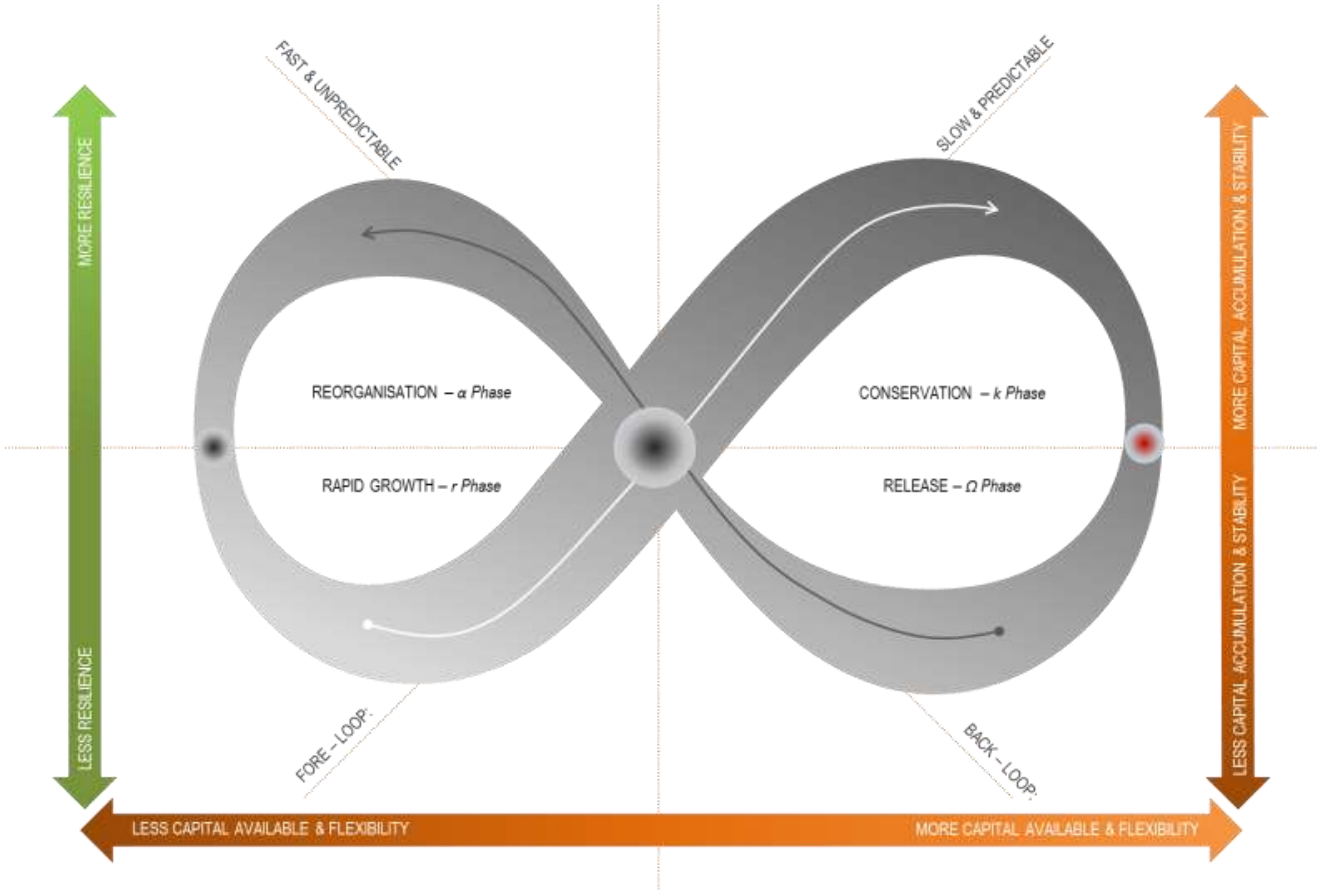


Figure 31 - A conceptual representation of the adaptive cycle consisting of four phases, as adapted from Walker & Salt (2006) and Resilience Alliance (2010), with the circles between representing thresholds between the phases (Author 2015).

The Reorganisation Phase – *the α Phase (Alpha Phase) in the reorganizational back-loop*

During this phase the system becomes disrupted into an uncertain, chaotic period of energy release and renewal, where all options are open and small chance events can change the future direction that the cycle will move in. Invention, experimentation and reassessment dominate the system, meaning that no stable equilibrium can exist; variables and functional groups are sorted out so that a new "identity" emerges. From the Reorganisation Phase, the system can move directly into any of the phases other than the Conservation Phase.

Understanding the cycles of adaptation in a system requires determining whether it is moving forward or backward in the adaptive cycle. Moving forward usually happens slowly, in predictable processes of capital accumulation and development consisting of the Rapid Growth and Conservation Phases, also known as the fore-loop. Accumulation will occur until a threshold is crossed, at which point the structure and function of the system shifts. The

tipping point where a focal system begins to collapse and move into a back-loop is defined by unprecedented uncertainty that is characteristic of the Release and Reorganisation Phases (Walker & Salt 2006: 81). A system does not need to follow these four phases in a linear pattern. Often it can move from Rapid Growth directly into Release or Reorganisation, and from Conservation into Reorganisation or Rapid Growth directly. However, each phase is separated by a threshold that marks a transition between two system states (as shown in Figure31, represented by the grey circles for flexible thresholds and a red circle for the critical 'collapse' threshold).

Resilience is said to be exposed by the dimensions and relationships between capital and complexity, which give rise to the capacity of a system to "adjust to internal and external shocks and disruptions and still maintain its functional structure and process" (Holling *et al.* 2002). This process of change, and the capacity for adaptation called the adaptive cycle, gives rise to an understanding of the flexibility required in a system in order for resilience to emerge. In contrast to a locked-in or inflexible system, resilience is mobilised after a disturbance if capital can be released and restructured so that it still bears the same functional identity (Pickett *et al.* 2014: 151). In building the resilience of urban systems to meet the goals of the post-sustainability movement, a study of the adaptive cycle can inform human institutions which adaptive processes should be favoured; these choices could foster the flow of capital between available and allocated, and shift connectivity between dynamic and fixed (Pickett *et al.* 151).

Familiarity with the phases of the adaptive cycle within the city enables urban practitioners to know when and how to intervene within a system, so that a shift back into the growth phase rather than an overall system collapse can be chosen. Interventions at the scale of concern can be created by generating Release and Reorganisation at lower scales, thereby preventing the development of a late Conservation Phase at the scale of concern (Walker & Salt 2006: 82). The focus then shifts to harnessing the energy released in the back-loop to create desired system qualities. Harnessing the energy released at these 'acupuncture' points forms the basis of regenerative sustainable design (Hes & Du Plessis 2015: 41), in which crossing the threshold into collapse is seen as positive if and when conditions arise from the collapse that can be used to improve quality in the system or eliminate destructive behaviours.

6.4.1 Adaptive cycles and thresholds

To understand the unique 'DNA' of a city, the patterns of change, both hidden and visible, need to be explored in order to arrive at a better understanding of what drives the system to

flourish or collapse. A social-ecological system viewed through the resilience thinking lens is seen to have adaptive cycles which allow it to change and evolve within its current state, and to be able to cross a threshold and move into a different regime and therefore a new state of being (Walker & Salt 2006: 53) when required to do so. Each system has variables or components, known as the system's "state variables", which contribute to the characteristics of that system.

Within a city, we can look at the system of transportation: we have motorised vehicles, non-motorised vehicles, people, and goods forming a four-variable regime; however, if we add in roads, traffic lights and traffic signals, we now have a seven-variable regime. If we zoom into each of these variables further, we will find that they have even more nested variables within them at different scales. In addition, the system is always reacting to external changes, therefore causing the system to never reach a state of equilibrium. It is therefore possible to intervene within the system to shift the trajectory of the adaptive cycle by reversing the movement of a system into the late Conservation Phase. This is achieved by using experimental interventions within the Rapid Growth Phase in the lower scales of the system, as well as by redirecting energy released during Release and Reorganisation. Interventions must be well timed, and it is important to identify the transitions that follow a threshold within the adaptive cycle – this can prove challenging since thresholds are dynamic and complex (Resilience Alliance 2010: 27).

6.4.2 Transitions

Transitions refer to a period preceding and following a threshold between each phase of the adaptive cycle. While adaptive cycles describe system behaviour over time, coupled with the changes in resilience according to which phase of the cycle the system is in, "thresholds represent transitions between alternate regimes" (Walker & Salt 2006: 93). Interventions to maintain the system in its current regime can, where possible, be managed by mitigating the drivers pushing a system closer to its threshold, before they reach the transitional period. This depends on the state of the slow variables, the capital available, and whether the system's condition is eroded or nurtured (Resilience Alliance 2010: 27).

The fore-loop therefore plays an important role in the eventual collapse of the focal system from one regime into another, since the levels of capital accumulated are the only source of capital available to the Release and Reorganisation phases (Walker & Salt 2006). It is argued that slow variables are best mediated in the Conservation Phase; however, the longer a focal system lies in a late Conservation Phase, the greater the costs to maintain the regime, so for a city, "where the scale of a society's costs exceed the benefits of the 'fix-up'

solution, the society will collapse" (Walker & Salt 87). The longer a focal system rests in the late Conservation Phase, the more vulnerable its slow variables become, and the greater the losses and impacts to the overall system once the threshold into the Reorganisation Phase is crossed.

The Conservation Phase offers the least change and therefore the best opportunity for most interventions to be conducted within the system to improve its resilience. If the change is rejected and the system is maintained in a static state, then the system is likely to get locked into a late Conservation Phase (and suffer a loss of resilience). The following measures are usually symptoms of a system suffering lock-in (Walker & Salt 2006):

–Increased efficiency, at the cost of removing redundancies

–Subsidies put in place that resist change

–Costs sunk into existing investments, rather than in new ones

–Increased command and control that results in less flexibility

–A preoccupation with process that involves more rules and procedures

–Suppressed novelty and innovation, with little support for experimentation

–Rising transaction costs to get things done

Once a threshold in the Conservation Phase is crossed from one regime of the focal system into the next, the best time to intervene and attempt a change in the trajectory of the system is before the system has reorganised. It is possible that the changes effected during a transition from one state to the next will be irreversible (Resilience Alliance 2010: 27). Transitions may be harnessed to actively build the adaptive capacity of the focal system to leverage change, by releasing captured energy and resources to cross a threshold into a more desirable system state, or for a shock to be absorbed to avoid a system collapse.

If the current focal system is desired to be more resilient, then building the adaptive capacity of the system (based on its adaptive cycle) can be achieved by increasing its functional diversity (to be discussed further in Chapter 7). Briefly, this gives the focal system options in the form of a number of different responses to pressure in the system, while still maintaining its functionality. Resilience thinking in the context of an urban SES offers the opportunity to avoid a transition to a new regime, by allowing for intervention to occur where locked up resources in the Conservation Phase can be released by undoing some constraints (possibly by causing smaller scaled systems to collapse and renew). This release

of constraints results in some loss of capital; but when a release point is inevitable, the focus shifts to navigating collapse gracefully and appropriately by using capital (Walker & Salt 2006: 87). Using systemic resilience concepts to identify slow variables (like the global economy), locking the planetary system in a late Conservation Phase can facilitate innovative action to mitigate the imminent threshold, or alternatively, to approach the transition from this planetary regime to one that regenerates conditions on earth in which life can flourish.

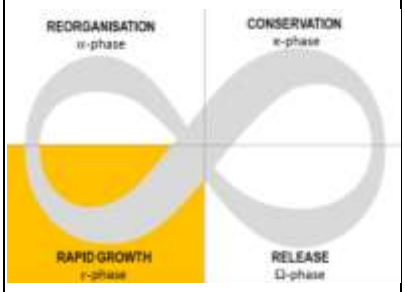
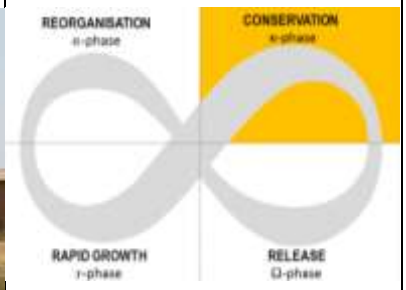
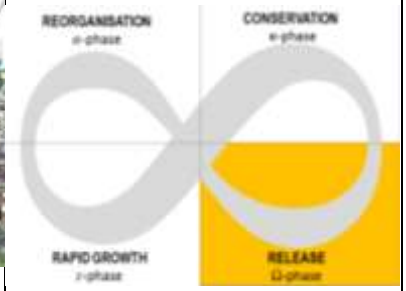
6.5 Applying the adaptive cycle within an urban context

While studying the story of a place over time, patterns begin to emerge. All living systems undergo cycles of change where the phases of each cycle have their own manifestation. Some cycles take a long time (e.g. centuries) to complete a sequence, while others change rapidly over the course of a few hours. As discussed previously, this cyclical pattern moves through four distinct phases of adaptation and evolution that continuously flow into each other, and are sometimes bypassed through collapse or emergence.

This pattern gives rise to the adaptive cycle in ecological studies (Walker & Salt 2006: 75), and the concept translates well into the built ecology. As man-made extensions of the natural environment, cities also undergo these four phases of adaptation across multiple scales (Du Plessis 2012a). The four phases of the adaptive cycle are usually illustrated through a figure of 8, with the fore-loop signifying the first two 'generative' development phases and the remaining two phases of the back-loop signifying a release of energy.

Using a city system as an example in Table 3 (Peres & Du Plessis 2014a), there is a steady period of Rapid Growth, with high investment into the focal system through various types of development opportunities that begin to flourish. This stage is followed by a Conservation Phase in which the dominant system-state streamlines and the existing built environment is maintained, often to the point of lock-in. The existing relationships might continue to a point after which the system-state will cross a tipping point to enter a chaotic period of Release, which is the next phase. Lastly, a Reorganisation Phase begins in which completely new opportunities for development emerge and are harnessed in a reboot of the whole cycle. Being able to read these changes in the study area's adaptive cycle (be it a building, neighbourhood or city), and understanding what possibilities and restrictions arise in each phase, is an important step in a resilience approach.

Table 3 - An example of an adaptive cycle focused on housing as it unfolds in a city system, starting at the Rapid Growth Phase (Peres & Du Plessis (2014a) adapted from Holling (1986).

PHASE DESCRIPTION	PHOTOGRAPHIC EXAMPLE	ADAPTIVE CYCLE PHASE
Rapid Growth Phase: For example, the migration of people from rural areas to a typical South African urban area increases the demand for affordable housing close to jobs. Where this is not available, informal settlements emerge as a self-organised response to the need for affordable housing, close to opportunities.		
Conservation Phase: The informal settlement described above might place enough pressure on the municipality to establish a settlement and provide basic services and RDP housing. This could attract more people to the area: informal infill structures, illegal connections to services and higher demands on limited resources result.		
Release Phase: A collapse of service delivery in the area, high levels of corruption or deteriorated building stock might lead to the destruction of existing municipal infrastructure through violent protest action. NGOs might mediate conditions and demand the redevelopment of large portions of land into different typologies.		
Reorganisation Phase: Conditions unlocked by the release phase allow for a reconfiguration of the housing policy, or lead to new building typology and tenure designed by engaging the community, which might also allow for incremental self-organised development in future. There might also be provision of a crèche, clinic, urban greening or parks.		

This representation of the adaptive cycle within an urban SES shows that, in the fore-loop of the cycle, the need for accommodation met through informal housing begins under conditions of flexibility in the system, at lower scales with weak resilience, that progressively become more conserved and complex with relationships to higher scales of the system. The Conservation Phase shows a slowing down of the system with an accumulation of capital. The risk at this stage is that efficiency overrides conditions for a dynamic system, highlighting concern for the costs and time restrictions for building in back-ups and quality. In contrast, the costs versus benefits of maintaining an efficient yet locked-in system can often lead to the collapse of the regime, at which point the capital accumulated in the fore-loop is made available in the back-loop.

During the transitional phase, at which point the threshold of collapse occurs, there is an opportunity for change agents to influence the trajectory of the system. In the example above, in a setting of failing service delivery, protest groups might begin to burn down infrastructure and amenities in a series of chaotic riots. This causes a release of energy, but it becomes directed into either rebuilding what was there, or in managing the social retaliation. Alternatively, different change agents in the form of local NGOs might direct the release of energy toward a reinvestment in new amenities, as well as social projects that build complexity and depth within the system. In the latter version, the system might create the favourable conditions that attract further investment in the area in novel ways that represent a transformed state from what was initially there. While this hypothetical neighbourhood has undergone extreme and dramatic changes, the system above it might not feel the effect of these changes if it is loosely linked to it.

6.6 Conclusions

This chapter examined two approaches for observing change in a focal system and how these might manifest in an urban SES. In both models, a change in the state or regime of a focal system and its sub-systems might be transformational, but in the larger scales above, this change might not necessarily appear to cause any effect. Therefore, both models are a means of understanding a system at a focal scale and not necessarily of understanding the entirety of the system. The regime threshold model addresses a focal system from the perspective of its state variables that maintain a measure of dynamic equilibrium between their levels. Alternatively, the adaptive cycle explores patterns of change and the influence of drivers on the system.

The above models do have a measure of overlap. When one regime crosses a threshold into another, this process usually occurs in a back-loop in the adaptive cycle. But this is more of a coincidence rather than a fixed rule, since "they are different models used for different purposes, and it is not always possible to equate the dynamics of a basin of attraction with the dynamics of an adaptive system" (Walker & Salt 2006: 93). At different points of the adaptive cycle resilience may be less pronounced, making interventions easier to engage. A transformation can occur without a release phase, where there is no loss of resources, but rather a loss of resilience. In this case, the threshold of the slow variable is the point where feedbacks change and a regime shift occurs (Walker & Salt 94). When managing SES resilience, the suggestion is that slow variables, thresholds and transitions between regimes provide clues to retreat or propel a system past a threshold.

Seeing the urban system through the lens of resilience begins with observing the drivers of change as well as the relationships between the system variables, in order to identify critical thresholds in the system where it shifts from one regime to the next. This basis serves as the foundational response to the question: 'resilience of what to what', without which a systemic approach to resilience is not possible.

This chapter has shown that while the above models and concepts have been well researched within the sphere of ecological resilience, their application to the urban system is tricky because of the social element. Ideally, both physical and social change should be investigated. In this dissertation the social element is used to explore an individual's actions in the panarchy, while focusing on the physical characteristics of a system in order to observe change. In both instances it highlights the potential risk linked to managing the resilience of a system, in that value judgements will be placed on whether the resilience of a system is desired or not. This places a high level of responsibility on the researcher to act in a holistic manner that considers multiple perspectives. Caution aside, to understand the resilience of a system one must first understand the changes it has undergone.

CHAPTER SEVEN

THE RESILIENCE PATH: BUILDING THE ADAPTIVE CAPACITY

7.1 Introduction to adaptive capacity

The ability to identify resilience in a system is a vital skill in the act of nurturing or destroying it. This implies a responsibility to act in a manner that promotes the potential of the system to evolve toward greater depth and complexity, rather than trying to prescribe goals. In achieving this evolution, resilience as a systemic property of a system versus resilience thinking as a descriptive concept offers practical insights. The aim of systemic resilience practice is to move beyond trying to manage for specific variables, accepting that optimising resilience in one place reduces it elsewhere (Walker & Salt 2006). If a particular aspect of a system's resilience is deemed undesirable and a value judgement is made to weaken it, the effects of this intervention may likely cause an unpredictable change in the system that could lead to the possible collapse of desirable systems. Trying to control the variables that pertain to specified resilience can lead to undesirable or irreversible changes of the system regime (Resilience Alliance 2010: 34).

Two resilience practices that build the adaptive capacity of a system are specific and general resilience. With specific resilience, we know what type of resilience we need toward disturbances we are aware of, but in general resilience, these disturbances are unknown (Walker & Salt 2006: 124). Creating adaptive capacity within the system depends on both practices, so that its variables manage to accommodate change in whichever direction needed in order for the system to evolve dynamically – to regenerate or to collapse. While adaptive capacity depends on both specific and general resilience approaches, if a system has a high level of overall resilience, it is more likely to absorb or adapt to unpredictable changes with enough capital reserves to regenerate. Walker and Salt (2006; 2012) posit that ecological resilience is more a general resilience approach than a specific one, and it similarly provides a platform to begin engaging urban resilience.

From the perspective of urban resilience the goal should be to encourage general resilience so that the city system has a greater capacity to manage how it absorbs or adapts to change on its long-term trajectory. This capacity is described as its adaptability, and a resilient system usually has a greater adaptive capacity. Qualities of diversity (along with redundancy) and modularity are key themes that create the basis for general resilience and the adaptive capacity of a system. Exploring how these themes manifest in the urban environment from a resilience perspective informs investigation in this chapter.

7.2 Diversity

> In an ecological system, one species fulfilling its role enables all the other species to play their roles, even those where there is no direct connection. The value of a role in an ecological system derives not from how something functions, but rather from the pattern of relationships that enable particular exchanges of value (Mang & Reed 2014: 3).

A healthy, resilient and sometimes stable system has diversity built into its DNA (Hamilton 2008: 16; Gunderson *et al.* 2002: 251). It is through diversity that a system can adapt to shocks and stresses in various ways according to the nature of the crisis. A city system without diversity or built-in redundancy can be crippled by a single disaster, which can potentially collapse even the most efficient urban network. In an SES, diversity refers to the variety of actors in the system and it relates to "flexibility and keeping your options open. A lack of diversity limits options and reduces your capacity to respond to disturbances. Increasing efficiency inevitably leads to a reduction in diversity" (Walker & Salt 2006: 121). However, the inverse may be true. High concentrations of diversity in areas that overshoot available resources might lead to fragility (Zolli & Healy 2012) rather than resilience.

Options in a system can be increased by improving both functional diversity and response diversity. Functional diversity (also known as functional-group diversity) refers to the range of functional groups that a system depends on for its performance. These functional groups are divided into *drivers* and *passengers*, where drivers are the *keystone* functional groups and subgroups that 'control the future' of a system, while passengers operate in the system without significantly altering it (Gunderson *et al.* 2002: 9). Removing the functional groups of a system that are drivers will fundamentally affect the system; this is made more difficult because the roles between drivers and passengers can change over time (Gunderson *et al.* 2002).

In a natural system, three functional groups or drivers that are present at every scale of the system are producers, consumers and decomposers (Du Plessis 2012a). Response diversity (also known as functional-response diversity) refers to the different types of responses within each functional group that create its resilience. As illustrated in Figure 32, under producers there could be a range of plants responding to that function while herbivores, carnivores and omnivores respond to consumers, and fungi and bacteria to decomposers.

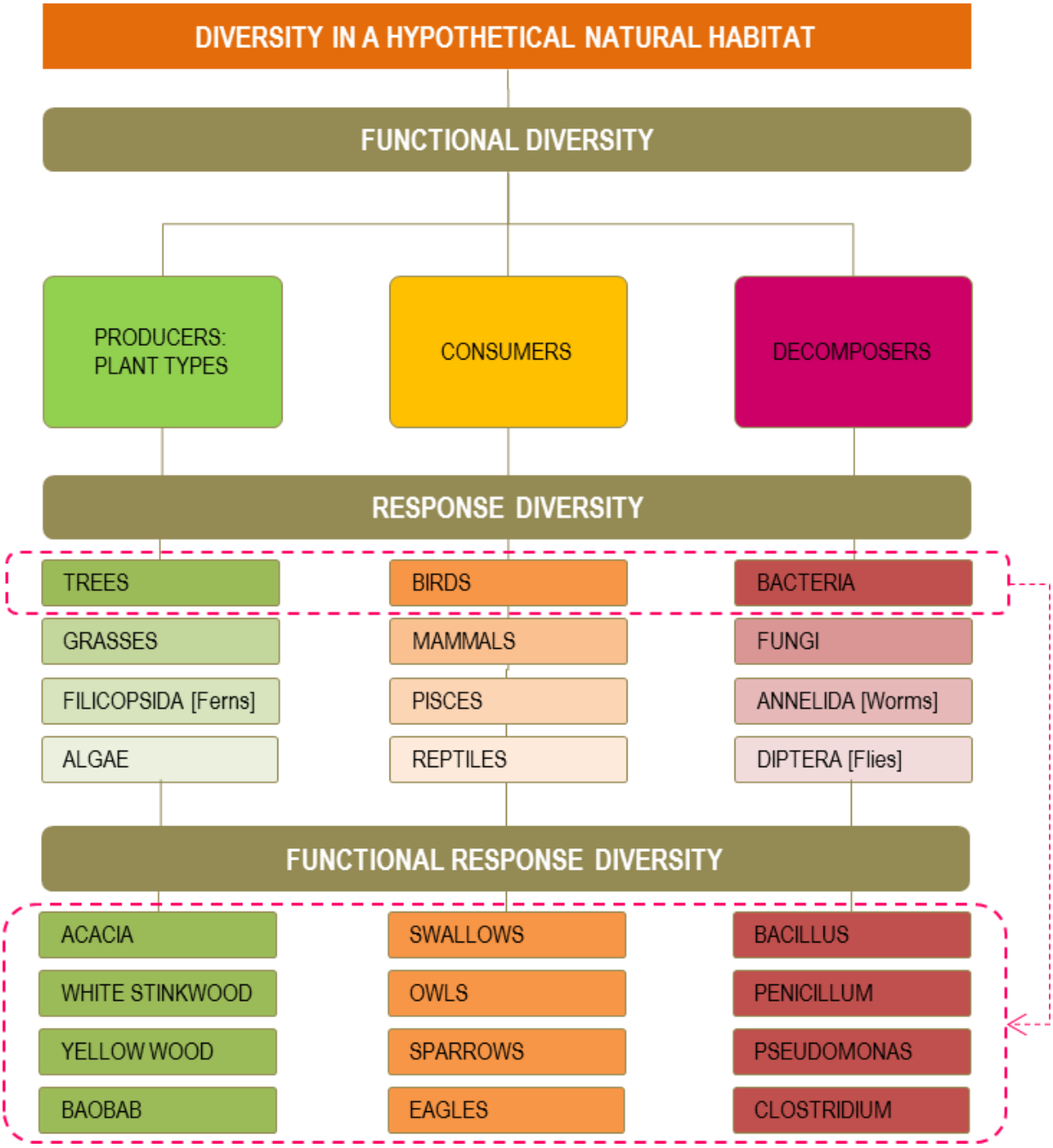


Figure 32 - Different types of diversity (in function and response) in a natural system (Author 2015).

Since the above concepts emerge from ecological resilience theory (Gunderson *et al.* 2002; Walker & Salt 2006: 69), they synergise once more with urban ecologies. In cities, addressing diversity should look at the functions of a city in all realms, the social, biophysical and man-made. For example, there should be social diversity in cultural expression and spiritual exploration, and biodiversity regeneration in natural systems and within the built environment. While these aspects are essential to a comprehensive analysis of diversity and general resilience in a city, this dissertation will focus on functional and response diversity in its physical realm; in other words, the man-made elements of the built environment and their spatial relationships to natural resources in the city that sustain its functioning.

7.2.1 Functional diversity

Before a translation of functional diversity into the urban built environment is undertaken, the understanding of the character and purpose of an urban setting needs to be framed. Traditionally, 'urban' referred to the condition of life in the city as "being urbane, courteous and well mannered" (Forty 2000: 113), and this definition extended to the relationship of buildings to the public environment. Urbanity as an urban characteristic was later referred to by Lewis Mumford as a positive condition or goal in which a "civilized collective urban life, and of personal self-fulfilment" (Forty 114) could be realised. He defined a city as a "point of maximum concentration for the power and culture of a community" (Kostof 1991), in which the social element forms the core purpose for the existence of the city. In the industrial cities of the 1800s and early 1900s, conditions of poverty, disease, sexual abuse, slum dwelling and extreme pollution defined life for many citizens (Hall 2002: 16), questioning the city as condenser of civilised collective life or personal fulfilment.

In reaction to the 'slums', Ebenezer Howard developed plans for a 'garden city' that would progressively transition capitalist society into a cooperative of commonwealths (Hall 2002: 88) in which people could live in dignity. His plan promoted social reform within a dense urban system that included natural systems, but his vision was adapted only as a physical planning tool. The garden city was demoted to suburban sprawl, and its future proponents made it possible for designers like Charles-Edouard Jeanneret, known as Le Corbusier, to suggest 'existing centres must come down' to make room for 'high' density, with large open spaces and vehicular circulation tying together the geometric urban layout (Hall 219-223).

Le Corbusier's *La Ville Radieuse* clearly divides and separates land uses through zoning; nature is controlled; the city is dependent on motorised transport; urban scale, hierarchy and fabric is disrupted (Salat 2011: 74); cultural or social traditions are negated. In response to the growing Modernist planning approach, Jane Jacobs (1964) actively fought the notion that cities were inert objects that could be planned without considering the lives of people living within them. Later, Whiston-Spirn (1984) added to the voices that argued that cities could not be planned without considering the natural habitat and the flows of resources through the city. Despite harsh criticism of the Modernist approach to planning, principally using land use zoning and geometric form to design new developments (Salat 2011:87), South African cities are planned primarily according to zoning rights without integrating other considerations, like exchanges between habitat, ecology, traditions, and social practices. Resultant building typologies and streets lack built in flexibility to change, since they react to zoning and uses, which are inflexible or difficult to change. Local examples of the closest

'integrated' land use, mixed-use such as in Melrose Arch or Menlyn Maine, lack richness and flexibility evident in historical cities (Salat 106) whose typologies have evolved over centuries.

The identification of the physical, structural components that create functional diversity within a city can be interpreted solely from a zoning perspective with specific land-uses, using categories such as retail, industrial or residential functions (Du Plessis 2012a; Ferreira & Du Plessis 2013). These however give no idea of the spatial character or flows through the city. Basing the interpretation on land use could be argued to perpetuate the problems created by the Modernist planning ideals discussed above, because it excludes relationships and flows between people, resources, infrastructure, and the building typologies that characterise the spatial qualities of the urban setting and how it is used (and its potential for manifesting resilience). While plots can holds multiple land uses and undeveloped plots can be utilised as open green space or recreation, their potential for adaptation is limited by their spatial development and supporting infrastructure and resource flows. Rather than exploring diversity through how land can be used, the approach considers how spatially the city can offer diversity for adaptation. Simply put, using zoning to reflect the functional diversity of the city does not convey the full potential that the city holds to evolve in a resilient manner.

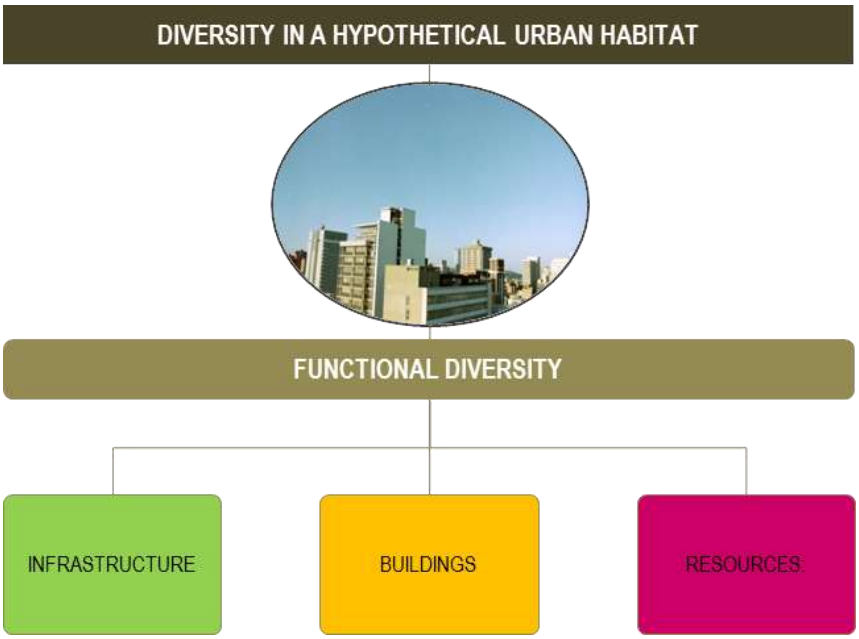


Figure 33 - Functional diversity in the physical urban habitat from which its spatial character derives (Author 2015).

Translating functional diversity of the physical structures of the urban realm that derive its spatial character, integrates the broader urban functions in built environment (as an urban ecological system) that foster the physical conditions for a city to survive. If, in a natural system, the functional groups that give structure to the system are producers, consumers and decomposers, then it is proposed that in an urban environment the functional groups,

that physically make a city function as 'a city', are infrastructure, buildings and resources (which include waste) – as illustrated in Figure 33. In this interpretation, infrastructure illustrates essential components (services and utilities) giving structure to the city and relating to movement networks like roads (vehicular and pedestrian), energy sources like electricity and gas, water systems like freshwater, potable water, wastewater and stormwater, and communication systems like fibre optic. Buildings relate to typologies and resources relate primarily to those environmental qualities that sustain life in the city, green open spaces, air quality or climate.

In the physical environment, infrastructure provides the 'skeleton', the physical service networks and utilities that are managed and maintained to enable city functionality. Buildings depend on infrastructure, but create the fabric of the city and the canvas for its character and its flow of resources. They cater to the function of 'shelter' or containment required in the city. They are also the primary habitat in which human lives unfold. Building typologies respond to zoning and land use functions; initial decisions can have a detrimental long-term impact on the urban morphology of a city due to the related building typologies and the 'left over spaces' around them. Although some building typologies like inner city perimeter blocks are highly adaptable and their land uses can change over time, others like large warehouses or factories are much more difficult to change and often have an urban structure that is difficult to adapt. So, while the zoning of a warehouse site may allow for a variety of land uses, the building typology often limits it practically to only one or two uses. This therefore directly affects the resilience of the city to adapt to changes and to provide the inherent capital for regeneration.

Resources refer to those aspects that regenerate, renew and provide the 'life force' of the city. These primarily refer to natural processes and inherent site properties from which the design management of the city harnesses latent potential. They form the basis for the broader public environment often ignored in the planning process. Resouces include left over spaces around and between buildings; private yards, public spaces and green open spaces that may include recreational amenities. These spaces hold potential and resources for natural and social exchange. In this category, flows and relationships of regenerative potential are systems on which the city depends, and can be curated by its managers.

These functional groups display two things. Firstly, a physical manifestation of the relationship between intangible flows in the city, and secondly, that there is a degree of overlap between the functional groups. The reason for having identified these urban functional groups with their spatial manifestations corresponds with the discovery that "it is not the

number of species that help sustain an ecosystem in a certain state", but rather the presence of functional groups (Folke 2006: 258). For example, a city may have a large diversity of building typologies, but without infrastructure or resource diversity it will cross a tipping point into another regime or possibly collapse. This exploration of functional diversity excludes intangible city systems such as people or governance (although these are implicit in the manifestation of physical conditions in the functional groups identified), since the focus is to understand how concepts translate into the physical urban environment. It is also because, without functional diversity in the physical environment (the biosphere), the intangible environment (the noosphere) will reflect limited diversity (refer to section 3.6.4). The physical conditions and functional groups give rise to greater potential for the city to unfold with greater depth in its intangible dimensions.

Infrastructure, buildings and resources create possibilities for the city to achieve its function as a 'civilised' physical environment of collective urban life. Without this functional diversity however, a distorted city system will take root, where environmental degradation, resource scarcity coupled with over-population and urban immigration, unbridled poverty, immature worldviews, riots and criminal activity create the 'infernal city' of the future (Whiston-Spirn 1984: 265), the present (Hamilton 2008: 76) and the past (Hall 2002: 16-18).

7.2.2 Response diversity

Within an urban system, many variables or components have specific functions that they provide. Functional diversity refers to the different functional groups that perform different tasks in an urban ecosystem. As described above, infrastructure, buildings and resources provide 'physical' functional services to the residents. To each function there are different responses for different aspects of the system. From an ecological resilience perspective, "what is important is that the different organisms that form part of the same functional group each have different responses to disturbances" (Elmqvist *et al.* 2003; Walker & Salt 2006: 69). Different response types within the same functional group are known as response diversity, and form the aspect of diversity that is critical to a system's resilience.

A highly 'efficiency engineered' system usually eliminates its response diversity to reduce high costs (Anderies 2014) and perceived wastage through 'redundancies', but in so doing creates a system vulnerable to collapse from smaller and more limited shocks. Response diversity is the aspect of resilience that efficiency and optimisation work against. Response diversity ensures that collectively each response strengthens the overall resilience of the system. If there is only one response to each function, then a disturbance targeting the destruction of that response will result in the destruction of the entire functional group.

Alternatively, if there is more than one response in the functional group and one of the responses fails, that is not to say the entire system would fail. A range of alternative responses 'step in' to take over the functions of the missing response to allow for continuity.

Based on the functional groups identified in the urban system, the diversity within their responses toward disturbances would provide a mesh of responses across different scales in the system (from more to less complex) (Folke 2006: 258), and would at times have relationships across the functional groups. This enables renewal and regeneration of the system after it undergoes a shock. In the case of infrastructure, one would find diversity in the number of responses within groups, such as road networks, energy systems, water systems and telecommunications. Scale therefore refers to the level of complexity of the response in relation to infrastructure and resources, rather than the physical area it takes up. For example, a homeless dweller illustrates a less complex response to the need for shelter in that it requires less formal investment and allows fast adaptation to pulse disturbances.

Response diversity of buildings, for example, would relate to the mix of *typologies* related to street edge and frontage and responding to the need for containment of uses like retail (exchange), residential (shelter), and civic space (amenity). While typologies reflect the physical response to land use and zoning, land use emerges from the intangible realm of legal frameworks and administration. It informs the regulatory use of a site, while building typologies determine its future trajectory and physical resilience. Land use can change over time, but the adaptability of the typology to respond to the changes is limited. Building typologies and the relationships between them provide clues as to how the city evolves and therefore serve as a valuable reference point in resilience thinking. In addition, the response to the 'building' function (enclosure or shelter) might not always be a 'formal' building in the traditional sense, but rather an 'informal' response determined by the resources available at different scales in the city.

As Figure 34 illustrates, residential or shelter responses might see informal responses like a homeless person appropriating the edges of an abandoned building, to structures like shacks, with more formal responses like RDP houses, sectional-title apartment blocks and low-density luxury estate with full-title houses (Du Plessis 2012a). In retail it might range between a street trader sitting in a caravan outside an office park, and big-box multi-national retail stores (with very slow response times) (Ferreira & Du Plessis 2013). An important aspect here is not the size of the response (since an RDP settlement, housing estate or informal settlement can all occupy smaller or larger parcels of land), but rather the complexity and rate of change the typologies hold in relation to disturbances. A sectional

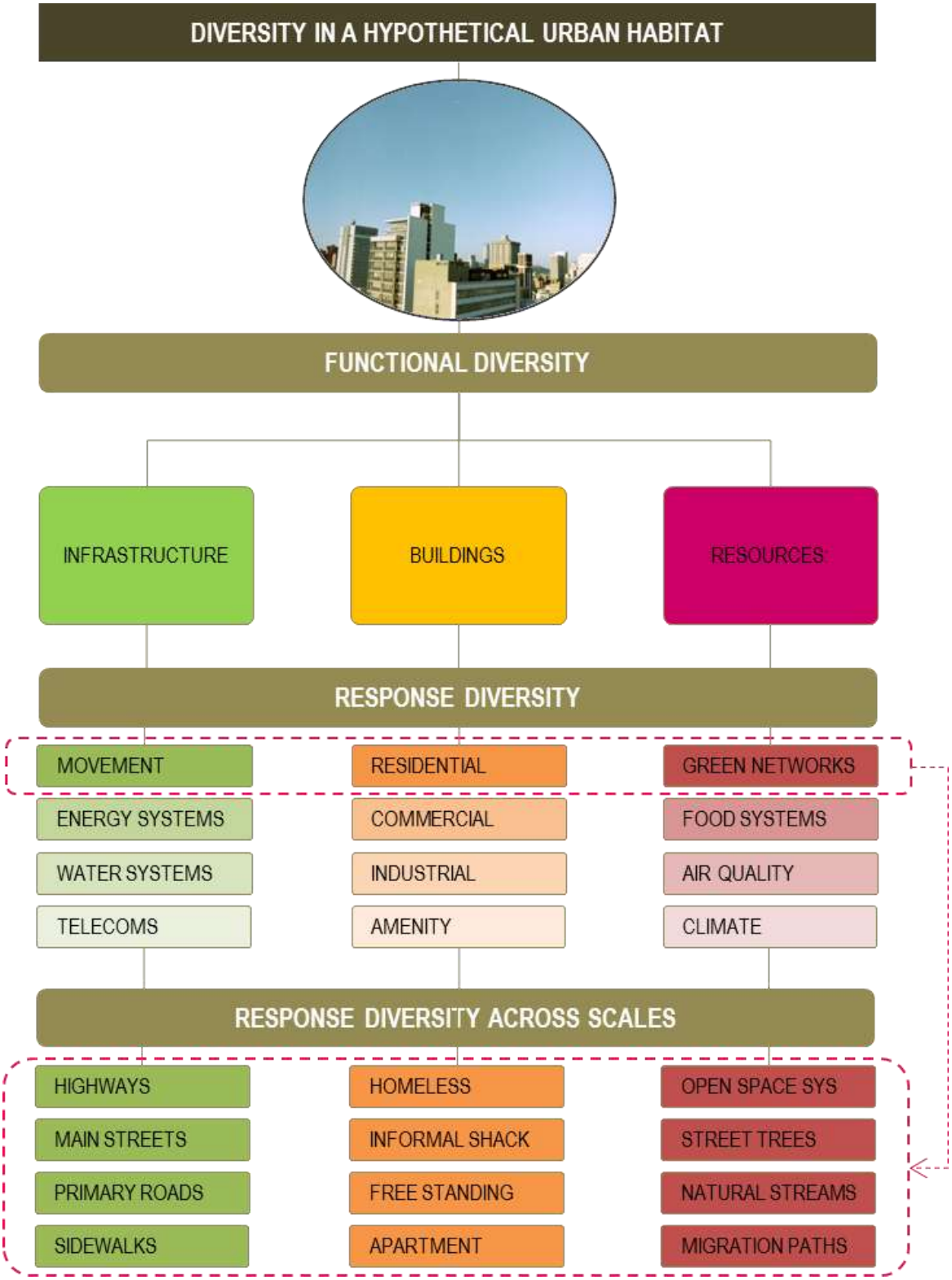


Figure 34 - Response diversity toward each of the functional groups in the physical domain of an urban system (Author 2015).

title apartment block (whether part of a larger complex or a small plot) represents higher complexity (yet limited flexibility) of responses to disturbances, than the homeless dweller (who may inhabit a street corner on his own or form part of a large group living under a bridge).

Destroying one functional response should have more manageable consequences than collapsing an entire functional group, because other functional responses can take over its role; but other functions cannot necessary take over the functional group. For resources, responses would include green networks, food systems, air quality and local climate. Similar to creating response diversity within the urban system, there should also be a diversity of planning strategies in the city. Accommodating a range of activities and open-ended design strategies can encourage a more diverse range of trajectories into which the city can evolve naturally.

7.2.3 Response diversity across scales

A key aspect of response diversity is that it changes across scales. Scale shows a level of complexity of a building unit's response rather than the area it takes. For example, a homeless dweller is a less complex response (and lower scale) to the need for shelter in terms of requiring less formal investment or capital and allowing for fast adaptation to pulse disturbances, but no less important in delivering the function need for shelter. The result of the diversity across and within scales creates "an overlapping set of reinforcing influences … like portfolio diversity strategies of investors" (Gunderson *et al.* 2002: 11). Some response types may be unique to a particular scale within the system's functionality, while there are other response types that can overlap and can function across scales so that "seemingly redundant species that operate at different scales generate ecosystem resilience by connecting habitats, thereby reinforcing functions across scales" (Folke 2006: 258).

Reponses across various scales to respond to two factors, illustrated in Figure 35: the rate of adaptation and response (response time) and the size or scale (Ferreira & Du Plessis 2013). An increase in the physical size of the unit in relation to the group also links to an increase in the complexity of the response. In a diverse response set, the disappearance of a specific response type due to a disturbance does not signal the end of the functional group. Other responses within the same functional group will 'assume' the role of the missing response and "the service provided by a functional group is likely to be sustained over a wider range of conditions" (Walker & Salt 2006: 70).

Within an urban system, response diversity across scales can be described as a set of different types of responses that fulfil the same function. For example, the response set for vehicular movement networks is divided into a number of types like highways, main streets, and primary and secondary roads. Green networks (which also overlap with pedestrian movement networks) in turn are divided into a wide range of response types such as, but not limited to, open space systems that include public spaces like squares and parks, street

tree networks, natural streams and migration paths. Building response types can be described by building typologies such as gated estates, apartments, RDP housing or informal settlements within the response set of residential or shelter. Architecturally, response diversity is reflected in the robustness of the building typology, its position on a stand and the design of its edge conditions, core structure, shape and technologies, which critically define the potential evolution, usefulness and reuse of the building in future and over time.

Building typologies have a very close relationship to their use - industrial buildings have a very different size, structure, and repurposing value than residential buildings. However, buildings are also highly adaptable and buildings with heritage value that are sustained over decades and centuries are often repurposed to accommodate uses that are very far from their initial intended use. This indicates that, within the building function in the city, there can be a lot of overlap between building typology responses over time, resulting in high levels of connectivity and diversity between responses across scales.

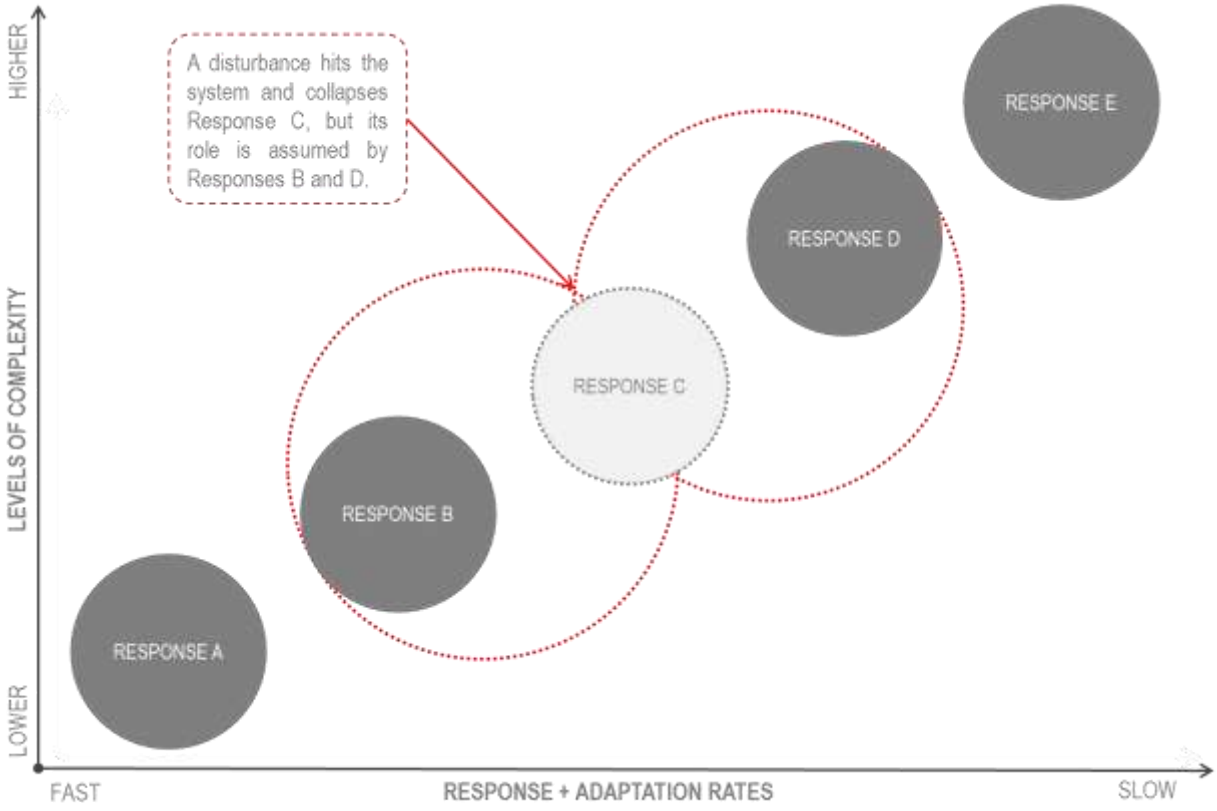


Figure 35 - Response diversity across scales, adapted from Ferreira & Du Plessis (2013) (Author 2015).

Focusing on the residential response set, a number of changes are visible in the different responses to the need for housing or shelter in the city of Tshwane (see Figure 36). At one end, with the fastest response time and best possibilities for adaptation to disturbances, is

the homeless street dweller living in the inner city. High mobility and few positions or other constraints allow the homeless street dweller to find shelter in undefended spaces in the city and to survive in parallel to formalised and highly complex urban management systems. On the other end, a high-rise apartment block shows high levels of complexity, but slower response or adaptation times.

Complexity is evident in the building systems, structure and technologies of the apartment block, the ownership mechanism (a sectional title scheme where each unit owns a proportional part of the capital asset, and is proportionally liable for all payments), social complexity in negotiating good neighbourliness among a high number of unit holders and residents, and in running and maintaining the property. Due to the increased complexity in this typology, it will respond to disturbances slowly and with difficulty since its built-in complexity requires more feedback from internal connections. For example, the homeless street dweller moves to a different location in the city in response to feeling threatened by criminal activity in the street. The apartment block will not have that level of mobility and will need to first hold a meeting to obtain a majority vote from unit holders to agree to invest more capital in the building to increase its robustness – this will take time to organise and the response time will increase.

Figure 36 - Residential response diversity displaying levels of complexity in the Tshwane panarchy, adapted from Ferreira & Du Plessis (2013) (Author 2015).

If the RDP typology is removed from the scenario shown in Figure 36, the informal settlement sector as well as the freehold housing typology will assume part of this need through a number of responses. For example, just in informal housing, responses might include: shacks built in 'left over' urban space, backyard shacks, overpopulation in densely renovated rental units in apartments, or the illegal construction of housing on land which has been falsely 'sold'. Each response set comprises a number of responses across scales that work together to fulfil the overall function of the systems group. Greater diversity in responses increases the potential of the system to absorb change.

7.3 Redundancy

> The bottom line for sustainability is that any proposal for sustainable development that does not explicitly acknowledge a system's resilience is simply not going to keep delivering the goods (or services). The key to sustainability lies in enhancing the resilience of socio-ecological systems, not in optimising isolated components of the system (Walker & Salt 2006: 9).

Redundancy within the response diversity of a functional group can be described as an 'insurance plan' or a 'backup' (Zolli & Healy 2012: 13) for the system at a time when things go wrong. Redundancy is the means with which the response diversity of a functional group can be increased, which in turn increases resilience in a system independent of time or scale (Anderies 2014). The diversity of responses creates a measure of overlapping roles and resilience where "interactions reinforce one another and dampen disturbances" (Gunderson *et al.* 2002: 9). A loss of redundancy in the system means a loss in resilience, which creates a brittle system that is unable to adapt or evolve to change and therefore becomes vulnerable to disturbances and collapse.

Interventions in response to vulnerabilities in a system are usually undertaken to make a system more resilient toward specific disturbances, like channelizing streams to prevent flooding or creating more lanes in a highway to relieve traffic. Capital and energy is invested in optimising the system in response to disturbances, while overall redundancies (often variables in the system that are not easily visible) are removed. Improving efficiencies in a system, usually at a cost of its reserves, increases demand since costs usually decrease with efficiency, and production that is more profitable is immediately possible (Jackson 2009: 63). The consequence of optimising a system to be prepared for specific disturbances is an optimisation of the capacity of the system for a specific threat (Walker & Salt 2012: 19). The general resilience in such a system becomes crucially diminished, and the "feedback mechanisms that had once contributed to expansion begin to work in the opposite direction" (Jackson 2009: 64).

Redundancy is usually considered with contempt, because of two perceptions that are rooted in the mechanistic or Modernist approach. The first perception is that redundancy in a system represents an inefficient waste of resources. The second perception is that it is too costly to build redundancy into a system, because it would basically be a duplication of existing functions (Anderies 2014).

Both these perceptions are true in the context of simple systems; however, when applied to a complex adaptive system, they are highly inaccurate. Firstly, a complex adaptive system has properties of aggregation, non-linearity, diversity and flows (Holland 1995) in which it becomes difficult, if not impossible, to specifically design for the efficiency of the system. In this case, the very redundancy that is eliminated from the system might be the aspect of the system that 'steps up' and gives it resilience during a disturbance. In addition, as circumstances change, the back-ups may no longer be as effective, in which case others will assume their role (Zolli & Healy 2012: 13).

In a complex adaptive system like a city there is no 'waste', since every aspect of the city is performing a function even if it is not always clear before a disturbance at which point its latent potential becomes a resource. Secondly, the high costs of building and maintaining redundancy (or resilience for that matter) are often placed under pressure in good times when they seem superfluous (Zolli & Healy 2012: 13).

Actions toward efficiency are usually a reflection of a capitalist system that seeks to optimise inputs to create maximum profits. Short-term costs and capital investment are the focus of business and governance planning and management, with little input given to the long-term costs of system failure and risks arising from system vulnerability. Rather, more focus on seeing resilience as resulting from "partially redundant control processes that act at different scales to mitigate effects of perturbations" (Gunderson *et al.* 2002: 61) would improve SES design and management.

Recognising that redundancy improves functionality, and thereby increases the profits of the system (not just economic, but social, ecological, spiritual), creates a shift in focus for development to recognise the hidden value behind things in a world that is changing fast. These aspects are discussed in this section with particular reference to motivating how redundancy plays out in the city, how this creates resilience in the urban system, and how resources should be nourished.

7.3.1 City system redundancies and their paradoxical efficiency

Anderies (2014) argues that ecological resilience approaches are translated into the design of the built environment with difficulty, and that 'robustness frameworks' that focus on specific resilience to a bounded system should rather be investigated. Robustness frameworks evaluate various systems, in order to gain some general principles for designing robust cities. However, given that urban systems are continually in flux, responding to social change through technological, political and economic shifts as well as profound environmental disturbances from climate change, designing a city to be robust toward a bounded set of known goals or disturbances at this fixed point in time can be detrimental to the general resilience of the city system over time. Furthermore, management of a specific set of "narrowly defined goals … encourages people to build up a dependence upon its continuation while simultaneously eroding away the ecological support it requires" to evolve over time (Gunderson *et al.* 2002: 3).

Reducing redundancies in a system creates the same difficulty that arises when a part of the system is held constant. The entire system adapts to maintain this 'efficient' regime, which usually means a loss of response diversity and therefore resilience of the whole – there is no room for change or evolution. Optimization or efficiency results in destroying complex values within a system in favour of simple ones, and usually involves limited time horizons driven by the singular focus of monetary profit (Walker & Salt 2006: 7). Efficiency itself is not necessarily 'the' problem. The challenge lies in using a resource to its full potential with little or no waste, without removing it. Completely removing a resource comes at the long-term cost of destroying the rest of the system. The problematic perspective of optimisation is derived from the flawed perspective that ecological systems are hovering at the point of equilibrium, and so their resources can be used infinitely by adapting their optimisation, as long as the ecosystem itself is not destroyed (Walker & Salt 31).

Complex adaptive systems do not exist in static equilibrium, and trying to 'fix' them is therefore an attack on their ability to adapt and sustain themselves. There is consequently no 'optimal' equilibrium for a system such as a city, because the nature of a system is that it is always in flux. There is also no possibility of control and command, because within a complex adaptive living system, no-one is in control. Optimization and efficiency of aspects of a system are paradoxes that work against the nature of resilience, which is one of diversity, complexity and redundancy. Instead, they make social-ecological systems more vulnerable to shocks. Making resources more efficient is not the path to sustainability that current practices push.

Redundancy in an urban system relates to creating a set of responses that work together to fulfil a function. As conditions change, the rate at which they take over more control of the system function becomes a measure of its resilience to persist beyond disturbances. Ironically, a system with a healthy diversity of responses and redundancy is probably more efficient at its own and higher scales and over time, than a system that is solely dependent on one response and which risks collapse following a single well targeted disturbance.

By examining the focal system of a small, gated estate south of Tshwane illustrated in Figure 37, we can look at the value of building in redundancies from the perspective of the road network, the electricity system, and security versus vulnerability. Currently, the neighbourhood is dependent on a single point of entry into and exit from the estate off a busy, high-speed road that links to a large residential development called Midstream Estate, and a number of commercial and industrial sites.

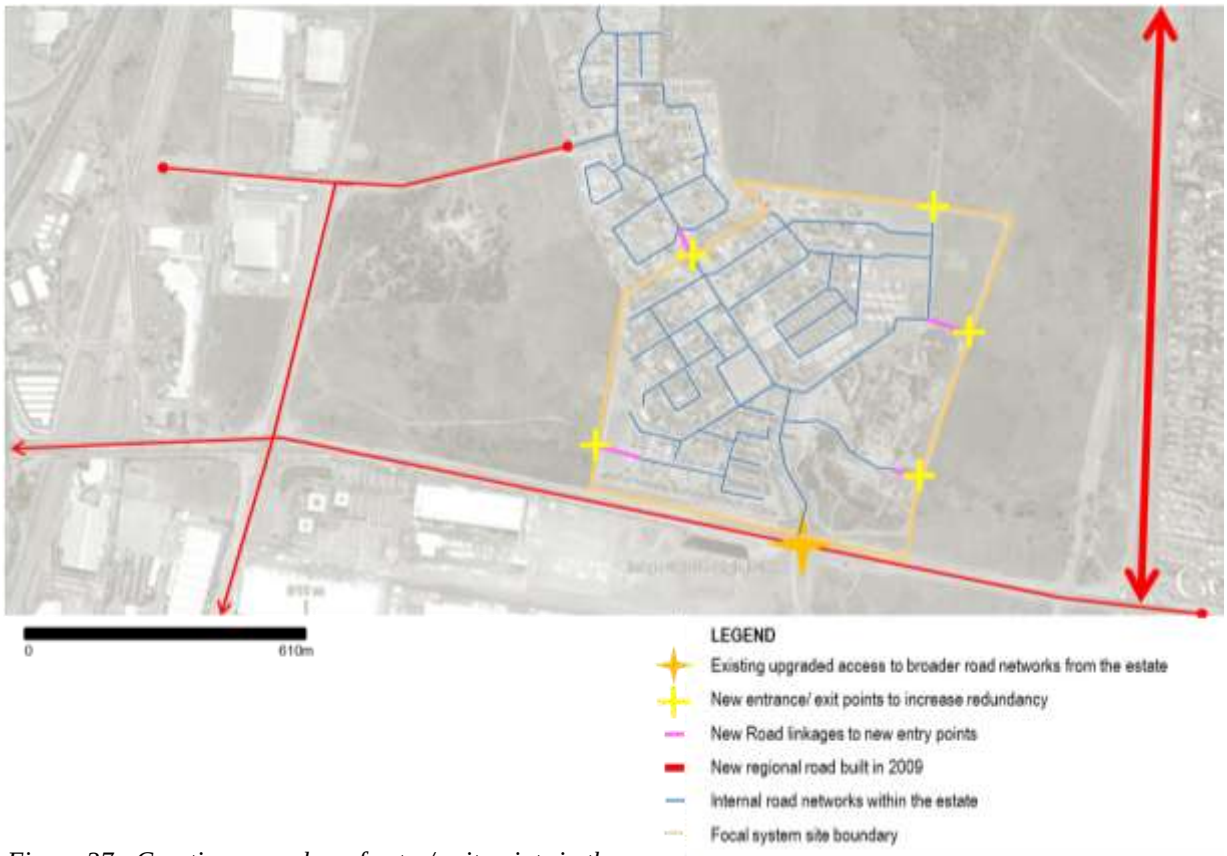


Figure 37 - Creating a number of entry/ exit points in the perimeter of the estate to increase mobility. Base image courtesy of Google Earth Images (Author 2015).

Traffic congestion and accidents have placed pressure on the regional road network to adapt, with an extension of a large regional road built in 2009, as well as road widening and traffic lights installed at the entry point in 2014. These interventions have made the larger road network more efficient for now, but efficiency does not eliminate the risk of traffic

jams or accidents. Future press or pulse disturbances stemming from increased development in the area, climate change, electricity cuts, and social insecurity, increase the vulnerability of the community inside the estate who are dependent on a single entrance point. Capacity for resilience could be built up by incorporating redundancy principles: create responses to the function of 'entrance/ exit' by including more entrance points and links in the broader road network. These responses need not be designed to the same high specifications as the existing entrance, but can respond to needs at various scales (from a few individuals to the entire estate).

Electricity concerns impact on property development in the current South African context. A mismanaged electricity service provider, Eskom, has the monopoly on electricity provision in the country. Various power stations supply the national electricity grid and diesel generators form their backups, thereby partially fulfilling the need for redundancy at a national scale. However, most of the electrical supply is based on a centralised grid generating electricity from non-renewable resources. The amount of electricity generated using this system and its back-ups can no longer meet demands, leading to frequent blackouts. Without electricity, the security systems at the estate cannot function, and the residents are once again vulnerable to criminal activity in addition to other problems associated with an electricity failure. At the scale of the estate, redundancy could help by decentralising the source of electricity provision by creating on-site solar energy systems (renewable), along with generators (non-renewable) or even a co-generation plant.

Solar geysers and photovoltaic panels on the roof of each home could ensure that, during the day, essential appliances or lights could work. Small back-up batteries could store some energy into the night. Heat pumps could further decrease the need for electricity, and gas for kitchen use (perhaps even generated from a local waste treatment plant) would ensure that households are minimally disturbed during a black out. Smaller demands for each of these energy sources and on-site generation would create a deeper awareness of what is being consumed by an individual household, as well as decrease the vulnerability of being dependent on a single source. The perimeter fencing, LED streetlights and CCTV cameras and beams could be supplemented by solar or generator power. Lower consumption and ongoing functionality means that this system of redundancy is actually more efficient, since the comfort of homeowners is not critically affected. They have more options available to respond with, and their security (perhaps a key reason for moving to an estate) is not compromised. Redundancies in the responses of the system increase the potential of the system to absorb change.

7.4 Modularity

> This modularity allows a system to be reconfigured on the fly when disruption strikes, prevents failures in one part of the system from cascading through the larger whole, and ensures that the system can scale up or scale down when the time is right (Zolli & Healy 2012).

The linkages between components in a system create a certain structure or pattern that affects its future performance. Lack of connectivity or isolation can create a vulnerable system; however, a highly connected system can also be exposed to greater risks and disturbances cascading through it (Gunderson *et al.* 2002: 136). Complex adaptive systems like SESs may appear to be outwardly complex, but their internal structure is often made up of simple arrangements between modular components that can accumulate or decouple in response to changes in the system.

Such a modular system is capable of localising the shocks of a disturbance and therefore maintaining the overall system functionality. Resilient systems have modular structures that are "diverse at their edges, but simple at their core" (Zolli & Healy 2012: 11) and have "subgroups of components that are strongly connected internally, but only loosely connected to each other" (Walker & Salt 2006: 121). In case one of the subsystems, illustrated in red, green and blue in Figure 38, is disturbed or collapsed, the nodes where loose links to the rest of the system connect (shown in grey) will be able to absorb or to adapt in response to the impact. On the other hand, a fully connected system following a pure hierarchical structure transmits the shock of a disturbance throughout the whole system. The optimal solution is a system with a diversity of tightly interacting subcomponents loosely connected within the holarchy (Walker & Salt 2012: 96).

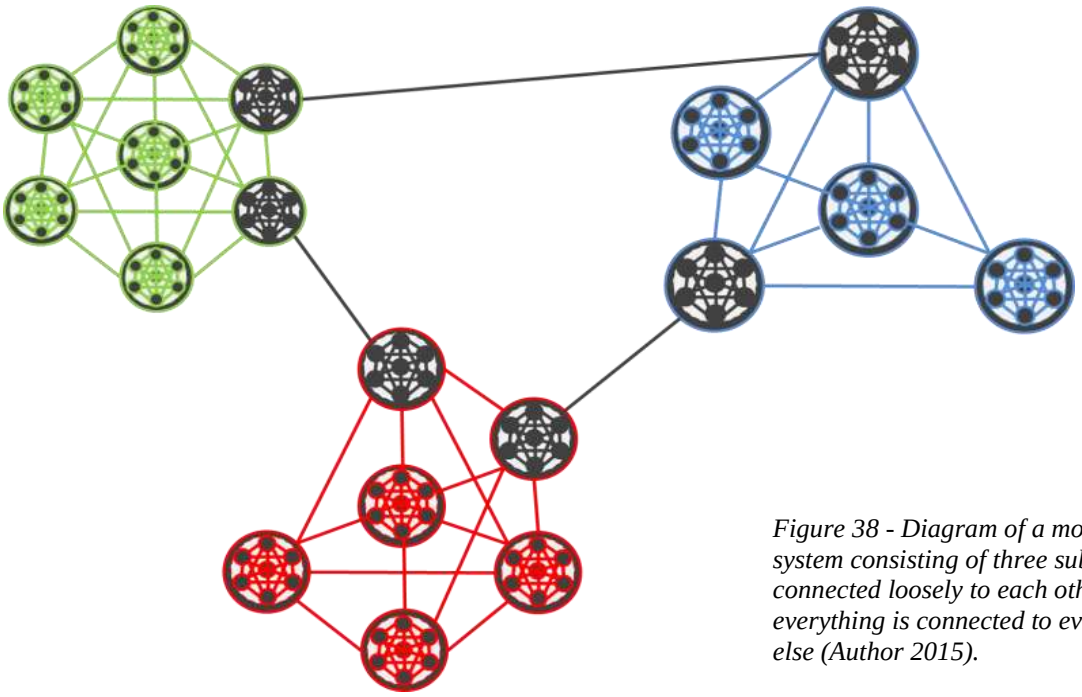


Figure 38 - Diagram of a modular system consisting of three subsystems connected loosely to each other. Not everything is connected to everything else (Author 2015).

7.4.1 Scales and networks

As described in Part Two, the scale of the system we call the focal system is linked to scales above and below. It is a holarchy, a whole system, of linked subcomponents undergoing constant adaptive change across different scales, the panarchy. A small set of processes at each scale govern structural patterns and dynamics that then form the basis of the behaviour of the whole system. These processes are often the simple rules that inform subcomponents in a system to create linkages between each other where the patterns found in the whole exist in the parts (Lipton & Bhaerman 2009: 226). When these rules repeat

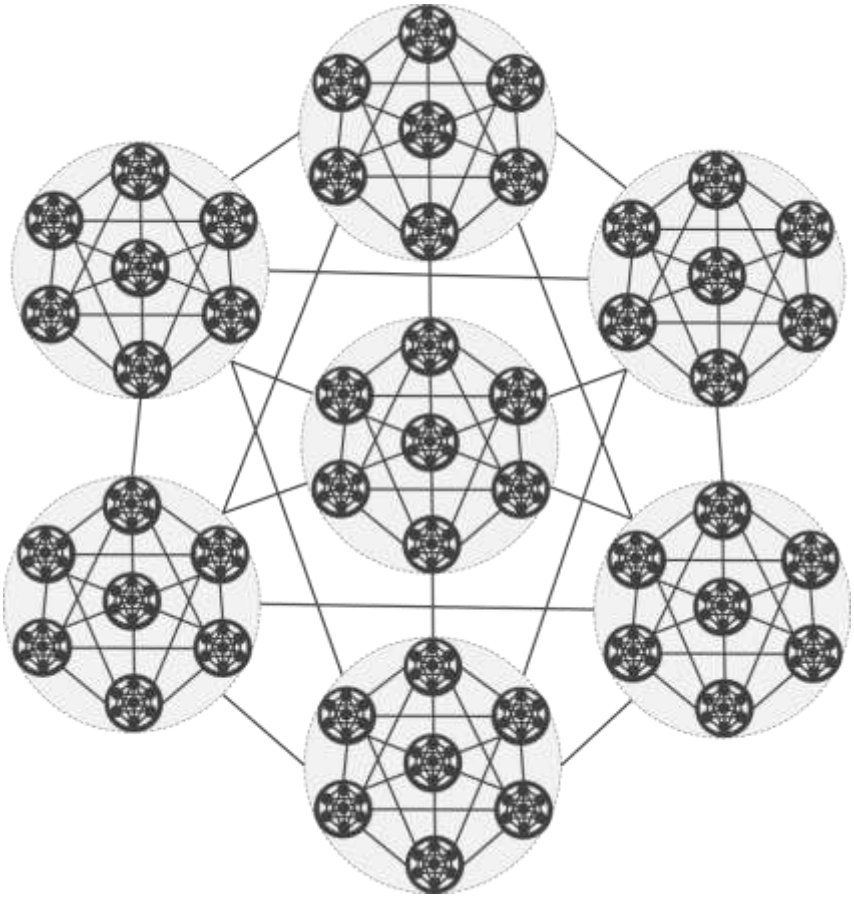


Figure 39 – A diagram showing a fractal, in which similar complexity levels repeat infinitely across scales (Author 2015).

across scales, and the same linkages repeat between subsystems, then a fractal relationship as shown in Figure 39 is formed. This structural feature represents a self-similarity where even at smaller scales "you will get a pattern that looks much like the whole" (Buchanan 2002: 102). This replication of processes and functions then produces across-scale resilience (Gunderson *et al.* 2002: 10).

An important insight into the exploration of connections between components and subsystems is that the weak connections between subsystems and components are stronger than the strong linkages (Buchanan 2002: 46). Weak ties can be described as 'bridges' (Buchanan 43) that link distant parts of the system. In times of a disturbance, systems that are tightly knit with strong links will feel the effects most pronouncedly, but will limit the distribution of the disturbance along its weak links. The alternative is also true. In times when a disturbance does strike, the weak links between systems can be used to call on reserves from elsewhere in the larger system.

Figure 39 represents one of the green subsystems in Figure 38. Internally, each light grey circle has a high level of complexity and relationships between subgroups. Essentially, a change in one subgroup is felt in all the subgroups inside the circle so that, if the disturbance is too big, the entire grey circle might collapse. However, each grey circle group has either five or six linkages to the rest of group. At higher scales, if one of the groups collapses it does not need to mean a collapse of the entire system. In urban systems, fractal geometries were embedded in the design of cities in the past, "maintaining the scale laws of urban complexity" (Salat 2011: 64). Complexity is visible in older cities from city-wide, to neighbourhood, to building scale. Fractals provide a solution to marry the contrasting scales of global versus human within the physical urban environment, and to follow the example set by the connective structure of a leaf (not a tree), where its internal connections make it entirely connected to its smaller scales (Salat 2011: 66-67).

However, cities do not only consist of the physical environment; they have social-ecological components that do not always behave as predicted. Harisson *et al.* (2014: 13) suggest that South African municipalities should be decentralised from other government structures to increase their autonomy and reduce their risk of collapse. In addition, they suggest cities should reduce their dependency links to other cities, a call similar to that in Jacobs's *Cities and the wealth of nations,* which seeks for cities to produce and diversify within their own footprints to avoid 'stagflation' (Jacobs 1984). This brings to light issues around politics and power and the impact that some systems and entities will hold over others. While decentralisation may be useful for management and governance of independent municipalities, it may also further disempower those entities with weak resilience. This risk is discussed further in section 8.6.7.

When social-ecological systems operate in a resilient manner, their subgroups have the ability to swarm when necessary or detach during disturbance due to the modularity, simplicity and interoperability that defines the linkages in the system (Zolli & Healy 2012).

When systems swarm, they create loosely connected clusters of resources and reserves with high density and diversity. This requires 'within-scale' overlap of functions between similar processes occurring at similar scales (Gunderson *et al.* 2002: 11). An example of this is when communities pull together during times of disaster, such as Hurricane Sandy or the recent Nepal earthquake. The alternative to swarming is when systems modulate their functioning and decrease it to a minimum for long periods of time until the right time emerges for them to swarm again (such as with microbial infections or terror networks) (Zolli & Healy 2012: 61).

Swarm outbursts can be the source of positive release of potential, but the inverse is also true. They can be times where 'dormant' groups cluster to create massive strategic disturbances in a larger fragile system (otherwise, the opportunity would not arise for a swarm). For example, Zolli & Healy (2012) describe how terror networks operate under the premise of assimilating radical cells of disenfranchised individuals around the world into a loosely connected network. When the opportunity arises, some members will swarm to produce a high-energy disturbance that will profoundly shock the system. Resources for growth are present but weakly connected, so that in a sea of chaos they can nucleate to explode into a new path (Gunderson *et al.* 2002: 14). In return, the system responds ineffectively by using far more resources to root out the trigger (but not the drivers) thereof.

Due to the modularity of the system, once the trigger (or persons) is rooted out, another will take its place so that even if ten to twenty percent off the organisation's membership is eradicated, "the network as a whole will continue to function" (Zolli & Healy 2012: 66). In this way, terror networks increasingly gain strength due to firstly, the small investment made on their part to get a big effect, and secondly, the continual presence of the broader drivers that are pushing them to act in this way. Until either the drivers putting pressure on the system change, or the broader system transforms to increase (or decrease) its own resilience, the trend will continue.

7.4.2 Flexibility, variability and openness

By encouraging flexibility, variability and openness in a system, the flow of energy and resources can shift dynamically to places where it is needed and for the system to evolve dynamically. In urban systems as in ecological systems, the tendency to dampen and control perceived 'negative' conditions, may be destroying variability within the system and thereby increasing its vulnerability to what used to be ordinary shocks (when the system still had variability). For a system to remain resilient, it must be flexible so that the system can

probe its own boundaries. To be flexible it needs to be open to the flows of people and social and economic forces through the system (Walker & Salt 2012: 94).

7.4.3 Exploring modularity (or lack thereof) in the Tshwane built environment

Lynnwood Road is a prominent connector road in Tshwane, linking the eastern suburbs with the high-density suburb of Sunnyside. Initially, it connected the 'early' eastern suburb with smallholdings far from the city centre; however, development along this route intensified over the past twenty years with a peak during the last ten. What was once an urban fabric characterised by agricultural smallholdings with a distinctive spirit of place, has become a series of security complexes and shopping centres catering to a high demand for property in the eastern suburbs. This section of the dissertation assesses modularity in a small sample area off Lynwood Road in the suburb of Equestria, illustrated in Figure 23 in section 5.6.1 and Figure 40. The assessment focuses on the physical road network and excludes possible levels of social or ecological modularity. It maps physical linkages or connections and pre- and post-residential development between 2001 and 2014, and will discuss how the morphology affects the scales above and within, as well as the impacts of flexibility, variability and openness on the urban network. Noticeable differences are visible in the aerial photographs taken between 2001 and 2014. Changes include:

- An increase in built up areas and densification. In the case of one smallholding, a single unit per stand increased to 56 units, resulting in 56 times more traffic, electricity demand, water use and waste, as well as volumes of storm water.

- A decrease in the volume of green space, with fewer trees and un-built areas, significantly decreasing biodiversity and ecological responses to absorb rainwater, purify the air, and reduce the heat island effect.

- A change in the dominant scale from coarse to fine-grained deformed grids. The change in typology marks a visible change in the city, from large suburban stands with freestanding units to new developments following a densification model of double storey houses on small stands within a secured perimeter wall.

- New broader or city-scale road linkages introduced. Roads upgraded to carry more traffic and access locked-in land parcels for development. Three new connecting roads built with one new connection to Lynnwood Road to relieve traffic.

The security complex or estate residential typology has a very significant layout. This pattern repeats irrespective of the scale of the development, and is described as follows. While the

local road layout (shown in blue in Figure 40) may represent a well-connected internal layout of vehicular roads and pedestrian routes, on a broader scale (shown in red in Figure 40) these complexes are limited to one monitored access point (or two to three in very large developments). Each security complex functions more like the tree Christopher Alexander warns against (Alexander 2011) than Salat's leaf (Salat 2011).

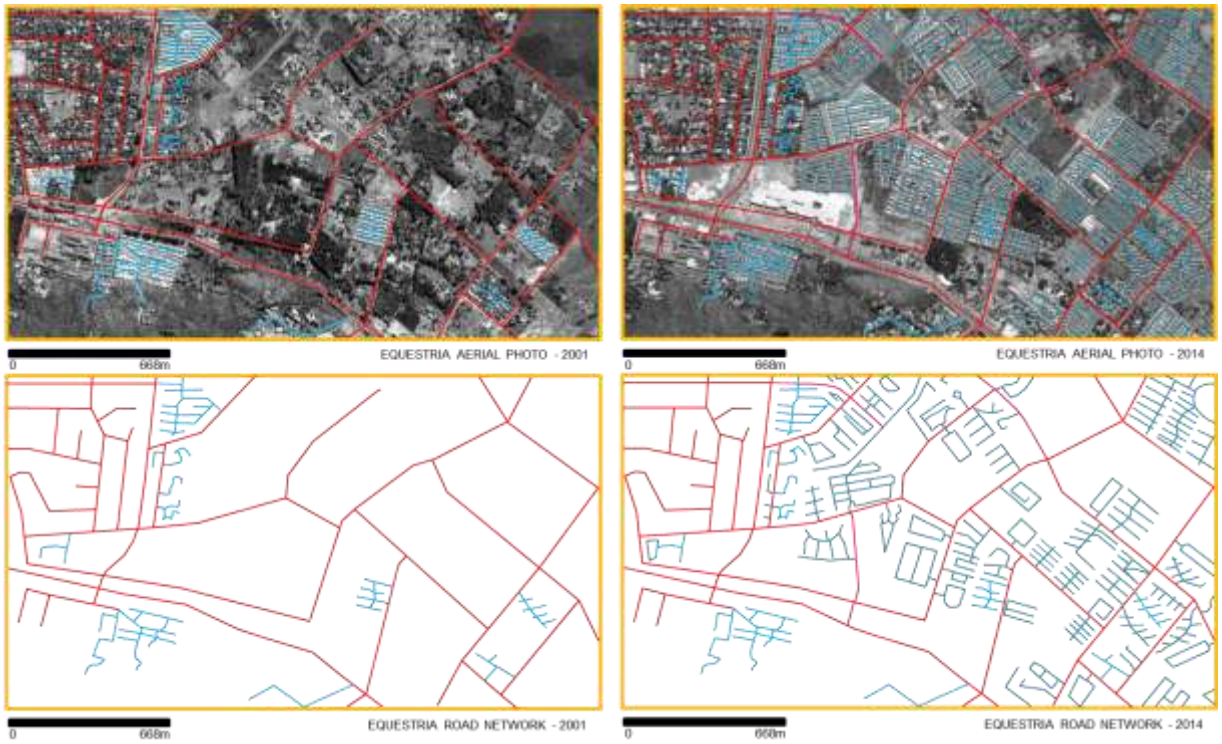


Figure 40 - A sample area of changes in Equestria between 2001 & 2014, focusing on the road network (aerials accessed from Google Earth) (Author 2015).

In a row of security complexes (1-4 in Figure 41) that share access to the same road, each complex forms an independent module. If there is any disturbance within the complex (say for example an explosion and subsequent runaway fire in one of the units near the main entrance), the complex would be highly disturbed and could possibly collapse (say if the fire brigade were unable to enter the complex). A collapse would be devastating to the complex itself; however, its long-term effects on the broader system would be minimal since there were no flows through the site and it offered no flexibility or variability to the larger network. At the scale of the security complex, the sample area has modularity (but no network flow, flexibility or variability). The broader system is not dependent on the individual complex, and can function in spite of disturbances within. It is not a holarchic system.

The inverse applies. The local system is highly dependent on the broader system for its optimal functionality. If the main access road shown as the thick red line in Figure 41 has a major disturbance, such as a sink hole at each intersection with the broader roads shown in red circles, access points to the complexes numbered 1 to 4 (the orange stars in Figure 41)

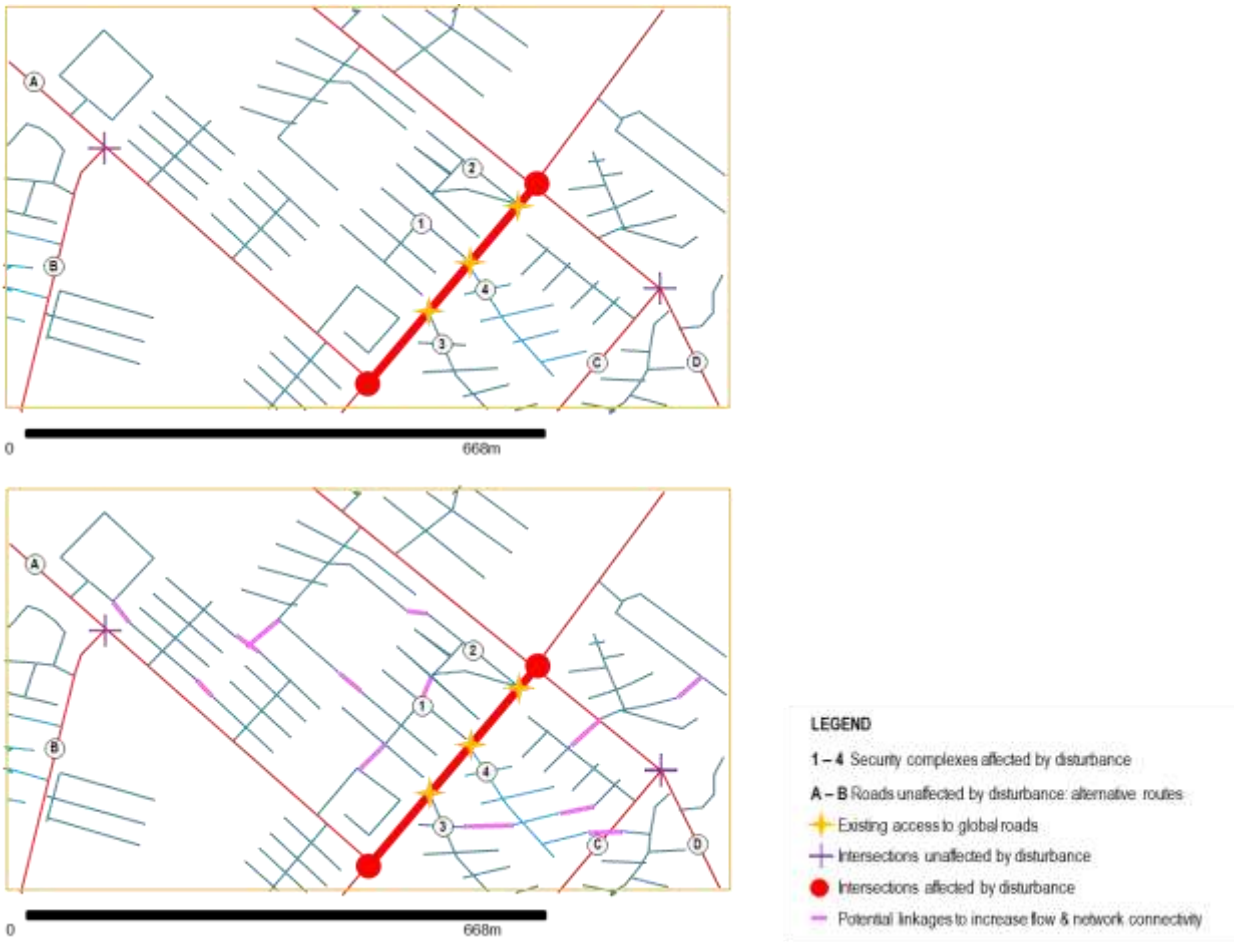


Figure 41 - Exploring modularity in a small sample area of security estates in Equestria. The image above shows the current situation, while the image below shows a modular system with loose connections to the broader system (Author 2015).

would be affected. Alternative access routes to the broader road network do not exist, since the internal layout is built-up along the perimeter edge. At the scale of the disturbed complexes the impact is significant, but at the scale of the broader road network, a loose network of alternative roads enables the broader system to continue to function.

What could a modular approach have been in developing this area? The definition of modular as being "diverse at their edges, but simple at their core" (Zolli & Healy 2012: 11) reflects the simplicity of a modular unit's internal structure or function, which builds in complexity in the way in which it connects to the broader system. In the example presented in Figure 41 the internal layouts have various levels of simplicity; however, there is no complexity built into the manner they as modules connect to the larger system.

The response is always the same: a single access point. The other definition of modularity as having "subgroups of components that are strongly connected internally, but only loosely connected to each other" (Walker & Salt 2006: 121) describes modules that have strong internal connections. This is partially true in the example above. Of the four complexes along the bold red road in Figure 41, most internal layouts depend on a sequential

hierarchy much like the structure of a tree (security complexes 1, 3 & 4) with only one (security complex 2) providing an alternative internal route to the main access point closer to the structure of a leaf.

As a result, the internal layouts are not necessarily well connected. They connect to the larger system with only one access point; this makes them more vulnerable on a network level. The modules do not connect to each other, meaning that while they can function independently, they need a lot more resources to do so, and when the system module eventually crashes, they will be unable to call on the network for backup assistance to absorb the disturbance. For security purposes, the single access point can be under constant surveillance to prevent unauthorised entry to the complex. It works from this perspective. However, focusing on security at the expense of other considerations has weakened its general resilience. This study area is not modular, for it has poorly connected internal networks and few loose external connections.

The answers to what a modular approach could have been are found in scale, flexibility, variability, and openness in the network. The design of at least one or two connections between each security complex, as illustrated by the lilac lines on Figure 41, would significantly improve the general resilience of complexes 1 to 4 to handle a wider range of disturbances. These need not be permanent roads; they could be servitudes with gates on the boundary line that open during an emergency. This would increase the capacity for resilience in the system; its ability to scale up or down as needed; variability in options; flexibility to evolve and respond; and openness to potential change. Complexes would remain responsive to current needs for security, without compromising on future needs.

7.5 Reserves

> Adaptability and transformability depend on the capacity of people to maintain or change the social-ecological system in which they live. Adaptability to upcoming challenges depends on human choices being made now. Better choices are likely if evolving changes are faced clearly and collaboratively, with minds open to the surprises to come (Walker & Salt 2006: 110).

Urban systems need high reserves of human, natural, built and financial capital that the city can draw on during times of disturbance (Walker & Salt 2012: 98). However, the trend in development over the last century has been to build, exploit and create in ways that weaken or destroy the built-in reserves of the global ecology and its social systems (Walker & Salt 94). Many modern cities shaped by an Enlightenment worldview perceived nature as a resource to exploit to serve human interests. Exploitation of natural systems occurs without consideration for the long-term effects. In addition, the pursuit of efficiency has led to a loss

in systems reserves and capital. Today, the disconnection between built and natural environments threatens the physical functions of the city due to a depletion of its natural reserves. However, the depletion of essential urban reserves extends to people, history, culture and memory, so much so that the "economist lives on capital that it cheerfully treats as income: this capital is fossil fuels, the tolerance margins of nature and the human substance" (Schumacher 1974: 16).

Resource reserves in an SES can be tangible resource reserves (comprising the biosphere) and intangible resource reserves (within the noosphere). Resilience is re-established by the system's 'memory' (Gunderson *et al.* 2002: 16) of past processes, i.e. the intrinsic qualities of the focal system that connect it to the present time and the broader system, and can thereby protect against known risks associated with disturbances (Gunderson *et al.* 127). The diversity, quality and quantity of resources in a system are directly proportional to the functional and response diversity in the system in both of the spheres. The more an SES destroys or depletes its resources without replenishing them, the more its response diversity decreases and subsequently decreases the resilience of the system as a whole. Monitoring existing resource reserves in a system, and those that are overburdened or overshot, highlights the importance of systemic functionality and resilience. However, urban sustainability experts are saying that this is no longer enough: resource reserves must be used efficiently, and above that, they need to be actively regenerated (Westley *et al.* 2011; Mang & Reed 2012; Du Plessis 2013; Hes & Du Plessis 2015).

Nurturing the diversity of resources by working with their inherent qualities and potential creates conditions to regenerate and manage the flows of the urban system. This notion of system regeneration ties to transformative resilience, where the system is influenced to achieve certain goals. Transformative resilience seeks to create conditions in the city where life can actively regenerate by transforming failing systems. Projects become "engines of positive or evolutionary change for the systems into which they are built" (Haggard, Reed & Mang 2006). The latent potential inherent in a site or building is analysed to find ways in which different systems can feed each other by sharing resources (such as cross-programming and industrial ecology), or how re-envisioning urban processes can enhance connections between local communities and nature. When development is valued from eco-positive perspectives not only economic gain, it is called 'net Positive development' (Birkeland 2014: 67). Systems produce more resources than they use. Although regenerative and net Positive development are not clearly outlined strategies in ecological resilience, they are critical perspectives in going beyond maintenance toward enhancing and renewing system reserves to increase general resilience.

7.5.1 Enhancing the inherent potential

Understanding the resilience of a social ecological system informs design interventions in the city that "can preserve or enhance a system's own restorative powers" (Meadows 2008: 78). There are times when an intervention, be it a building in a city or a social enterprise in an ecosystem, follows the correct procedures, engages with the right people and aims to create a positive contribution, but fails to thrive into the future; despite best intentions, the project is misaligned. This is partly because interventions are often looked at in isolation of disciplines and their context (Mang & Reed 2014). The deepest qualities of a context as well as the roles and relationships flowing through it are missed due to working and thinking in 'silos'. These qualities define the 'personality' of a place that will inherently have an effect on any intervention. When new development functions are misaligned with the inherent qualities of the site, then they are always out of sync, and in worst cases expend more energy to maintain them than would have been necessary if the intervention incorporated the natural 'story of the site'. This inherent potential is therefore revealed in narratives called the 'story of place'.

Resilience emerges from and is rooted within a specific context. Strategies that amplify local processes, characteristics, and 'natural dynamics' are more responsive to the inherent tendencies and potentials of a site (Gunderson *et al.* 2002: 245). Contextual uniqueness affects interconnected and interrelated systemic relationships influenced by pulse (fast) and press (slow) disturbances across many scales that burden system functionality. Every place has a story of its origins and functions, and this story provides clues about the potential and direction that future development can follow. Design is then generated from its positive qualities, rather than from trying to 'fix problems'. New functions align with the potential sets of the site, allowing uses to evolve toward greater complexity and depth. Designing for regenerative conditions leaves room for the unexpected to occur, by creatively unlocking ways for the latent potential on site to connect the tangible environment with the intangible psychological and spiritual well-being that is integral to life in the city.

Regenerative projects create or 'give back' more than they expend across social, historical and ecological systems by working with the potentials on site, and amplifying inherent qualities to build reserves in a system; they are generated from a keen appreciation of the physical integrity, biography and 'essence' of the site. Christopher Dey asserts, "all places are formed in the past. All ideas for building projects are in the future. Unless we can marry past and future, everything we do will always be, at least in part, 'out-of-place'" (Dey 2000:134). Furthermore, there are certain patterns that emerge following an investigation of the history of a place that can describe how "the network as a whole would still have the

same fractal character" (Buchanan 2013: 103). Aligning development to the historical evolution of the site and its natural trajectories – its story of place – contributes fundamentally to the long-term success of any intervention (Mang & Reed 2012) and builds the reserves of the site to provide greater resilience. It also allows for the city to continually emerge in agreement with the evolution of the smaller scales that ripple through to higher scales to create the order of a city, which at a time of profound urban change that is breaking the evolutionary process (Salat 2011: 106) seems essential in looking for solutions.

7.5.2 Renewal

The adaptive cycle shows that the collapse of highly conserved systems are usually followed by periods of renewal. Following collapse, resources are released back into the system and transformed into a completely new regime. During this window of opportunity, the system can reorganise in such a way that the resources released can be harnessed to their full potential while simultaneously being encouraged to regenerate. Transformative resilience recovers a system's health (Chapin *et al.* 2009; Gotham & Campanella 2010) and is brought about through regenerative design, an active and creative process that renews the system and which sees projects as "engines of positive or evolutionary change for the systems into which they are built" (Haggard *et al.* 2006). The capacity of a system to be able to renew itself depends greatly on the resource reserves within the regime. It takes a long time for resource reserves to build up, and their ongoing depletion results in renewal into new regimes that are potentially reorganising with lower complexity, because of decreased resource reserves.

7.6 Conclusions

This chapter sought to expand on principles of resilience that are said to build the capacity of a system to absorb, adapt and transform to change, as illustrated by examples from the physical environment in the City of Tshwane. It saw a shift from trying to control the future, to understanding and embracing change. Urban resilience thinking informs the importance of urban morphology in the future evolutionary potential of a city, or its collapse. While the resilience of an urban system is not limited to urban form exclusively, because environmental, social and economic issues play a vital role, urban form does fundamentally influence the future trajectories of a city. Resilience thinking embraces a dynamic world where resources can be put to best use in developing an urban form that continues to remain useful in the long run. Three concepts contribute toward building capacity and reserves for resilience in a city, namely diversity, redundancy and modularity (shown in Figure 43). Diversity highlighted functional and response diversity in the system,

and emphasised the importance of redundancy in creating 'back-ups'. Modularity was explored as it relates to network fitness, under which scalability, flexibility, variability and openness were discussed as fundamentally important to achieving a healthy balance between energy flows. These concepts build reserves from which the system draws in times of disturbance.

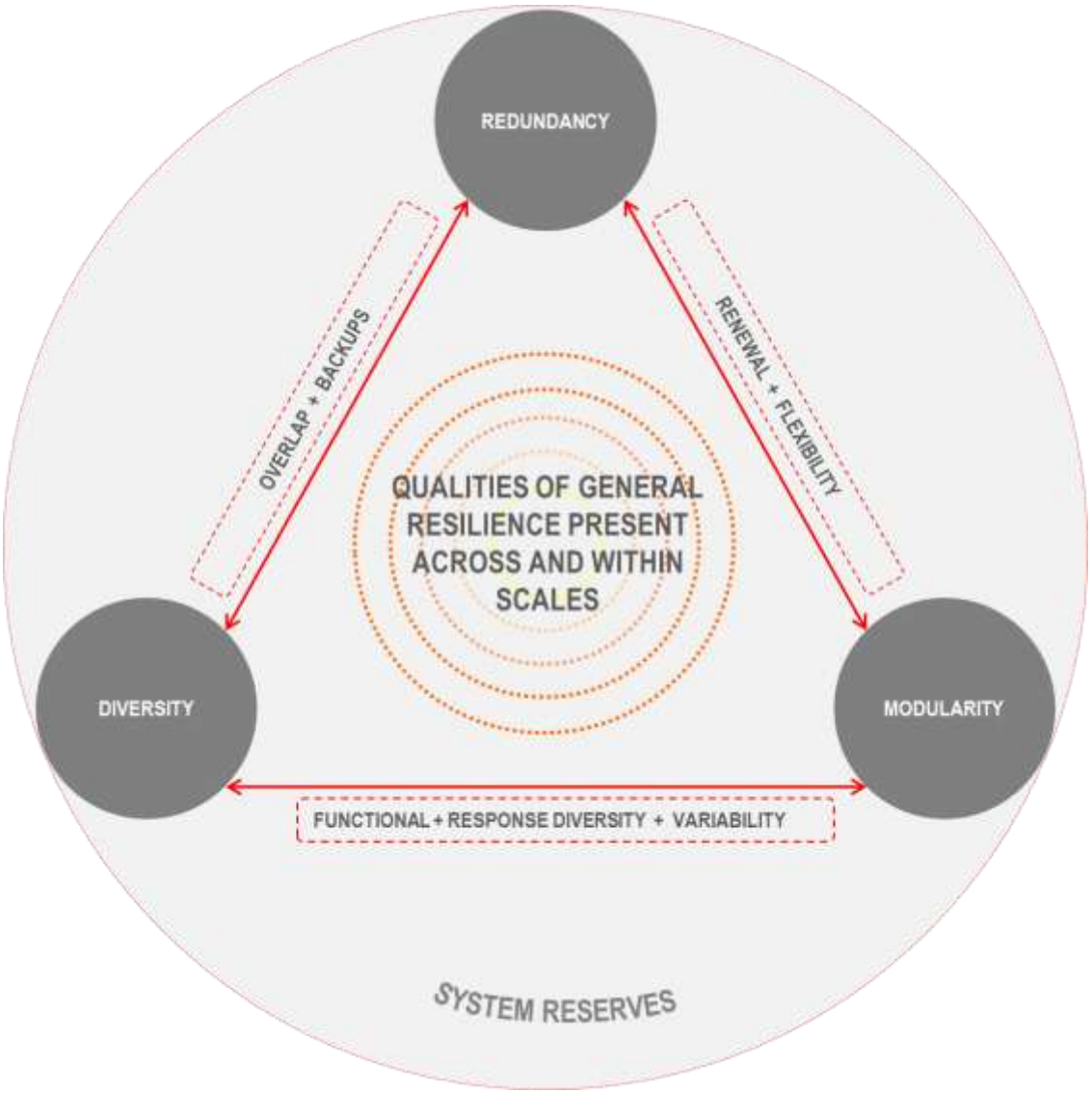


Figure 42 - The qualities of general resilience and the building blocks for adaptive capacity in the urban system: diversity, redundancy & modularity (Author 2015).

PART THREE

KEY POINTS OF AN URBAN RESILIENCE APPROACH

CHAPTER EIGHT

UNPACKING 'URBAN' RESILIENCE – A BASIS FOR URBAN BUILT ENVIRONMENT PROFESSIONALS

8.1 Introduction

Part Two discussed urban resilience practice as the ongoing study of city systems to create conditions for them to adapt to and evolve with changing circumstances without losing their functional identity as human habitats. As complex whole systems, the core function of cities is to create life-nourishing conditions, even if it means that some of its systems may need to collapse. Studying resilience in an urban context begins by finding clues to understanding the status quo of a system in relation to the broader context. It identifies a focal scale and then maps relationships to scales above and below it to form an idea of the panarchy. It then explores how the system has changed and adapted, where it showed vulnerability thresholds, and where its drivers and triggers lie. Thresholds, regimes and adaptive cycle modelling provide clues as to the nature and behaviour of a system in relation to disturbances.

The above information can be used to design the system to achieve specific resilience toward known risks, or to engineer the system toward particular goals. However, specifying resilience of a particular set of properties can make the overall system more vulnerable. Therefore, the final section discussed the qualities that are generally present in systemic resilience, and which contribute to making a system generally resilient toward unknown disturbances. These are diversity, redundancy, and modularity. Apart from understanding the basic (and prerequisite) concepts of ecological resilience and their manifestation in the urban realm, urban resilience as it has been explored within this dissertation needs to be packaged into a meaningful, easily understandable and useful theory that can easily be applied in the built environment and by municipal governance.

As a concept suggested to be able to achieve sustainable development (Gunderson *et al.* 2002; Walker & Salt 2006; Du Plessis 2012a), resilience needs to be critically engaged before it is promoted as such. Resilience thinking will achieve very little if promoted as a panacea to all the problems of urbanity. Problems will persist unless the worldviews driving their structure change. *Urban* resilience holds potential for being able to innovatively leap-frog the 'poverty alleviation' debate, or to outgrow the 'sustainability' checklists which are trapped in maladaptive system-states, and to do so by leveraging the city's regenerative renewal qualities, in order to envision and create *different* conditions and systems that hold the capacity within which life can flourish and evolve (Hamilton 2008). From this perspective,

for example, sustainability is not about maintaining the status quo, but about understanding the kind of regime the system should be in or should avoid, and how to manage the thresholds to get there (Walker & Salt 2006: 118). However, any level of active engagement in the transformation of a city system is based on a value-judgement on whether the system is good or bad, and will favour the resilience of certain aspects of the city over others. Caution must be taken against the use of resilience in the urban environment as a strategy for specific interventions that enhance the resilience of one aspect of the system at the expense of others.

In view of shifting the perception of resilience from goal to practical tool for thinking about design, Part Three of the dissertation aims to highlight the benefit of thinking about and practicing resilience approaches in relation to the built environment. Given the predicaments of urban life today, and the unknown challenges facing humanity in the decades to come, an urban application of resilience thinking and practice must be a tool from which:

- newly designed buildings, suburbs, parks, cities and regions can be provided with flexibility to adapt to future 'unknowns';

- interventions based on studying the 'windows of opportunity' in the adaptive cycle of existing built environment systems can make cities more generally resilient;

- and insightful decisions can be made about whether highly resilient yet detrimental aspects of the built environment should be collapsed to maintain or enhance the broader system.

In all three instances, interventions may likely have unpredictable (and possibly unwanted) results. In order to provide fruitful ground for further exploration of these aspects, one needs to firstly define the purpose of an urban resilience approach, including what it is (can achieve) and what it is not (cannot achieve). Thus this chapter looks further into the potential embodied in designing and engaging with cities passively and actively from an ecologically grounded resilience approach to, lastly, ascertain how general ecological resilience provides the most potential for the urban environment.

8.2 The potential of engaging with cities through an ecologically grounded 'urban resilience'

> Real solutions to the problems of both city and suburb can now be achieved only though understanding the place of each within the larger region and by viewing the city, suburbs, and nature as a single, evolving system linked by the processes of nature and the social and economic concerns of humans (Whiston-Spirn 1984: 37).

To approach urban life on earth from an ecological resilience perspective requires an alternative way of seeing the world. In this worldview, there is a focus on life in all its forms, and a deep awareness of the invisible layers of systems, energy, linkages, thresholds and cycles that hold things together. There is an appreciation for the complexity that underlies life, and modesty about ambitions for managing it. It calls for the general resilience of the system to be built up by working with the inherent potentials of the site, and by applying principles of diversity and modularity in the physical and social-ecological realm too. It favours small-scale (bottom-up) experiments at the local level that can ripple through the holarchy, rather than large-scale top-down ideological shifts that force perspectives on the holarchy and possible end in collapse.

There are potentially two ways in which resilience can be engaged with in the urban environment. The first shall be termed a 'passive' engagement based on observation, in which the focus of study lies on learning about system behaviours, vulnerabilities and strengths. With this knowledge of the evolutionary resilience of a system, the aim is to strengthen the overall resilience of the urban system by building on its existing behaviours and patterns, to increase depth and thereby resilience, and to ultimately increase diversity, redundancy and modularity. In passive engagement, there is no pre-set goal to enhance the resilience of a specific aspect of the urban system above another, since this might be weakening the overall resilience of the system (Gunderson *et al.* 2002: 3).

The second approach with which to engage the resilience of the urban environment can be called an 'active' approach based on transforming the system. Beyond the observation and study of the system, decisions are made on whether the findings are positive or negative based on pre-set notions of what the city system should achieve, such as more economic growth or sustainable development. These decisions are based on the value judgements and worldviews of a group of individuals engaging with urban resilience. While their knowledge about resilience and the built environment may be extensive, their own lived values and consciousness will permeate the decision-making process (Hamilton 2008: 112) and may not only substantially influence the physical city system positively or negatively, but also the quality of life of its citizens.

In view of this incredible power that individuals hold (both top-down and bottom-up), *integral theorists* argue for change to be framed by a *Gaiaic* (holistic) worldview (Wilber 2007; Hamilton 2008; Esbjörn-Hargens 2012), with the paradigm of "global interconnectedness and the individual [seeing] herself in terms of service to the evolutionary well-being of the world" (Hamilton 2008: 115). The active approach to resilience with the aim of transforming the system requires a holistic framework to limit the destruction of complexity and depth in society, urbanity and biodiversity. Therefore, this dissertation suggests that an active transformative resilience approach requires practitioners that embrace an ecologically holistic worldview and nurture conditions for Integral evolution.

A resilience thinker looks at the larger system of interlinked adaptive systems, which is effecting or affected by change, and acts upon the knowledge (Walker & Salt 2006: 114) from an ecological perspective. That is, applying ecological resilience to an urban system with the intent of creating a resilient urban system would involve the following processes:

1. Understanding the social-ecological system as a whole system
2. Looking for the key change variables that drive it
3. Studying the thresholds that cause regime shifts
4. Learning which feedbacks define thresholds and how they change under different conditions
5. Identifying which phase of the adaptive cycle the system is in
6. Identifying what is happening in the scales above and below the focus scale
7. And lastly, looking for linkages between the different scales

Knowing the capacity of the system to manage its resilience – known as its adaptability or adaptive capacity – and understanding when the system may need to be transformed are equally important. The greater the number of redundancies, the greater the potential of the system to have a better response diversity and, consequently, adaptability in managing change. On the other hand, transformability becomes especially important when assessing the short-term profit losses associated with maintaining or enhancing resilience, versus the long-term benefits of not undergoing a regime shift. For urban resilience based policy and management, the following considerations are applicable (Walker & Salt 122-124):

1. Due to its linkages to other scales, an SES cannot be managed in isolation
2. Interventions change according to the phase the adaptive cycle is in

3. What is happening in the scales above and below influences the focal scale
4. Key slow variables and their thresholds or feedbacks are critical aspects of the system
5. Slow variables can be used to develop alternative regimes for the system
6. Simplified systems that reduce the systemic diversity may increase vulnerability
7. Key points for intervention may avoid, or navigate the system toward, alternate regimes
8. Subsidies for change rather than subsidies not to change need to be prioritised
9. Adaptability can promote learning and experimentation
10. Existing governance structures should focus on responsibility versus time in office
11. The short-term costs of maintaining the system should be traded off versus the long-term rewards
12. If a system is moving toward a new regime, then it is better to transform sooner rather than later

As with ecological resilience thinking, urban resilience applies principles and qualities needed to create more space for the system to have more options, since "[a] resilient [city] system has the capacity to change as the world changes, while still maintaining its functionality" (Walker & Salt 2006: 144). An ecologically resilient urban environment is one in which awareness allows systems to evolve, and trust forms the basis of interactions with life on earth. It therefore values (Walker & Salt 145-148) the following:

1. Diversity in all forms and variability that is not controlled
2. Modularity between different systems that are not all directly or weakly connected
3. Slow variables informing policy and planning, with tight feedbacks to identify thresholds before they are crossed
4. Overlap in governance to include redundancy
5. Active nourishment of Social Capital (individuals, social networks and leadership) to evolve their consciousness
6. Promotion of adaptation and innovation – emphasis on learning, innovation and novelty
7. Eco-system services that are integral to design and valued for their regenerative qualities

Active or passive engagement with resilience in an urban context relies on resilience thinkers that are aware of the systemic qualities of resilience and the constraints of resilience thinking, as well as the principles that underlie the capacity to adapt to change. This engagement relies on a holistic approach, which can form the basis for integration of multiple perspectives and practices in the built environment.

8.2.1 The potential of urban resilience to provide a holistic approach

Resilience theory provides a rich umbrella concept to bring together a number of professions in the built environment, and equip them with a common language with which to approach the tricky subject of development in an uncertain world. When applied to urban systems, resilience highlights the need to look beyond the study area toward the broader system in order to identify the invisible links that influence flows in the city web. Issues when seen in isolation remain issues. To create change and intervene effectively, one needs to understand the system holistically. Studying the resilience of a system provides clues as to where and when change can happen in the city's adaptive cycle.

Different facets of the city require different resilience responses to align appropriate interventions to a holistic solution, built on the evolution of the place. To that end, resilience is neither good nor bad and it is neither a dogma nor a goal. It is simply a way of thinking about and understanding cities, in order to make informed decisions about the impact of an intervention on the future trajectories of the city. In its application to cities, resilience thinking provides principles with which to better design and equip cities across scales to deal with unpredictable disturbances (Gunderson *et al.* 2002; Wilkinson *et al.* 2010; Walker & Salt 2012). The general resilience of a city can be increased by providing options for it to bounce back, absorb change, to adapt or to transform, and this capacity can be promoted through a diversity of functional and design responses.

A resilient city system holds reserves for regenerative potential, building on the strengths of a site to harness flows of energy that can regenerate living systems (including the human system) on site after a disturbance – an important aspect of survival for any system. Above all, resilience is an overarching characteristic that humans will have to build within themselves and their environment, to transition through drastic changes confronting contemporary society. Building resilience requires of us to move from a mind-set of fixing empirical problems toward embracing uncomfortable multidimensional change.

8.3 The purpose of urban resilience

> City dwellers have demonstrated a sustained interest in nature throughout history. Today that interest has been heightened by a growing consciousness across society of the costs to health and welfare exacted by continued environmental degradation (Whiston-Spirn 1984: 37).

The purpose of urban resilience is to empower professionals engaged with the design and management of the built environment to embrace change. It provides a tool with which to inform professionals about the city they are working in, to create awareness about the contextual problems and opportunities of a site within the city system, and to provide a small sense of empowerment to design and build in the face of a rapidly changing and deeply challenging world. A potential definition of urban resilience is therefore beginning to emerge:

Urban resilience is the capacity of a city system (comprising both social and ecological aspects) to maintain its core purpose and integrity (Walker & Salt 2012) *as a life-nurturing environment for collective and individual fulfilment* (Forty 2000: 114; Hamilton 2008: 59) *in the face of dramatically changed circumstances* (Zolli & Healy 2012) *or, if so required, to transform in response to disturbances in order to maintain its integrity* (Gotham & Campanella 2010).

This definition puts forward the paradox and complexity of the urban resilience approach: it has the dual purpose of both maintaining healthy urban systems within a dynamic range of flux as well as transforming or possibly collapsing weak ones when they are no longer functioning.

The objective of urban resilience can be the persistence of the city system as a whole versus the collapse or regeneration of its subsystems; the resilience of human beings to bounce back from increasing pressures on their environments, communities and way of life; or alternatively, the transformation of a system toward a new, more positive state while maintaining its identity. This choice of objectives depends firstly on the focal scale, and secondly on the intention behind the engagement of resilience in the urban system, i.e. active or passive. In an urban context, a system may be providing functions and services efficiently with signs of high resilience (for example, the informal housing response), but to the detriment of the system as a whole (informal housing conditions negatively affecting social and environmental well-being).

Consequently, urban resilience thinking offers a way for built environment professionals (among others) to understand SESs by challenging the way in which the world is interpreted.

It embraces a dynamic world and explains why current resource management models, veiled as 'sustainable', are failing because they are being pulled apart and separated from their ecological context. It explains how functional systems become dysfunctional due to critical thresholds within social-ecological systems being crossed, making a return to the previous state impossible. Urban resilience thinking is therefore the exploration of a system wherein humans and their biophysical context form an integrated whole, and its aim is to sustain all forms of life in a positive manner, by "weighing up options, keeping them open, and creating new options when old ones close" (Walker & Salt 2006: 140).

8.3.1 What urban resilience is not

As greater interest develops in the use of urban resilience within the built environment, one of the objectives of this dissertation is to define urban resilience by developing its meaning further in order to provide a clear conceptual basis going forward. In doing so, five points that an ecologically grounded urban resilience approach does not include, have been identified:

- Fundamentally, urban resilience is not about controlling or engineering a city system to remain within a range of preset conditions. As time moves on, these conditions will change, making the engineered system obsolete.

- It is not about keeping the city system static within predefined notions of what a city is. A city should 'have room' to evolve in depth and complexity, by rooting new interventions in the potential of existing city patterns and structures. As society, technology, climate, economy and consciousness evolve, the city should mirror these changes by having capacity and reserves to reflect them in the urban environment.

- Urban resilience cannot be used to predict the future – predicting the likelihood of future behaviour based on past events assumes that events will repeat and unfold in the same way as before. They rarely do. While it may be probable that patterns manifest in a range of behaviours, these are not certain. Future challenges and opportunities will take on new forms and patterns which themselves are unpredictable. Therefore, resilience thinking cannot be used to bolster the resilience of the city toward a specific set of known disasters at the expense of its general resilience, since this action will make the overall system more vulnerable and will see engineered 'resilience' systems fail when disasters fall outside 'predicted' ranges.

- There is no quick fix or 'ten easy steps' to make a city more resilient. Rather than a checklist, building resilience is a process of study. It requires an in-depth study of the focal system that brings together a number of professionals and stakeholders with different areas of expertise, who meet regularly to engage in the study of the city systems.

- Bolstering the urban resilience of a city through in-depth study and experimentation across scales is not a once off activity. It is an on-going process of assimilation and interrogation. New information in the form of feedbacks and evolutions in the system feed into the resilience assessment and study continually, making it a continual process of embracing change and designing for it.

8.3.2 What urban resilience is indeed

By knowing what urban resilience is not meant to achieve, a better idea of its scope as a built environment tool can be developed. As a tool for thinking about design, urban resilience functions like a set of lenses through which professionals and stakeholders alike can begin to think about the city while using a similar language and viewpoint, and which can be useful in informing decision-making in the city. Urban resilience therefore incorporates the following key notions, which reflect its purpose in the built environment:

- Urban resilience is, at its core, a built environment approach that embraces change and the opportunities created by change. Its main premise features change as a dynamic quality driving the flow of life that should be embraced. It argues that change can increase the resilience of a system, while restricting it makes the system more fragile and depletes the potential for evolution.

- Resilience is merely an emergent characteristic of a city system. It either is or isn't resilient. When resilience is present in a system, evolution of the system toward greater depth and complexity is possible.

- Urban resilience thinking is about observing resilience within a system, and can involve using the knowledge gained to effect transformative change. Transformative interventions should be done within a strong holistic framework.

- Urban resilience is about bolstering the general resilience of a city system to deal with slow change from press disturbances as well as providing specified resilience to pulse disturbances. It is about building capacity, space, and options within the city system for unpredictable alternative future scenarios and trajectories to unfold.

- Engagement with urban resilience is a constant process. It never ends. What might be 'resilient' now might be vulnerable in a few weeks, months, or years. It is critical to keep studying the changes and thresholds within the city system. And to continually bolster general resilience across scales.

- Urban resilience leans toward the normative position that, as the primary habitat for humans, the resilience of cities should include evolution toward greater depth and complexity.

8.4 A focus on building general urban resilience and integrating many 'resiliencies'

> The city is as much about selfishness and fear as it is about community and civic life. And yet to accept that the city has a dark side, of menace and greed, does not diminish its vitality and strength. In the last analysis, it reflects man and all his potential (Sudjic 1992: 338).

This dissertation defines a city as an integrated living system that promotes full tangible and intangible expressions of reality, and in addition has capacity to evolve in order to maintain a thriving habitat for humans and life within broader natural systems over time. In order to expand upon this definition, the city is explored through an 'integral city lens', and is seen firstly as a whole living system or "an ecology of consciousness" (Hamilton 2008: 51) that includes experiences, cultures, behaviours and systems.

A living system is a multi-scaled, interrelated and linked network that is able to survive continually, remains connected to the context from which it emerges and therefore depends on it, and lastly, is able to regenerate and provide more functions than those that it extracts from the system (Hamilton 2008: 26). It is argued that an alive, dynamic and adaptive 'integral' city is far more capable of enabling the evolution of consciousness than, say, the Modernist city paradigm, which created policies and practices of fragmentation under which limited awareness emerged. The process of evolution toward greater consciousness is dependent on environment or context (Hamilton 55). Resilience plays an important external role in city infrastructure, creating the parameters between and conditions under which cities adjust and adapt and new development evolves. It is within a specific city context that citizens' lives unfold and from which they will demonstrate their resilience to rise to challenges and adapt or transform to changing conditions; an 'integral' city therefore builds and embodies the external capacity of an engaged citizenry to demonstrate its internal resilience to life's challenges.

In order for a city to survive, remain connected and regenerate, it has to be resilient. The description of an integral city above shows that urban systems consist of many fields, both

tangible and intangible, that contribute to its greatness and its failures. Therefore, an urban resilience approach must be multi-disciplinary, and should include the tangible aspects of resilience as evident in the physical forces playing out in the environment, but also, as touched on earlier, those aspects of resilience crucial to the intangible dimensions of the city, i.e. human consciousness, culture, worldviews and spirituality. Due to the complex SES nature of cities, resilience therein requires engagement with hard (built environment) and soft (knowledge or institutional) infrastructures (Anderies 2014: 136), including those of the citizenry. While this dissertation does not focus on the intangible aspects of urban resilience, it is important to note that there is a foundational understanding, that of general resilience, that is linked to three concepts – diversity, redundancy and modularity – that can provide common ground for resilience discussions between different disciplines.

This general approach brings together all of the different disciplines in the urban environment and directs their efforts toward an integrated approach. At times, as the city system undergoes change, some disciplines will assume more of the responsibility of engaging the resilience of the system than others (much like in the case of response diversity in a functional group). With their own rich, detailed framework and methodologies, they will provide appropriate contextual responses according to need. Other fields do not go dormant, but continue to work together to build general resilience. For example, in Woodlane Village, ecological (or agricultural), economic, psychological, theological and educational resilience practices offer greater value to the community at this moment than engineering or urban design responses, until such time as the go-ahead to develop the site is given. However, until that happens, general resilience can still be built into infrastructure and urban morphology around the site.

If a 'golden rule' must be given to urban built environment professionals to make their analysis of urban resilience clearer, it would be that urban resilience is focused on maintaining or building up the *general resilience* of the city system. This is achieved by first understanding the focal system and then intervening with diversity, redundancy and modularity across scales, functions, structures and across disciplines, in order to contribute toward the survival, connection and regeneration of the city – in other words, toward its evolution. The reverse of the above would be for each discipline to focus only on its own field, to enhance the resilience of aspects of the city perceived within that discipline as essential and, consequently, weakening the overall resilience of the city and making it more vulnerable. General resilience, as explained, gives the whole city system a greater chance of survival and a greater chance at regenerating its systems.

8.4.1 Why use Integral Theory as a basis for urban resilience practice?

Integral by definition refers to whole, comprehensive, and inclusive notions, systems or practices, and therefore reflects processes of life that are aware, complex, adaptive to change, and evolving in ways that build integrity and integration. An integral lens identifies cities as dynamic, complex-adaptive and responsive environments that allow for diversity in the system, which ultimately increases resilience. An integral urban resilience approach has the potential to act as both an indicator and a compass for development on the path toward regenerative sustainability. Integral urban resilience can therefore be defined as: *the capacity of urban systems to maintain their holistic identity and function as thriving habitats for humans that co-exist with other diverse forms of life and display high levels of integrity*.

As an indicator, integral urban resilience provides warnings regarding how far the system has moved away from embodying the qualities of resilience that are required to sustain a regenerative system. Some of the qualities that are capable of fostering the conditions of a healthy (and thereby resilient) system require an understanding of the broad context and its ongoing capacity for adaptation, made possible through built-in redundancy across scales, in combination with an increase in the diversity of functions and responses that leave room for growth and complexity over time. If none of these qualities are present, or if they abundantly perpetuate a dysfunctional system, then the knowledge provided by indicators can direct catalytic interventions within the system to effect regeneration at that point; in this instance, integral urban resilience provides the metaphorical function of a compass.

An urban system consists of a variety of interconnected and co-dependent relationships and cannot be successfully isolated without compromising the integrity of the whole. In addition, a city does not only consist of what the eye can see, such as the physical buildings and services; it consists of places with a unique spirit and meaning for their citizens. While built environment professionals focus almost predominantly on designing aspects of the city that can be seen, they are most successful when they integrate the 'hidden' flows of experience and meaning pertaining to life forms in the city as well. Simply put, since a city is a whole system of equally essential tangible and intangible aspects, its resilience cannot depend entirely on a singular perspective of resilience.

Integral theory is often called an 'all-quadrants, all-levels' approach to transformative practice across various disciplines, because it assimilates various competing perspectives into one cohesive vision that builds on the strengths of each to form an integral and multi-dimensional response. As indicated, the application of resilience theory to the urban realm highlights two concerns that require an underpinning framework from which to find clarity in

application and practice. It has been noted that, due to the complex nature of cities as social-ecological systems, principles for understanding resilience therein require engagement with hard (built environment) and soft (knowledge or institutional) infrastructures (Anderies 2014: 136).

However, the current trajectory in the development of urban resilience is externally focused and has not manifested the internal qualities that also make up the whole of city life, and therefore is not integrative of various resilience approaches in response to complex urban systems. Secondly, the understanding of urban resilience as a means to better understand the strengths and weaknesses of a system, in order to build its capacity to absorb disturbances or to change and evolve into something else, requires a framework from which to make value judgements about positive or negative systemic aspects. In addition, certain decisions regarding intervention points or aspects of the system that require investment, or possibly collapse, call for a holistic perspective as a basis and framework from which to make critically important decisions.

The Integral Theory conceptual framework assimilates the partial truths in various external and internal dimensions of life from which a richer collective truth derives. It has already seen significant evolution and adaptation to alternative disciplines, including sustainable architectural design (De Kay 2011) and urbanism (Hamilton 2008; Buchanan 2013), implying that integral design can benefit urban resilience practices. However, as a characteristic of a system, the level of resilience that a city offers can also be seen as a litmus test for the health of the city as it changes over time, providing clues about aspects of the Integral city that are 'diseased'.

Using an Integral framework to inform urban resilience practice can therefore be the logical extension of existing Integral Theory research in the built environment (De Kay 2011; Hamilton 2008). While this dissertation posits that Integral Theory forms an important research avenue in the design of urban environments geared toward building transformative resilience, it is not the focus of the dissertation.

8.4.1.1 Integrating resilience perspectives – mapping different resilience perspectives

Urban systems are interpreted through four different perspectives or *quadrivia*, illustrated in Figure 44.1. Within each quadrant, resilience theory applications will differ (Peres & Du Plessis 2014b). For example, the external paths of a city can manifest in the following ways: on the measurable terrain of behaviours would be located buildings, organisms, infrastructure, typologies and morphologies. On the terrain of systems would be located political,

economic, social, legal, institutional and educational systems, each having manifestations in architectural styles (Esbjörn-Hargens & Zimmerman 2009). These are usually the focus of sustainability practices trying to force behaviours into optimal efficiencies, and systems into representations of the whole of reality. These first two perspectives exclude the internal paths that are essential to the healthy sustainability of a city and, consequently, to its resilience. On the terrain of culture, worldviews and ideologies held by groups, values can be created that give rise to architectural identity and a 'sense of belonging' that communities or individuals associate with the built form of the city. Lastly, on the terrain of experience, beliefs and emotions can take root in the phenomenological states that give rise to experiences of 'spirit of place' and poetics in landscape (Esbjörn-Hargens 2012).

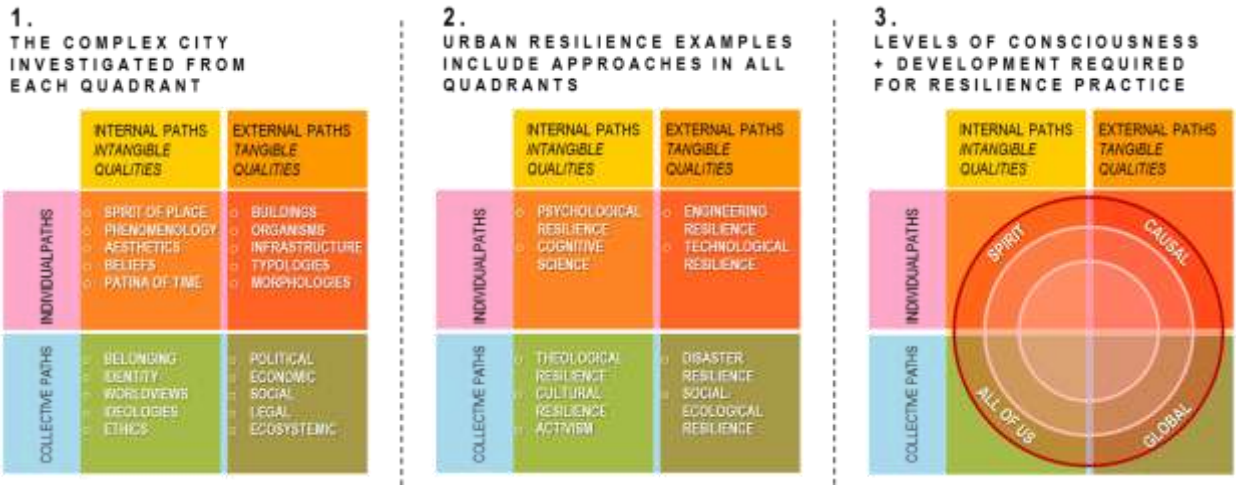


Figure 43 - Integral Urban Resilience: All-Quadrants & All-Levels (Author 2014; Brand & Jax 2007; Peres & Du Plessis 2014b).

Engaging with how resilience manifests within each terrain requires shifting between resilience practices that offer the most appropriate responses (Peres & Du Plessis 2014b). As illustrated in Figure 44.2, the design of a road will require resilience approaches that can mitigate known disturbances and can accommodate a variance on the standard through 'bounce back' and equilibrist engineering resilience. In the case of systems, mapping the impacts of climate change disasters on health, political security, economy and social interaction requires an appreciation of various types of systems-based resilience practice. When dealing with internal paths on a collective scale, the resilience of cultural norms or political ideologies affect the resilience of a community's beliefs or worldviews and how its members identify with built environments, which in turn affects their actions on the external terrains. In the case of experiences, the resilience of 'spirit of place', emotion, and the quality of phenomenological exploration all become important, and psychological resilience can provide clues for creating spaces that can evolve consciousness development in carefully crafted environments.

8.4.1.2 Mapping the different levels of resilience (facets)

The interpretation and application of resilience theory in the urban realm requires a focus on development within the internal paths. It is suggested that individuals on this path evolve beyond thinking only about themselves, their family or their tribe, to a higher, more complex level at which they are able to think about national ecosystems and global networks (Hamilton 2008: 245); this way of thinking requires stepping well outside of oneself to achieve greater depth, as illustrated in Figure 44.3. Communities and groups also need to be guided to evolve their average operational centres to higher levels of empathy and away from selfish goals. In addition, external paths also have levels of development which increase in complexity at each level by transcending and including wisdom from lower levels. On an urban scale, integral resilience theory has to foster development along internal and external paths toward their highest levels and beyond, if it is to ensure the resilience of truly sustainable social-ecological habitats.

8.4.1.3 Putting it all together

To reach a holistic understanding of a subject, more truths than otherwise might be expected to require representation. For this purpose, the AQAL framework provides a useful start. Initially, the subject under investigation, for example a city, is explored from four dominant perspectives of reality (quadrants or quadrivia): experiences, behaviours, systems and cultures comprising the dominant external or tangible and internal or intangible qualities of life, as shown in Figure 45.

An integral urban approach views city phenomena from the four quadrants and responds to each with a specific perspective and field of resilience. The domains reflect increased levels of complexity or depth that correlate with evolutionary processes and personal development; the subject is engaged in a relationship with reality that is rooted in a similar centre of gravity that sits at a certain *level* in this process. These first two explorations provide an understanding of the range and complexity of the subject. While ideally, further foundational concepts of the AQAL model (Addendum B) should be tackled, the use of at least quadrants and levels will already provide a stronger intervention. In addressing the challenges facing urban areas and forcing material changes in them, it becomes necessary to realise that issues include internal (LH) perspectives of consciousness, intention and responsibility, in addition to the traditional empirical perspectives (RH) (Hamilton 2008: 14). Internal (LH) and external (RH) dimensions are interrelated and affect each other profoundly, either in their contribution to the perception or the creation of reality. Internal (LH) perspectives have direct bearing on external realities which physically impact on the city. It

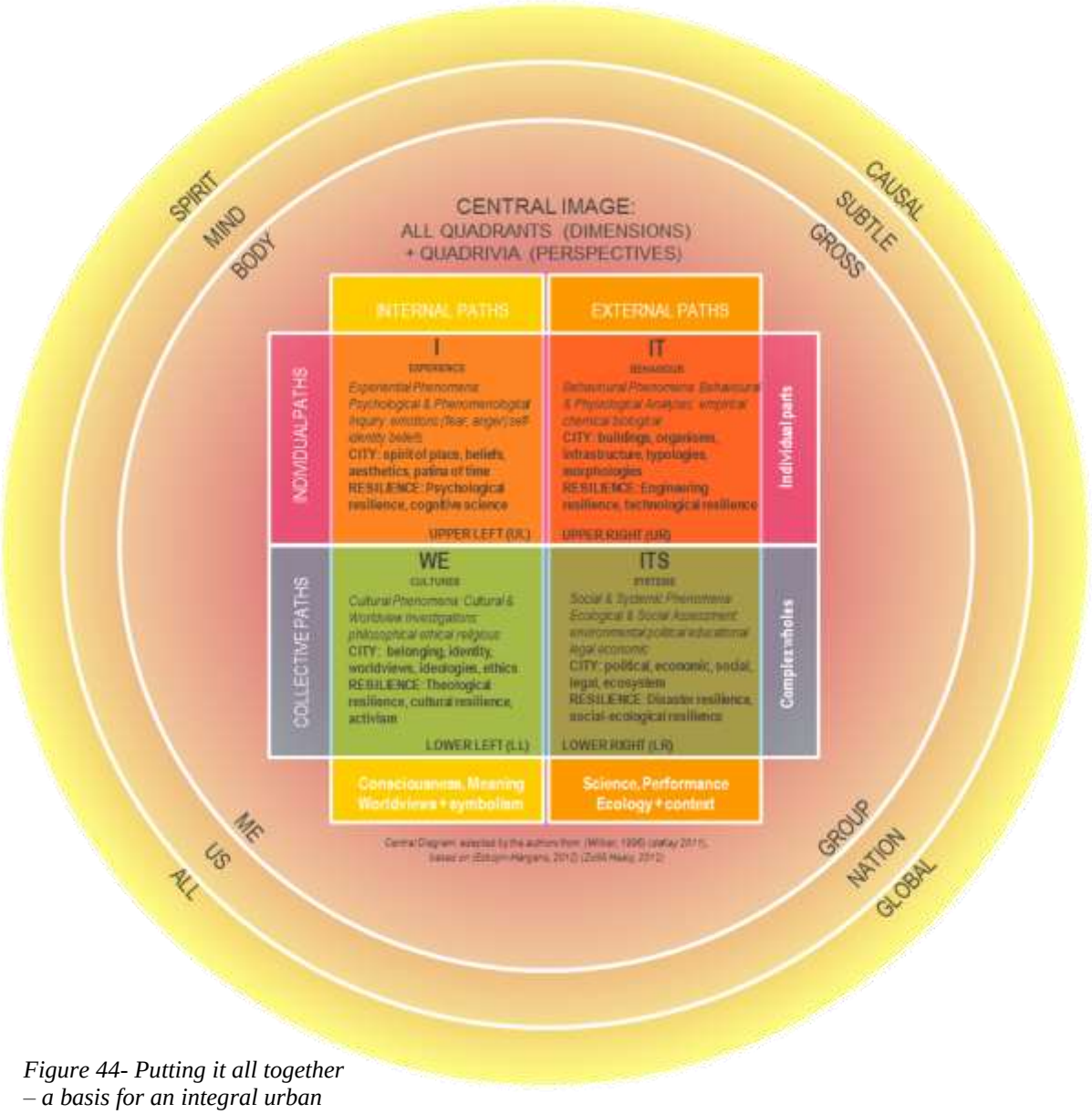


Figure 44- Putting it all together – a basis for an integral urban resilience exploration (Peres & Du Plessis, 2014b).

appears clear that, to change the external environment, the internal ecologies that inform its emergence first need to change – "our inner capacities must match our outer intentions" (Hamilton 2008: 15-16). Consequently, if integral urban resilience was to be used on a city, it would have the capacity to maintain its functional identity as a thriving human habitat co-existing with all life, by holistically integrating its external and internal qualities and regularly transforming its subsystems.

8.5 Considerations when using 'transformative' urban resilience

> … [N]ew norms must frequently be charted during periods of extreme change. Resilience is often achieved through the ability to readjust to a new normal (Pickett, Cadenasso & McGrath 2013: xxii).

A bigger picture view of the Tshwane urban system forms a complex lattice of relationships stretching across scales to make up the entirety of the built environment. Two considerations emerge from the attempt to engage with this bigger picture: firstly, the goal or intention with which resilience is being applied to, for example, arrest the potential for unpredictable change, to bounce back to a condition that preceded an event, or to transform aspects of the city system holding back the potential for revitalisation of the whole; secondly, the appropriate means of application, in other words, the perspective (systems-based, hybrid or transformative) from which resilience theory is applied, has an impact on the success of realising the goal in a complex system.

Awareness of systemic resilience ensures the making of more informed choices going forward by understanding the system and giving it room to adapt, whereas a transformative approach will directly influence change within the system to meet a set of objectives. For example, if the aim is to make the city more sustainable and resilience is used as a means to achieve this, what is perceived as 'sustainable' by a core group of individuals will take precedence over the resilience of everything else. As discussed in Chapter Six, enhancing the resilience of one set of conditions over others results in a loss of overall system resilience. While every approach to resilience is important to the overall resilience of the city, the creation of a sustainable, well-functioning city will require an integration of all the perspectives of resilience (De Kay 2011: 167).

The use of 'resilience' as a broad term in development policies is problematic. Firstly, there is no distinction between the use of resilience as a metaphor versus as a way of thinking and studying the built environment. Resilience stands to be promoted in policy as a desirable 'goal' without specifying the resilience of what to what (see 8.6.1) and stands to become a trend rather than a useful design and systemic thinking tool. This can easily turn into a rigid dogma that does not have the flexibility to evolve as social-ecological conditions change. Secondly, resilience thinking as outlined in this dissertation cannot directly underpin a policy for three reasons; it is process not outcomes driven, it is too complex to transcribe into a checklist for policy and lastly, resilience is not always desirable. There is a further risk to the use of resilience thinking in policy and that is as an active tool for transforming the urban environment; it can be used to destroy positive systems as easily as negative ones depending on the outlook of the political party or commercial interests of the time.

This brings to light the biggest opportunity and threat that engaging with resilience thinking holds, that is, the level of awareness, ethics, conscience and consciousness of the individuals studying urban resilience and making decisions regarding the findings. Decisions

are of course not necessarily permanent; however, the physical timeline of a city generally spans generations, so the implications of decisions may have lasting effects over centuries, and in the course of that time, might profoundly affect the lives of millions of individuals (Hall 2002; De Kay 2011; Buchanan 2013). In the context of South African development, corruption, unethical policies, censorship and discrimination compounds this concern.

Is the built environment fraternity in South Africa ready, able and equipped with the holistic framework from which to be able to understand and process urban resilience thinking and practice? And beyond that, is it possible that an understanding of urban resilience practice might be put to use in furthering immoral short-term goals for a niche group of individuals over the long-term vitality of the broader urban system? The social and psychological state of morality in South Africa, which gives cause for concern (Gauteng City-Region Observatory 2013), highlights a need for further exploration of the refinement of a transformative urban resilience approach that is based on a holistic approach facilitated through integral theory.

8.6 Risks posed by the current use of resilience in the built environment

> Our lack of intelligent design in city building, servicing and maintenance means that someday soon multiple disasters striking multiple locations simultaneously will outstrip our capacity to respond and/ or rescue (Hamilton 2008).

This section of the dissertation raises a few problematic points regarding the use of resilience. Going forward, resilience practices should avoid using it superficially, since identifying the resilience of a system has potential to either regenerate or collapse it. While resilience (thinking) is being described as a pathway to sustainable development (Folke 2006; Davoudi 2012), its definitions and examples of application to urban systems must be clear along with its purpose and usefulness within the built environment. Its application to cities needs to transcend its focus on pulse disturbances like natural disasters to press disturbances like the reductionist worldview that is perpetuating global system shocks.

The shift in the value of resilience, from managing narrow margins of change, to an acceptance of the evolutionary need for change, needs to be reflected in its application to cities. Resilience is not aimed at 'quick-fix' solutions. As a system property (whether mechanical, social or ecological), resilience can never be a 'quick-fix' for the long-term. Rather, resilience becomes a *lens* through which to see whether cities have the capability to navigate through unpredictable futures.

8.6.1 Risk 1: Turning into a shallow built environment trend

As 'resilience' gains popularity, there is a risk that it will be used as a buzzword rather than a theory to direct research and development. To avoid resilience becoming yet another empty byword for 'development as usual' (100 Resilient Cities: 2015), and to understand its application to architecture and planning, clarity is required in identifying the problems associated with the 'resilience trend' (Peres & Du Plessis 2014a). While resilience can be an umbrella concept that brings together many disciplines and fields of research, it may begin to encompass too much and lose its specific meaning, leading to the purpose or intention behind the theory becoming unclear (Brand & Jax 2007: 9). In the 100 Resilient Cities initiative pioneered by the Rockefeller Foundation (100 Resilient Cities: 2015), valuable research is being conducted in creating awareness for the need to be resilient toward the physical changes being faced in the urban world today. However, the initiative risks oversimplifying a complex research area (by omitting deeper questions around intangible value systems for example) and furthermore setting resilience up as a goal for cities.

From the assessment of a well-defined ecological system to large complex adaptive systems like cities, or even as a general perspective or way of thinking about the world, the meaning of resilience will get more vague as the lines between the different branches of resilience blur. As complexity and scope increases, so resilience becomes interpreted shallowly, due to a lack of background and time for investigation. As more knowledge accumulates in resilience theory, critical engagement in its use becomes important to inform its future as a useful construct. The range and depth of resilience theory can be confusing, and so in its translation to the broad spectrum of built environment professions and related fields, its power as a metaphor takes the lead. Consequently, resilience could easily become represented as a new solution to all problems, when it is actually a characteristic of the systems that produced the problems in the first place.

While resilience as a descriptive concept can create common ground for discussion and collaboration between different disciplines, in practice it becomes particularly important to develop defined strategies. In this instance, it becomes important to deepen knowledge about the systems we are in (Walker & Salt 2012: xi). The evolution of resilience thinking within developmental fields like urbanism (which is an embodiment of many complex disciplines and spheres of social, ecological and economic life) synergises well with social-ecological (evolutionary) theories of resilience and interpretive planning, in that both "advocate the exploration of the unknown and search for transformation" (Davoudi 2012: 304). As urban resilience research grows, it becomes necessary to define resilience, and its purpose in the context of urban systems, as embracing change and building capacity for the evolutionary

potential of a city to develop. However, without a consensus around a clear understanding of the underpinnings of resilience, and what the purpose of using resilience in the urban realm is, there can be little of value extracted from further investigations.

8.6.2 Risk 2: Maintaining multi-perspectival richness

While it may be easy to differentiate between the use of different perspectives of resilience as they apply to different fields or disciplines, it becomes more difficult to do this in an urban setting, since the city is an embodiment (whether direct or indirect) of every field. The very nature of urban resilience requires a multi-perspectival approach (Peres & Du Plessis 2014b). However, being able to identify which branches of resilience to use when, becomes critical given that they operate at different levels in response to different scales of disturbances (see Table 4). For example, resilience applied to return a system to a previous state of equilibrium usually employs specified resilience approaches within a focal scale.

These three approaches – systems-based, hybrid and normative – are used interchangeably rather than simultaneously, and consequently create conceptual confusion. For example, the normative perspective of resilience as being 'good' (the city must be resilient) is used in place of systemic resilience research (what aspects it is made up of). Aspirations to transform the current system to another perceived 'better' system override the slow rate of evolutionary processes in favour of small revolutions in the system.

Table 4 - Resilience branches and their scope of activity in the urban system, based on Folke (2006), Walker & Salt (2006), Brand & Jax (2007) and Davoudi (2012).

RESILIENCE BRANCH	SCALE OF ACTIVITY	LEVEL OF COMPLEXITY	DISTURBANCE	RESPONSE
Systems-based	Focal scale	Lower	Pulse	Specific
Hybrid	Focal scale as well as scales above and below	Higher	Predominantly press with some pulse	Predominantly general with some specific
Normative	Focal scale	Moderate	Pulse and press	Specific and general

To build upon the existing potentials in a city and allow for the whole system to persist, hybrid approaches of specified and general resilience are employed, using specified resilience at a focal scale and building up the adaptive capacity at scales above and below. To transform the city toward a desired state, a combination of specified and general resilience strategies at a specific focal scale in the urban system is used to regenerate or collapse subsystems.

An urban system consists of interconnected and co-dependent relationships or networks which cannot be successfully isolated without compromising the integrity of the whole. In addition, a city does not only consist of what the eye can see, such as the physical buildings and services; it consists of spaces that hold intangible qualities for their citizens, like a unique 'spirit of place' or subjective meaning and identity. It is a whole system of equally essential tangible and intangible aspects; similarly, its resilience cannot depend on a singular perspective. Different situations and systems will require different resilience practices to build the capacity of the system to withstand shocks and pressures.

8.6.3 Risk 3: Becoming a climate change management or risk-reduction strategy only

Resilience is gaining ground worldwide as an essential feature for developing the resilience of cities in the face of climate change disaster. Major cities around the world are responding to natural disasters with 'urban resilience' plans and frameworks for bouncing back from disaster (ICLEI – Local Governments for Sustainability 2012). International cities are responding to the state of urgency arising from climate change and the inadequacy with which they are able to deal with multiple crises stemming from climate related disasters. As emphasised in *Resilient Cities 2: cities and adaptation to climate change* (ICLEI – Local Governments for Sustainability 2012), resilience is seen as a means of mitigating urban vulnerability toward climate change.

The 2011 United Nations *State of African Cities* report states: "the manner in which cities are developed today will affect future options for resilience in the face of climate change" (UN Habitat 2010: 3). In South African cities, the spatial separation of closely related urban functions will play an important role in addressing carbon emissions and urban ecological footprints (UN Habitat 2010: 39). In this report, the focus remains on resilience toward climate change and rebounding or transforming in the face of disaster. While the need to rebound from devastating natural disasters is evident, crippling human-driven disasters are less noticeable until their effects are tangible, and are often difficult to reverse.

Gradually, the need to reconsider these long-term human-driven pressures as equally critical to climate change resilience, is growing within the built environment. The resilience conceptual framework allows us to understand the drivers within rapidly urbanising cities (and the relationships between them) that are perpetuating twisted spatial manifestations. Framed differently, a resilience approach explores the full causes of the symptom affecting the system as a whole; the degree to which the drivers of symptoms endure over time reflects the system's resilience. Considering not only how cities can be more resilient toward climate change, but also toward other human-driven disasters, becomes important in

informing further research and discussion at an international level in order to inform future trajectories of urban development.

8.6.4 Risk 4: A 'brand' for policy and development that promotes resilience as 'the goal'

In addition to the potential vagueness resulting from the use of resilience as a descriptive concept and its appeal as a quick-fix solution for many urban problems, there are two areas where its current use within the built environment in South Africa risks diluting its full potential. The first area is in the shallow interpretations of what resilience is and how it can solve urban problems. These interpretations are gaining popularity in the public sector and resilience is becoming a 'brand' or goal for the major South African cities (South African Cities Network (SACN) 2011), such as in future development in the capital city of Tshwane (City of Tshwane 2013).

The built environment and development sciences in South Africa have focused primarily on the anti-adaptive 'bounce back' understandings of resilience, in order to attempt to manage or maintain the status quo of cities in the face of pulse disturbances like natural disasters or protest action. The second area where the current use of resilience risks dilution is the perception that a city must be resilient, or rather, that resilience is the ultimate goal. In most public strategic plans and commercial developments it is assumed that resilience is the necessary goal and so should be promoted. It precludes any investigations into what is understood as resilience, and further distances the issue of defining what the qualities of a preferred system should be to make it resilient.

The influential 2011 *State of South African Cities Report* (SoCR) (SACN 2011) reviewed post-democratic development using a resilience perspective. In its introduction, the report mentions the potential that resilience offers to chart a different pathway in development, but for the most part it focuses mainly on the ability of cities to continue functioning within their status quo, and 'bounce back' from threats and disturbances. In addition, it inaccurately frames resilience as a positive systemic goal through statements like the following: "… governance difficulties experienced by the metros indicate vulnerability and instability rather than resilience" (SACN 2011: 140). This misinterpretation of resilience as a positive goal needs consideration; resilience is not (nor can it be) the final goal without contextualising the resilience of 'what to what'. The perceived vulnerabilities resulting in difficulties might be highly resilient in spite of efforts to eradicate them. The alternative framing of the SoCR sentence given this understanding would be 'to identify governance difficulties experienced by the metros that result from highly resilient albeit adverse system-

states that perpetuate the existence of negative urban values, in order to allow for the urban system to adapt to changing circumstances'.

8.6.5 Risk 5: Falling into the same pitfalls as sustainability and the 'green' movement

With more reference to resilience in research and practice, one of the main criticisms against its application to the urban realm is that it is simply a rebranding of the green movement or sustainability itself (TRUST 2012). However, the notion that resilience is the broader, more dynamic means of achieving or augmenting holistic sustainable development is increasing (Du Plessis 2011a; Davoudi 2012; Zolli & Healy 2012: 21). It is being seen as the means of curbing environmental catastrophes (Stocker *et al.* 2014) unravelling from the *anthropocene* and set to irrevocably change the 'truths' of the world. Resilience assumes this position, because the sustainability movement has become so broad that any action that addresses a fraction of its ethos can claim to be sustainable (Zolli & Healy 2012: 21). However, criticism is increasing against industries, companies and consumer-driven enterprises that are fundamentally unsustainable, yet claim to deliver the holistic sustainability imperative.

The holistic sustainability paradigm calls for a deeper perspective based on an ecological worldview (Du Plessis 2009; Hes & Du Plessis 2015) "of an interdependent and interconnected living world" (Du Plessis 2011b), and calls for a review of the status quo preservation of global consumption-driven growth economies. If resilience is to be the pathway toward sustainability, then the purpose behind sustainability itself must be defined: resource efficiency and maintaining the status quo, versus an ecological view toward rethinking the status quo and the role of humans within it. Alternatively, when the understanding of sustainability is entrenched in a holistic and ecological worldview, then it is impossible to be sustainable without being resilient and regenerative (Hes & Du Plessis 2015: 112). Resilience risks becoming trapped in the same messy think space in which the sustainability industry finds itself, if it is seen only as a means of achieving sustainability rather than a product of a holistic system.

8.6.6 Risk 6: Are global systems ready, open or willing for an extensive rethink?

The UN Habitat 2010 *State of African cities* report states that the first decade of the 21st century has shattered "belief in linear development, the start of worldwide accumulative growth, and broad access to a global consumer society. The free-market ideology has facilitated a number of serious worldwide mistakes in governance, environmental management, banking practices and food and energy pricing which in recent years have rocked the world to its foundations" (UN Habitat 2010). Clearly, the shocks on the current

system are causing vulnerability in aspects of the system poised for collapse. For decades an urgent 'rethink' of the growth model (Schumacher 1974; Jacobs 1984; Jackson 2009; Diamond 2011; Gilding 2011; De Kay 2011; Hes & Du Plessis 2015) has at times even been suggesting a collapse of these destructive systems and practices. With a future framed by climate change, resource depletion and irreversible environmental destruction in combination with political unrest, religious fundamentalism and an increasing polarisation of the extremely rich and poor, the future seems bleak if the current trajectory continues.

While most thinkers agree that a major shift in approach based on an alternative and ecological worldview is required, global political systems and consumer ideologies remain entrenched in unchecked free-market growth models and deep-rooted materialism. The mental constructs supporting these systems remain highly resilient. The current fractured worldview "that drastically separates mind and body, subject and object, culture and nature, thoughts and things, values and facts, spirit and matter, human and nonhuman" (Wilber 2000: 12) is the root of the current global problem (Eisenstein 2011: 12). As challenges facing humanity increase, demonstrations of alternative practices embedded in a consciousness of the union of the living world may propel change.

Wilber suggests that, to direct the current system toward a more positive outcome, its mental constructs need healing "by replacing this fractured worldview with a worldview that is more holistic, more relational, more integrative, more Earth-honouring, and less arrogantly, human-centred" (Wilber 2000: 12), or as Eisenstein suggests, by changing our "story of the people" (Eisenstein 2011: 12). He suggests "we live in an abundant world, made otherwise through our perceptions, our culture, and our deep invisible stories" (Eisenstein 32). Changing the stories that entrench the reductionist worldview is possible (Capra 1982), through broadening consciousness and awareness. This new capacity would create changes happening in parallel in every aspect of developed institutions and rippling beyond them (Eisenstein 2011). Resilience does not only need to be the means to avoid disaster; it could rather be the means of building a more ecological and hopeful mindscape.

8.6.7 Risk 7: Who makes decisions on resilience: another political weapon?

Urban resilience thinking that moves past a systemic (understanding the nature of a system) toward a more transformative application (understanding the nature of a system in order to actively transform its properties toward desired goals) outlines its fundamental risk. Transformative resilience approaches suggest design and policy decisions that shift the built environment (current and new) toward 'resilient' or sustainable goals; calling for a review of

the status quo (PORTER, L and Davoudi, S, 2012, p.329). While a rethink is necessary, the level of awareness, ethics, conscience, lived values and consciousness of those 'rethinking' will permeate the decision-making process (Hamilton 2008: 112). Decisions are not necessarily permanent; however, the physical timeline of a city spans over centuries **Invalid source specified.**, so decisions have lasting and profound effects on the lives of millions of individuals (Hall 2002; De Kay 2011; Buchanan 2013).

When it comes to applying urban resilience thinking to transform cities, there are ethical concerns related to who gets to make resilience assessments and who can act upon them (Vale 2014: 193). Groups with particular worldviews might to engineer a perceived 'perverse' system to collapse and bolster the resilience of a perceived 'positive' system, which groups differing worldviews may question. In the political arena especially, resilience thinking might be used to maintain or promote limiting ideologies that cripple the overall urban system in the long-run. Lastly, and perhaps of most concern, it is possible that an urban resilience understanding might be put to use in furthering immoral short-term goals of a niche group over the long-term vitality of the urban living system.

8.7 The strengths of using resilience themes in the built environment

> The celestial city is no utopian fantasy. It is an achievable reality. It is necessary merely to recognise what is good in the present and to nurture it, to adapt successful models already forged by cities of the past and present, and to develop new ones (Whiston-Spirn 1984: 275).

Categorisations within the fields of resilience delve into the use of resilience as a boundary object (systems-based) or descriptive concept (normative position) (Brand & Jax 2007). *Urban* resilience can potentially form an overarching hybrid concept that identifies opportunities for integrative architecture and life-enhancing development through transformative design. In understanding the city as a system, resilience becomes the measure of the city's ability to survive and persist in a variable environment. Resilience arises from a rich structure with many feedback loops that work in different ways to restore a system's functionality after a disturbance, and is achieved through various mechanisms and scales, as well as with redundancy (Meadows 2008: 76).

Designing the built environment as a holistic system in practice and at municipal level would create a rich urban environment structure that is flexible enough to absorb pulse disturbances, but can also adapt to press disturbances over time and thereby survive and persist. In fact, these qualities of resilience have allowed many of the world's oldest cities to continue to exist over centuries, while the lack of resilience at critical points have led to the collapse of some great historical cities. Resilience is also a measure of a society's ability to

survive and persist: past societies on Easter Island and Mangareva, and the Anasazi Indians and Mayans have shown that passive inaction to population and environmental problems and their feedback loops eventually lead to avoidable collapse (Diamond 2011: 177). At this time, the latest Intergovernmental Panel on Climate Change report (Stocker *et al.* 2014) indicates that global society has reached a critical point at which it cannot avoid the impending environmental and social devastation that will result from irreversible climate change accelerated by human activity. However, *urban* resilience serves as a hopeful umbrella concept, where we can firstly, find common ground to move forward, while secondly, strengthening the positive qualities of our urban systems.

8.7.1 Strength 1: Resilience as an umbrella concept for common understanding

Resilience has the potential to act as a metaphorical *lens* through which to study a city system. The resilience lens is the means through which clarity in understanding the overall state of a system can be achieved; a means of identifying aspects of the city system that show stronger or weaker resilience. The lens itself does not ask the questions of what should be resilient, what the resilience is in relation to, or whether it is 'good' or 'bad' resilience; rather, it makes the systemic relationships clearer.

The notion also exists that resilience theory provides a rich umbrella concept to bring together a number of professions in the built environment, and equip them with a common language (Brand & Jax 2007: 23) from which to find solutions for the unprecedented development demands of the 21st century. This is particularly useful in the urban context, where so many role-players and professionals are engaged in finding large-scale solutions, but then end-up working in silos due to different methodologies and goals. Resilience can bridge various study areas, practices, professions and sciences related to cities, and through this process of integration a whole systems approach to building the future can be unlocked.

8.7.2 Strength 2: The ability to strengthen or weaken the resilience of the overall system

Resilience thinking is useful for working with the general resilience of the city in the branches of hybrid and normative resilience. In studying the relationships within the holarchic city system, the resilience lens also highlights resilience present at various scales of the holarchy, and at which point the lack of resilience at lower scales might start affecting the overall resilience of the city at higher scales and vice versa. This introduces the idea that, while the overall system may be resilient, some of its components may not be. The resilience lens gives insight into potential areas (at different scales of the holarchy) that are ripe for intervention and that might be able to further overall development objectives such as

sustainability, holistic design or ecological urbanism. In relation to these targets, resilience might highlight the need for components to increase their resilience to either absorb, adapt or transform with change or, if they are detrimental, to collapse.

As with any intervention in a complex system, its impact, whether small or large, will likely ripple through the system in ways that cannot be predicted. While this is a strength in that a small positive action may have a large positive effect, the inverse is also true. However, the use of resilience theory to inform the study of city systems, in order to see which aspects of the city may need to collapse in order to transform into more positive systems through regenerative design strategies (Hes & Du Plessis 2015), is still in its nascent phase. By furthering the above understanding, interventions can follow that understand the potential power that different interventions can exert at different scales, using for example strategic top-down catalytic projects supported by designed interventions that encourage the system to self-organize in response (Anderies 2014: 136). The challenge lies in being able to make holistic, aesthetic, just and accurate decisions in response to the findings.

8.7.3 Strength 3: The ability to bring together various perspectives

One of the main problems in the application of resilience theory to the built environment stems from the fundamental split between the external (hard) and internal (soft) domains of reality. These traditionally compete in their quest to explain the unknown and are not perceived to have the potential to be co-existent and complementary. In *War of the worldviews* (Chopra & Mlodinow 2011), essays on various topics debate perspectives of spiritual exploration versus scientific reason. At times they offer complementary answers and at other times they clash. Interestingly, these worldviews have fundamental influences on how we construct reality and approach problems; within the built environment and sustainability sciences, the 'science-based' or 'reductionist' worldview has predominantly driven the thinking behind problem-solving.

The lack of substantial progress in light of the narrowing time-frames available to affect change (Lovelock 2007) requires input from every possible source, including the internal domains of spirituality and consciousness. If the built environment is meant to achieve a level of development that promotes and sustains the well-being of its living systems, then resilience can offer the means of embracing the external realities of science and the internal realities of spirit (in all its manifestations). The application of resilience theory to the urban realm will require an overarching view or framework that can synthesize competing worldviews and different perspectives, as well as different values, in order to guide and

develop a foundation for its holistic application that is able to address a diversity of requirements that arise in a complex system (Peres & Du Plessis 2014b).

8.8 A (very) short summary of urban resilience

It is useful at this stage to summarise what has been identified in this dissertation to be the foundation of urban resilience practice within an ecological resilience perspective. This is an urban resilience 'take home message', hopefully making it easy for researchers, built environment professionals and city managers to engage with the theory and practice of urban resilience on a grounded basis of knowledge.

8.8.1 Definition

Urban resilience is the emergent capacity of a city system, comprising both social and ecological aspects, to maintain its core purpose and integrity as a life-nurturing environment for collective and individual fulfilment, in the face of dramatically changed circumstances or, if so required, to transform in response to these circumstances in order to maintain its integrity.

8.8.2 Core concepts for thinking about urban resilience

Urban resilience thinking and practice are based on a whole systems approach, engaging with the city as a system with complex-adaptive behaviour spanning both the tangible and intangible sphere of life from which resilience emerges. Without a systems perspective underlying resilience thinking, it will be seen as a metaphor or a normative concept only, and no clear method or process of resilience engagement in the city will be achieved. As an emergent property of a system, resilience is framed within the following propositions:

- Resilience itself is neither good nor bad. It is an emergent property of a system, so it is the system state that is either good or bad. In the case of a bad system being highly resilient, it may be decreed to be 'perversely resilient'.

- The resilience of a system across scales can either be in response to a specific disturbance, or it can be a general characteristic of the system as a whole. For urban resilience, the latter is more useful.

- A city system is a holarchy. It consists of component systems or holons that exist simultaneously as whole entities, but also as parts of larger systems. A holarchy increases in depth and complexity, from less complex to more complex systems. In a holarchy, these levels of complexity are all essential to the system; however, higher

levels can disappear without destroying the rest of the system, while destruction of the lower levels would lead to a collapse of the entire system (see section 4.2).

- The city system consists of nested systems undergoing adaptive cycles of change that interact and interconnect with each other, continually influencing and adapting to changing conditions. For every action in the system, there is a ripple effect that moves through all the scales of the system. This notion of interconnected scales above and below is called the panarchy (see section 4.2). It is important to study any area of interest (or focal area) from the perspective of what is happening in the panarchy at the scales above and below it.

- The city system gains its character from a few key variables that have a major influence on the resilience of the city and its trajectory. These variables are either fast-changing (pulse disturbances) or slow (press disturbances), and can emerge from within the system or from outside influences. Variables can become drivers of change over time, with efforts being made to manage or mitigate their influence over the system. It becomes critical to identify key variables in the focal area and their relationships across the panarchy.

- The city system is constantly undergoing change. There are two approaches to map change in the urban system. The first is that of regimes and thresholds. A regime is a certain clearly identifiable state that the system manifests itself as (for example, the medieval city (regime 1) with its later modernist suburbs (regime 2)). Being able to study the changes to the system over a period of time, along with its key variables, gives clues as to where potential thresholds lie in the system before it tips from one regime into another. The second model is that of the adaptive cycle which identifies growth, conservation, reorganisation and renewal as four phases a system goes through between one regime and another. Each phase offers different opportunities and weaknesses for intervention, with increasing or decreasing levels of resilience.

- Lastly, a resilient city has diversity and variability, as well as modularity and redundancy built into its fabric, as a means of generating reserves for adaptation.

8.8.3 Engaging the practice of urban resilience

For parties interested in engaging with resilience in the urban realm, there are three aspects that need to be tackled on an ongoing basis: analysing the system, mapping changes and identifying the degree of general resilience. These aspects are closely connected and

influence each other. Studying them provides valuable clues as to the state of resilience of the urban system, and furthermore can guide decision-making in the case of a transition being sought for the system. Tackling resilience practice is therefore and ongoing process of study which includes the following three areas of exploration:

1. Understanding the system, its drivers and variables, and scales and relationships: this includes identifying a focal scale addressing a particular issue of concern within the panarchy. The focal scale then forms the entry point to study the dynamics of the system.

2. Understanding the changes that have occurred in the system, its patterns and behaviours, its thresholds and transition points, and regime shifts: where the dynamics of the system are explored over time with the transitions between different states of the system forming important clues for understanding the system.

3. Understanding the degree to which general resilience exists – levels of diversity, redundancy, and modularity: provides clarity about the capacity of the system to draw from its reserves during disturbances.

The above knowledge provides a basis into the nature of the focal system and the patterns of change with which it adapts. It creates an awareness of the strengths and weaknesses in the city system and to design new interventions accordingly. However, it can also be used to intervene quite drastically in the existing system in order to perhaps 'collapse' highly resilient yet perceived to be perverse systems. In this case, transformative resilience requires two further steps of engagement:

4. In what is perceived to be a perversely resilient system, engage with a process of Integral Theory enquiry (see section 8.4.1) in order to consider multiple perspectives in making a decision about its potential partial (sub-systems only) or total (the whole system) collapse. This depth of inquiry is essential because collapsing a system might be making the overall system less resilient, and might mean that the reorganisation of released reserves might be in the form of a regime that is worse than its predecessor.

5. In order to transform the system toward a desired state, the action should be to create a number of small experimental interventions at lower scales (that deal with diversity, redundancy and modularity) by consulting the adaptive cycle. Focus on building general rather than specific resilience. Observe how these changes ripple

through the panarchy and create feedbacks. Fast feedbacks are a sign of increased resilience, but they may be perpetuating negative or positive states.

8.9 Conclusions

This chapter reviewed and condensed the findings in Chapters Four to Seven. It did so by putting forward a cohesive definition of what urban resilience practice is, so that it can form an easy to understand concept that built environment professionals and individuals practicing in the urban realm can apply. In putting forward a definition, it became important to define the scope of resilience; in other words, what it is useful for and where its usefulness detracts from its full potential. It explored the need to focus on building the structural qualities and relationships in the urban system that contribute toward the general resilience of the system overall, rather than trying to make a specific aspect of the system resilient at the expense of the rest. And lastly, it highlighted the potential risks that need to be considered.

While resilience could be used to ameliorate conditions and build the health of the city system over the long term, it may also be used to enhance specific conditions or redirect the entire system toward singular objectives and short-term goals. Either of these approaches would seem 'correct' from the perspective of the individuals practicing them, therefore some form of decision-making framework that would be able to guard against short-sighted decisions is required. A more considered approach would guard against 'transformative resilience' practices that expect certain outcomes, since these are difficult to predict in a complex-adaptive system like the city, and the consequences of agitating the system might return unwanted results.

CHAPTER NINE

FINDINGS & CONCLUSION

9.1 Introduction and summary of findings

This study originated from an interest in resilience theory and its growing popularity in the built environment sector in South Africa. This interest extends to understanding the complexities of urban systems, where harnessing the dynamics of change and latent potential can maximise regeneration (potential) and minimise risk (stagnation) to the urban system (Folke 2006). It aimed to disentangle many contradictions and confusions in the way resilience is being used locally, to derive some cohesive clarity for its use as a meaningful tool in thinking about cities and developing them. The further concern was to contribute to and expand the knowledge about what urban resilience is and how it can be applied.

This interest in the urban resilience topic led to a particular problem. If urban resilience practice is to contribute meaningfully to the development of the built environment, then its core concepts must be clear. Furthermore, in trying to refine and enhance the methods and practices of urban resilience, it would be valuable to borrow approaches from established resilience theories that synergise with urban areas. This led to this study which explores the practices of ecological resilience theory to see how they might inform urban resilience theory and approaches. The basic premise of this study was then derived, proposing that *it is possible to translate core concepts from ecological resilience theory into urban systems to form the basis of a clear urban resilience theory*.

A number of questions followed to support or test the premise of the study. The main question is: *how do ecological resilience concepts translate into a holistic urban resilience approach?* This then resulted in three sub-questions which aimed to look at what resilience theory is, what the core concepts of ecological resilience are, and how these translate into an urban environment. From these questions, the following objectives became clear and guided the research process and methodology that generated finding:

1. To refine the definition of urban resilience based on a sound foundation within existing resilience theory.

2. To develop the meaning and conceptual clarity of urban resilience, building on an ecological resilience perspective.

3. To explore how ecological resilience concepts translate into an urban system.

9.2 The contribution the dissertation makes to the research field

The conclusions and findings of this study have added new knowledge to the field of resilience theory in general and urban resilience specifically. This dissertation has added new knowledge in three ways:

1. Core concepts from the field of ecological resilience theory were translated into an urban environment.

2. Explorations into *urban* resilience definitions were developed and enhanced.

3. An approach or framework for applying urban resilience thinking was suggested.

These findings may, firstly, provide conceptual clarity concerning the basis of an urban resilience approach, and make it easier for professionals working with urban development to find common ground around the concepts, applications and scope of urban resilience and thereby enrich the theory further. Secondly, it puts forward an urban resilience framework and process that can be used in future research as the basis for a methodology of practice. Thirdly, since resilience has been identified as one of the themes for its 2055 Tshwane Vision, the findings provide a number of useful examples of how urban resilience currently plays out in the city and helps to elaborate an understanding of the Tshwane system. These examples may be of benefit to other cities.

Lastly, this dissertation supports the understanding that resilience thinking can bring a number of divergent fields together towards a common understanding of what resilience is and how it contributes to urban development and management. It also brings together many traditionally competing ideas and shows that they are all relevant at different scales and in different relationships in the city. Resilience thinking assimilates many ideas into a cohesive practice.

However, there are also limitations to the study. It is acknowledged that the data focuses only on the physical aspects of the city and does not include the intangible qualities that also contribute to the resilience of worldviews, people and places. These aspects will have to be engaged in future studies, so that an inclusive or integral perspective can be gained on urban resilience in order to ensure its practitioners are fully engaged with the entirety of the system in which they are working.

9.3 Areas for future research

In this dissertation the premise was explored that ecological resilience concepts could be translated into an urban system. Using the Tshwane urban system to illustrate this, this study found that ecological resilience concepts can indeed be translated to cities, and a basis for a holistic urban design approach based on the findings was established. Furthermore, in exploring how these concepts translate, a number of questions were identified that could form the basis of future research.

Firstly, what lessons can be learnt from applying the urban resilience framework generated in this dissertation into other urban areas? This would see the application of this framework to other areas, with possible adaptations that are generic with others that are location specific.

Secondly, how do the intangible urban aspects affect the urban resilience of a city? The ideologies of politicians, and hopes, fears and dreams of the citizens, shape and are influenced by cities. What would an urban resilience framework that integrates these aspects look like? This would see an investigation into the developmental psychology and worldviews influencing the decision-makers informing the development of a city.

Thirdly, this dissertation identifies the potential for urban resilience thinking to influence change in the urban environment, by identifying aspects that are responsible for transformation in a system. This can be both positive and negative. What would the normative basis be from which to transform the system? Would this lead to an improved state, and what (or who) defines an 'improved state'? How can decision-making be guided in the use of transformative resilience to ensure that changes made to transform the urban system toward a specific set of goals are ethical, just and holistic? This would see the identification of a normative 'goal' for the range of qualities for a city, and then the type of responsible entity the would be able to make informed decisions about this.

Fourthly, Integral Theory can serve to bring together multiple resilience theories in order to find a holistic approach toward urban resilience practice. How might an Integral Theory approach assist in creating a basis for using urban resilience thinking in transformative decision-making? This would require a deeper exploration of the basis of Integral Theory and its framework along with the interpretation of the urban resilience framework in relation to it.

9.4 Providing an answer to the research question, and findings of this study

In order to substantiate the premise of this study, namely that *it is possible to translate core concepts from ecological resilience theory into urban systems to form the basis of urban*

resilience theory, it became important to answer *how ecological resilience concepts translate into a holistic urban resilience approach?* The short answer is that ecological resilience concepts easily translate into the urban system; however, the long answer shows that due to the complexity of an urban system, further explorations are required to develop a holistic approach toward urban resilience.

9.4.1 Findings for the conceptual basis of resilience

In this dissertation, the investigation into urban resilience is grounded in the practices of ecological resilience theory, because ecological systems and urban systems share a lot of synergy in that their structures are similar. They are both complex-adaptive systems that result from the close partnership between humans and the natural system of which they form a part. In addition, ecological resilience theory is well established, with advanced theoretical underpinnings and research as well as in its application over the last forty years. Lastly, an ecological resilience base ensures the development of an urban resilience theory and approach grounded on whole systems thinking and an ecological or holistic worldview.

In refining resilience thinking for the urban realm, based on an ecological conceptual basis, the first finding was that there are various manifestations of resilience that exist simultaneously within a city. More importantly, all of these manifestations are important and necessary when engaging with urban resilience thinking. Loosely linked to these manifestations of resilience are various perspectives from which to engage with resilience, and more a hybrid approach which includes the various definitions and approaches toward resilience are required in urban social-ecological system. The second finding is that an ecological, holistic or integrative viewpoint is required to bring together these various conflicting, yet necessary aspects of resilience. The third finding in establishing the conceptual basis of resilience is that an urban resilience thinking framework, is rooted in a systemic description and understanding of the city, while also applying normative values over what should be transformed.

9.4.2 Findings for understanding the system

In the focal areas studied, core concepts from ecological theory can be successfully translated into the urban system. Observing the City of Tshwane as a social-ecological system with a hierarchy of interacting adaptive cycles, i.e. the concept of a panarchy, translates well to the city, as can be seen in sections 5.2 and 6.2. This ties to another finding, which is the importance to work across scales over a period of time. Defining a panarchy and key drivers gave rise to a better understanding of the urban system; identifying the drivers and variables in the city working across different scales and in different time-frames

(fast and infrequent versus long and frequent) (Chapter Six). The concepts and methodologies used for observing change in ecological systems also translate easily into the city, with the regimes and thresholds model, as well as the adaptive cycle model, being illustrated within the urban system (Chapter Six). An investigation into the thresholds and regimes model explored a site in Waterkloof Glen, east of Tshwane, which has seen significant growth and development between 1944 and 2014 (see section 6.3). Clear threshold periods define regime shifts from undeveloped, to residential, to the current uses.

Secondly, the adaptive cycle model explored using an imaginary site, but representing the usual cycles of change that manifest over decades in urban areas, illustrated in section 6.5, plays out in different ways and scales in the city. Similarly, the regimes and thresholds model applies to various parts of the city, and while the thresholds between regimes emerge from that context they may provide lessons in similar contexts in the city. In both models, the intangible, social domain has a significant effect in defining thresholds of change and collapse between regimes. Thirdly, relationships between variables inform feedbacks and thresholds that create patterns of change over time. These patterns, variables, and feedbacks start to provide clues about the level of resilience (diversity, modularity of connections and redundancy) within the system to sustain and adapt to change.

9.4.3 Findings for understanding the resilience of the city system

The adaptive capacity of an ecological (and urban) system emerges from three useful concepts, namely diversity, redundancy and modularity. The concept of adaptive capacity translates into the Tshwane urban system as the capacity for a city to evolve using its existing resources over time. Diversity, modularity and redundancy were explored within three different focal areas (Chapter Seven), and the results were interpreted as to whether the focal areas embodied the qualities of resilience.

The first finding was that the adaptive capacity of the Tshwane urban fabric in to evolve, is decreasing. New gated communities at the scale illustrated in this dissertation (that of a townhouse complex and a gated estate) are showing fewer levels of modularity and redundancy in terms of services, accessibility and building typologies. The second finding is that in relation to urban form or typologies, new developments in are causing the city to lose its functional diversity. Buildings are increasingly being designed to address mono-functional uses related to town planning prescriptions. While the town planning requirements may change, buildings designed for specific functions within rigid typologies will not be able to adapt as easily, resulting in more of the existing fabric of the city being demolished. This is true for functions or uses within the buildings as well as the densification of the city (which is

increasing through demolition rather than city block infill). The success with which the inner city and higher density residential areas (and to a lesser degree the older residential suburbs) has adapted to cater to societal changes demonstrates a resilience within the building typologies and urban morphology prevalent in those areas. However, within the focal areas studied, the gated community examples indicate a loss of overall resilience in the system both at the local and city scale. Further investigations into other gated communities of varying scales like large estates and enclosed suburbs may likely show similar results, but would need to be investigated in detail.

9.4.4 Findings for actively engaging with the resilience of the city system

Following from the three previous sections, it became clear that a resilience perspective over an urban system proves valuable to inform future development decisions. To actively engage with resilience thinking is to purposefully change the trajectory of a system toward desired goals or a desired regime. This transformative approach to resilience thinking considers how small adaptations might be made over time to increase the adaptive capacity of the sites to evolve over time. It also engages with bold interventions that might see the collapse of subsystems perceived to be decreasing the integrity of the overall system. The first finding in this active or transformative engagement with resilience thinking is to experiment at lower scales of the city system first in order to observe feedbacks. Secondly, given that future disturbances are unknown, it becomes important to build resilience across scales, to increase the overall resilience of the system. This is achieved through building reserves by increasing diversity, modularity of connections and redundancies in resources in all aspects of the city. This requires a holistic or integral approach since normative positions over what aspects of the city are favourable over other may actually be limiting the resilience of the city by leaving out key areas of concern. This leads to the third finding, that while ecological resilience topics transfer well in the physical urban fabric, their translation into the social domain still requires investigation. This investigation could be guided by an ecological, holistic or integral worldview (Figure 46-1C), that assimilates various perspectives or truths that contribute toward the integrity of a system with potential to evolve over time.

A closer look at the three qualities of resilience showed that diversity in the city was explored through function, response to function, and diversity across scales. In the physical fabric of the city, diversity manifests in infrastructure, in building typologies, and in resource networks. Diversity also manifests in non-physical systems, like town planning regulations, social and cultural norms, and in monetary systems. In this exploration, an additional finding was that in

a city, diversity is not limited to the physical environment; however, the physical environment does largely affect the options for diversity in the socio-cultural environment.

Urban redundancy was explored from the perspective of a gated estate settlement, using the perspective of accessibility and electricity provision. It was seen that, while a single entrance increases the monitoring of vehicle entry and exit to limit criminal threats, it did not necessarily increase the overall safety of the community in the case of service failure or other disasters, nor did it fascilitate accessibility to the broader urban network. Dependence on external sources of electricity increased the vulnerability of the community in times of power outages. Alternative solutions for building redundancies into the road and service networks were discussed. The finding in terms of redundacy was that the city was decreasing its backup, with greater dependence on a few, vunerable components.

Lastly, modularity of connections was investigated from the perspective of scale, networks, flexibility, variablity and openness in a suburb where townhouse complexes form the dominant development response. This investigation therefore also found that the current network fails to create a loose-knit system on a finer and broader scale, and that the current layout lacks the variablity that could provide flexibility and openness during times of disturbance. Together, diversity, redundancy and modularity create the basis for system reserves to be regenerated or depleted (see section 7.5), and can contribute to the success or failure of urban development. Consequently, understanding the inherent quality or story of place, and its latent potentials is critical in building general resilience.

In this dissertation it is demonstrated that core concepts from ecological resilience theory translate well into urban systems. The findings further establish awareness of urban resilience theory in the management and design of the built environment. The understanding of urban resilience discussed in this dissertation can therefore inform development in urban systems that create environments (and in future, people) with the capacity to persist and thrive in a rapidly changing world.

9.4.5 Findings for the practical benefits of resilience thinking in city spaces

For professionals engaged in the making and management of cities, the practical benefits of resilience thinking include a metaphorical lens through which to see the city and a compass to guide actions toward a dynamic resilience state. For built environment designers, this dissertation highlights the usefulness of resilience thinking as both a lens and as a compass; a multipurpose tool for design decision making. The following discussion briefly explores two examples in using the urban resilience framework developed in this

dissertation and tracks the process an architect using resilience thinking on a brownfield site, and a policymaker using resilience for local government management, may follow.

An architect, would begin by familiarising herself with the various manifestations of resilience potentially at play in the project site. With this knowledge, she would begin to develop an understanding of the system within which the site is located by bounding it as a focal system. She should then identity key variables and feedbacks that have had an impact on the site over a period of time and how these problems and possibilities link to the scales above (larger urban context) and below (within the site itself, including the client and the intervention) (see Chapter 6 for examples). From this, she would gain an understanding about the potential for change that the site holds, whether it is at a critical threshold, whether the intervention can be used to unlock potential in the broader area or whether it is blocking potential. This is linked to an understanding of the reserves available to the site that then influence its level of resilience. This effectively forms the basis of a 'lens' through which she can understand the site.

From this, based on the intention behind the intervention, the architect can determine whether there is a preset condition and scale to which she will aim to build specific resilience (which she understands may make the intervention more vulnerable once conditions in the system change. For example, if she makes the design of the intervention resilient to climate change, this particular design might take into account many structural considerations for energy harvesting, flood and fire control, and temperature regulation. However, the way in which the community engages with the building might not have been considered and in that instance, the building would not have included a more general resilience response and might be rejected by the community. In developing the design, she would explore the qualities of resilience, namely diversity, redundancy and modularity in relation to what she has identified should hold greater resilience or weaker resilience. Her interventions would be at difference scales and she might begin by experimenting with a few options to see how feedbacks and variables respond. In all of this the architect would be making a number of value judgements related to her interpretations and her proposed intervention as well as those of the client, which would ripple beyond to the broader system.

For a policymaker, again the urban resilience framework (Figure 46) provides a tool for engagement, and the policy maker would follow a similar process as most other professionals engaging with it. In reflection, the practical benefit of resilience thinking for policy is not in suggesting that resilience is the goal for development. Rather, it is a means to assess whether certain policies are indeed achieving their intentions, or whether they are

actually decreasing the resilience of positive aspects of the city while increasing the resilience of destructive patterns. How the city is understood to be resilient (and what is seen to be positive or negative), through which policies are constantly revisited, therefore is of importance. This implies that in developing policy, the resilience lens requires an active engagement with a continual study of a dynamic city system. If policy making continues in the locked-in and slow to change method it has been thus far, the use of resilience will be limited to critically studying the urban system. However, if the nature of policy making can become more flexible and dynamic so that existing policies can adapt and change easily and quickly to accommodate a changing world, then they become resilient themselves and reflective of a dynamic system. This would mean that policy writers would both study and adapt policy continually to the findings of the resilience of the system to disturbances and would create policy that allows for the city to evolve in a more dynamic and emergent manner. Again, these policy makers would be guided by certain value-judgements that profoundly affect the lives of the urban citizen.

These theoretical examples have not been applied or derived from an actual case study, and it would be valuable to test them as the basis for further and on-going research. What they show, is fluidity and a certain ease of translating resilience thinking concepts to different situations; whether it be the design of a building or the creation of a new policy.

9.5 Summary of the conceptual framework of urban resilience

This dissertation summary outlines the conceptual framework of urban resilience as illustrated in Figure 46. Findings were summarised into a resilience thinking approach for urban areas. This approach could potentially also establish a pathway to follow when studying resilience in different neighbourhoods or cities. This approach or framework has been adapted from an ecological theory base as well as practical exploration in the Tshwane urban system. It begins by addressing the foundational understanding of what resilience is and how it can be used in the built environment as illustrated in Figure 46.

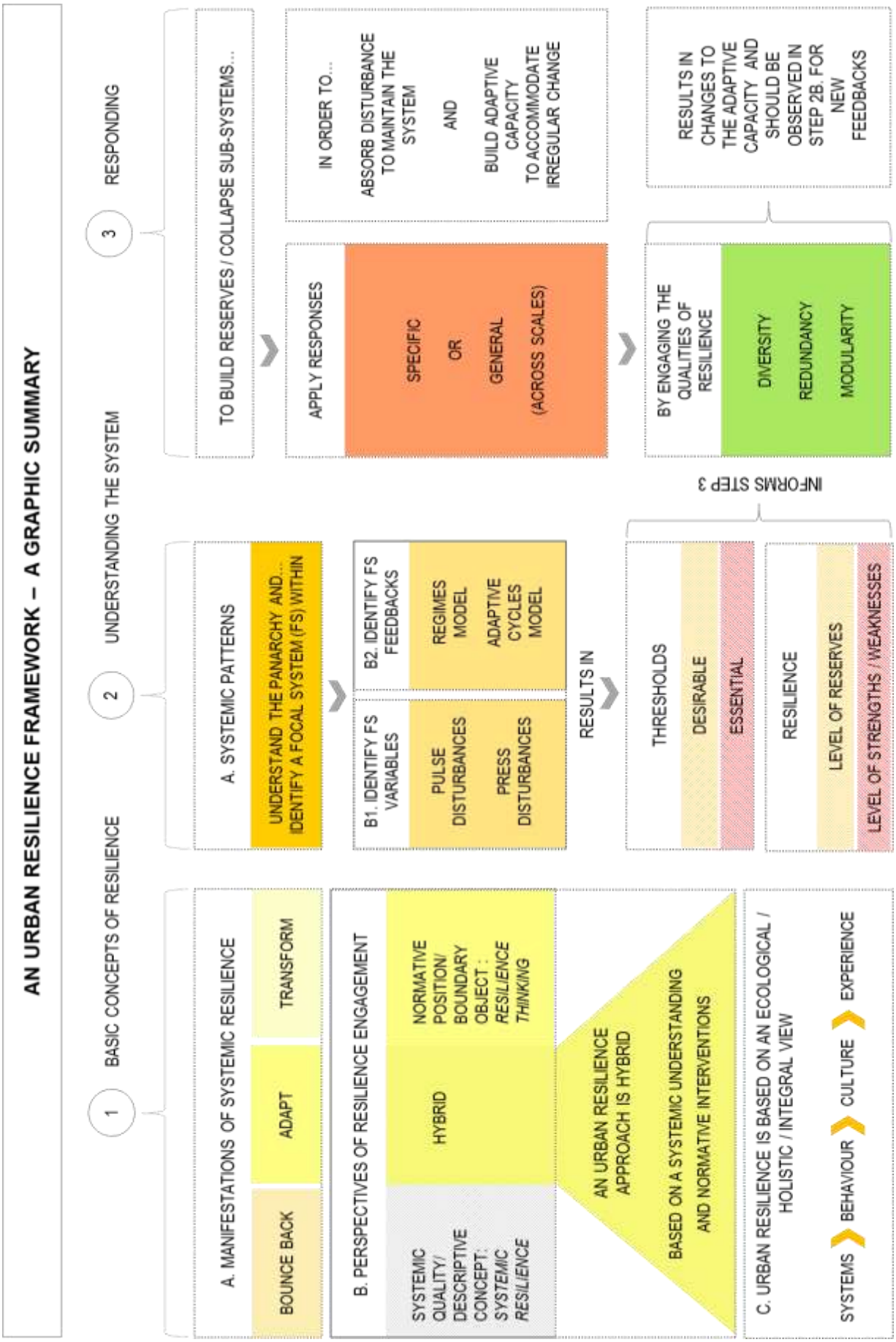


Figure 45 - A graphic summary of the conceptual framework for an urban resilience approach, based on ecological resilience concepts (Author 2015).

Firstly, three definitions seen in Step 1 – Basic concepts of resilience 1A, are derived from the understanding of resilience as an emergent property in the urban system that reflects its capacity to deal with change. These definitions can briefly be summarised as:

1. Bounce back – the ability of a city system to recover quickly to a previous state following disturbance, thereby maintaining its functional identity and not changing.

2. Adapt – the flexibility in a system to accommodate and absorb disturbance and change within subsystems, while maintaining existing functionality, integrity, structure and feedbacks.

3. Transform – the capacity of a system to change its subsystems through collapse or regeneration. This affects the functionality, structure and feedbacks between subsystems, while maintaining the overall integrity of the larger system.

The way in which the emergence of resilience in a system is perceived, affects how resilience is engaged with in the built environment. These multiple perspectives also affect how resilience functions as an umbrella concept in multidisciplinary projects. On one side, resilience is seen to be an emergent property of a system as shown in 1B, and is therefore a descriptive concept. On the other, resilience is seen to be a normative concept, as the pathway to achieving sustainable development. Between these two perspectives lies a hybrid of both, in which resilience is understood as an emergent property of a system, but also as essential to achieving the goals of sustainability. In *urban* resilience approaches, both of these perspectives are important – in understanding the city system, and then in engaging and responding to it. In addition, urban resilience is not an 'either or' approach. Rather, in reflecting the complexity inherent to an urban system, urban resilience thinking reflects and integrates a diversity of resilience thinking approaches, perspectives and practices. Incorporating Integral Theory perspectives of experiences, behaviours, systems and cultures as shown in 1C, for both resilience thinking and for the city itself, provides a means of arriving at a more holistic engagement with resilience thinking.

Secondly, following on from this basic understanding of resilience, the next area of investigation illustrated under Step 2 – Understanding the System, involves defining the focal system within the panarchy, as well as the relationships between drivers and variables: its slow changing variables resulting from press disturbances and its fast changing variables resulting from pulse disturbances, as shown in B1. To piece together this understanding of feedbacks, two models shown in B2, are explored: the thresholds and regimes model (that deals with the basin of attraction resulting from the relationship between key components in

a focal system), and the adaptive cycle model (that deals with the phases of change that a system goes through) as described in Chapter 6. This gives rise to an appreciation of certain thresholds that are desired for a system and those that when crossed result in a system collapse. It also illustrates the level of resilience currently within the system; are there sufficient reserves for known needs, and are aspects of the system are showing stronger or weaker resilience to known disturbances?

Thirdly, in response to the systemic understanding created thus far, the third step in the framework for urban resilience is the response. Up to this point, knowledge gained could be used as a means to observe the existing patterns and structures of the city in order know how the system has evolved and what its vulnerabilities might be and to build upon existing systems not to question their value. However, what an understanding of the system provides is a basis from which to actively respond to pulse or press disturbances, and the potential to knowingly transform aspects of the system in order to meet desired (normative) goals. Specific responses would see design measures put in place to allow for the city to absorb known disruption, while general responses would see the adaptive capacity and reserves of the city increased across scales and many subsystems to allow the city to adapt to unknown disturbances. Care would need to be taken not to disrupt the system as a whole, but rather to minimise extensive transformation to sensitive localised interventions that build upon existing patterns and can be used to monitor feedbacks.

To build reserves, regenerate, or collapse subsystems, specific concerns or disturbances in the system are addressed through specific resilience responses, where on the one hand, the system is capable of absorbing disturbances without affecting the status quo and on the other, changes are effected to ensure the resilience of the system to a specific disturbance. Alternatively, enhancing the resilience of the system as a whole is approached through a general resilience response. This response is concerned with the capacity of the whole system to adapt to disturbances that are largely unknown and irregular. In this case, subsystems and their relationships, drivers, and variables may adapt or even transform through collapse, in order for the larger system to maintain its integrity and identity.

Specific and general resilience depends on the presence of three determinants or qualities in a system: diversity (of both functions and responses), redundancy or back-ups, and modularity in connections, as illustrated in Figure 46, Step 3. These become the key areas of concern in engaging with interventions in the urban system. The use of these responses is rooted in an understanding of the focal system outlined in Step 2. This understanding can identify the types of responses that may be used to attempt to diminish or enhance the

resilience of aspects of a system in the case of transformative resilience interventions. Thereafter, their effects should be iteratively reviewed by following Step 2B once more.

The urban resilience framework can be outlined by two approaches to resilience thinking discussed in section 8.2:

1. Evolutionary urban resilience – an ongoing study and observation of the city system (focused on the systems-based and hybrid branch of resilience) that explores and enhances its natural trajectory of evolution i.e. Steps 1-2 of Figure 46:

    a. Understanding the system, its drivers and variables, and scales and relationships

    b. Understanding the changes that have occurred in the system, its patterns and behaviours, its thresholds and transition points, and regime shifts

    c. Understanding the degree to which general resilience exists – levels of diversity, redundancy, and modularity

2. Transformative urban resilience – an ongoing observation and study of the city system (in accordance with the normative branch of resilience) that actively changes the strengths and weaknesses of the city and can drastically alter or collapse systems. In these cases, transformative resilience requires a further step i.e. Step 3 of Figure 46:

    a. In what is perceived to be a perversely resilient system, engage with an enquiry based on Integral Theory (1C) in order to consider multiple perspectives in making a decision about and intervention in the system.

    b. Create small experimental interventions at lower scales (that deal with diversity, redundancy and modularity) rather than grand, large-scale interventions.

    c. Focus on building general rather than specific resilience.

    d. Look out for fast feedbacks as a sign of increased resilience.

It is evident the two approaches share a similar process up to Step 3 as illustrated in Figure 46. For a system to be able to evolve or transform itself in order to maintain its functionality

and integrity, it may have to bounce back, adapt or transform in response to a number of variables within its system; over time it may have to apply all three responses to resilience. It also shows that systemic, hybrid or normative definitions of resilience, may at times embody different manifestations of resilience as conditions would necessitate.

To gain insight into these processes, and thereby benefit from this knowledge, understanding the relationships between system components that create its integrity is necessary. This is gathered by looking for feedbacks using the a) thresholds and regimes model, and b) the adaptive cycle model. Resilience can be identified by looking for its three determinants or qualities (see Chapter 7) in both 'dysfunctional' or 'perverse' systems, and 'positive' systems. Engaging sensitively with resilience qualities can build the capacity of the system as a whole to adapt and evolve in response to change. The framework provides a basis from which to engage with resilience thinking in an urban system, by providing a clear process within which to research the city system. It also brings together the many conflicting meanings and understandings of resilience within a simplified approach.

9.6 Conclusions

This dissertation emerged out of an interest in the topic of resilience theory, a concept that seemed to surpass those aspects of the sustainability movement failing to gain ground in a fast-changing and highly interconnected world. Of course, the complexity of resilience theory itself soon proved that 'resilience' is not a panacea for all urban development problems. It is also not a means of achieving sustainability *per se*. In the muddle of multiple perspectives and fields that characterise the urban system, various interpretations of urban resilience have emerged; however, these are often contradictory or very specific to certain conditions. In trying to bring them together to form a cohesive base of urban resilience thinking, it became apparent that any exploration of resilience within the urban realm would be difficult to articulate. A framework or urban resilience approach emerged from exploring the premise that ecological resilience concepts apply to the urban system. Urban resilience has stood the test of time as the capacity of a city (its functions and meanings) to evolve and persist over time. The practice of urban resilience thinking embedded in whole systems thinking, consequently provides the core concepts that allows cities to evolve and thrive.

This dissertation contributes to resilience theory and its translation into the urban system, by refining an urban resilience approach. It argues why resilience plays an important role in development thinking however, its application requires some uncomfortable, costly and difficult to realise changes in managing urban development (which will yield higher rewards in the long term). Firstly, the process outlined in this thesis demands active engagement with

the focal system – no copy-paste designing, checklists or quick fixes. Time must be taken to study the system, before generating 'experiments'. Secondly, resilience requires a whole systems perspective based on an ecological worldview contrary to the dominant narratives of private and public sector development. Thirdly, and perhaps most importantly, the notion is put forward of a holistic imperative to transcend and include (in both tangible and intangible dimensions) what came before, as part of an evolutionary approach.

The knowledge developed in this dissertation may not effect change in time to prepare cities for the literal and metaphoric storms that lie ahead, but there is comfort in knowing that this knowledge does exist. It shapes an urban resilience understanding that is dynamic and useful to build upon. It acknowledges that urban resilience represents a mind-shift that needs to occur in the ongoing study, design and management of cities. Perhaps as more people begin to engage with resilience concepts, they can contribute toward the evolution of humanity and its resilience in an integral partnership of live on this little planet us humans call 'home'.

ADDENDUM A

10.1 Broader changes in Waterkloof Glen – the Menlyn Maine development

The Menlyn node located in the east of Tshwane has developed significantly over the last few years. Most prominent has been the redevelopment of a 165 000m^2 established suburb into a new private high-density commercial development called Menlyn Maine. The project is a mixed-use development that is being promoted as Africa's first 'Green City'.

Advanced technology supposedly puts Menlyn Maine at "the forefront of the green revolution" (Menlyn Maine, n.d). Three internationally recognised green building strategies are used to achieve this: GreenStar, LEED-ND and Climate Positive. All buildings achieve at least a four-star GreenStar rating from the GBCSA, the entire precinct is being certified under the United States LEED neighbourhood development (LEED-ND), and zero carbon emissions during its operational phase are targeted as part of the Clinton Foundation's Climate Positive project (Otto 2013).

'Green building' is used to differentiate Menlyn Maine from other developments in a depressed building industry and flailing economy (Corobrik SA 2014). This marketing strategy appears to lack authenticity given what has been built so far – an office park with pavilion buildings rather than a fine-grained emergent city (Hes & Du Plessis 2015). A well-established residential suburb was demolished. Multi-layered integration of energy services and civil infrastructure in the broader environment and ecological services are limited. Imported building materials and resources are being used to build medium density office parks and yet another future shopping centre between established shopping nodes – Menlyn Value Mart (3) and Menlyn Park – set to become the largest mall in Africa (2) (see Figure 47). The mix of uses focuses on the formal market, and limits economic diversity across scales (Ferreira & Du Plessis 2013).

The site illustrated in Figure 47 was previously suburban land, and housed an established middle-income community of over 100 households. The neighbourhood, along with its social networks and memories, was demolished to make way for an upmarket 'mixed-use' development. The development promotes an island of pedestrian space and a public transport stop in a car-dominated city. However, the 85 000m^2 of luxury residential units offered cannot solely feed the 35 000m^2 of retail and 140 000m^2 of office space; the area still relies on private transport, as evidenced by its large parking basements.

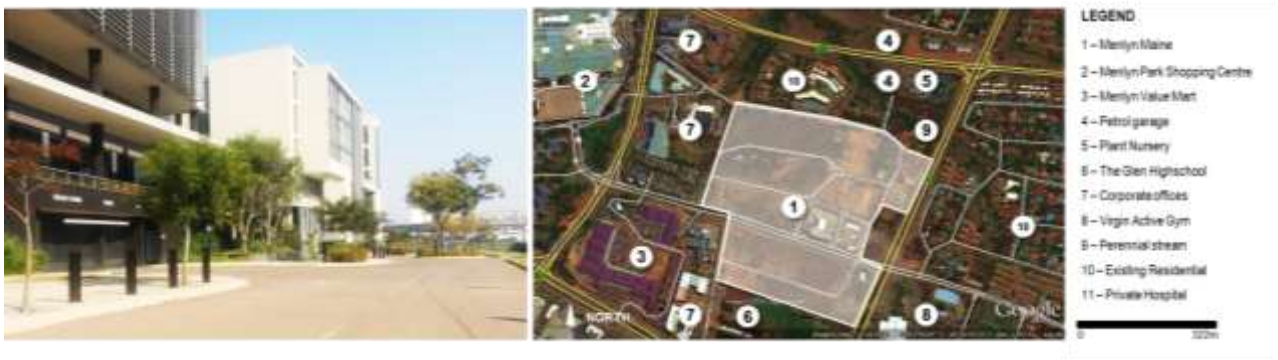


Figure 46 The Menlyn Maine "Green City" development (Author 2014). Base image courtesy of Google Earth; photo by Willem De Lange (2014)

In spite of opposition from neighbouring suburbs and other interested parties (Mudzuli 2014), the development includes a multi-billion Rand casino within an entertainment and events facility (Corobrik SA 2014). While the casino may generate income for the city, it represents an internalised anti-urban and unsustainable typology contrary to the green vision being marketed. Disappointingly, in a country where economic and educational segregation is fast replacing racial segregation, Menlyn Maine perpetuates unsustainable cultures of consumption.

Menlyn Maine has transformed a suburban condition into a new state. However, without considering the flows within the previous suburb and the potential released by the collapse, the consequences might lead to problems in the broader resilience and functionality of the city. For example, the shift of private business away from the CBD adds pressure to the already depressed inner city economy. Increasing commercial activity in Menlyn without the provision of affordable housing may potentially increase instances of informal settlements in leftover land. Quantitative goals are met, but the internal qualitative aspects that address sustainability and 'green' ethics have been ignored (Hes & Du Plessis 2015).

ADDENDUM B

11.1 Integral Theory as basis for clarity in urban resilience practice

Reality is reality. There is only one, and it's permanent. This means that at some point the inner and outer worlds must meet; we won't have to choose between them – Deepak Chopra (Chopra & Mlodinow 2011).

The application of resilience thinking to urban systems presents two practical challenges. These challenges arise from the range of methodologies relating to various fields of resilience inquiry, as well as from the inherent complexity that underpins any practice within social-ecological systems. The first challenge relates to the difficulty in assimilating the various resilience theories and their methodologies into a strategic practice of urban resilience in order to intervene holistically, taking into account the external manifestations of a city and its internal directives. This challenge is summarised as, *how do you appropriately apply different facets of resilience theory to the city as required?*

The second challenge relates to the responsibility inherent in resilience practice – to make holistic choices for the good of society and all living systems. As the study of the resilience in a particular city grows into an understanding of which aspects of the city system show strong or weak resilience, so too does the understanding develop that interventions may build up or collapse systems. Actions ripple beyond the focal system. Urban resilience practice therefore requires holistic thinking.

Engagement with holistic urban resilience is not an easy task. For example, a rapidly urbanising Global South imposes a duty on the urban resilience practitioner to think holistically. Where dirty energy is an available and secure source of economic growth in the Global South, should the opportunity it provides be denied out of the knowledge of its effects on global climate change? How does one overcome the initial colonial or later nationalist or dictatorial spatial planning that contributed to the history and development of the Global South in a way that transcends the scars of the past, and which would enable a positive and fulfilled citizenry to constantly emerge?

These are not easy challenges to solve. They require philosophical engagement and a framework that can facilitate an urban resilience practice that is both integrative of the various resilience perspectives required in a complex social-ecological system, as well as motivated by strong holistic practices which illuminate a life of purpose. Proponent of integral philosophy, Ken Wilber, indicates that, for holistic development or an 'integral vision'

to occur, perspectives must be assimilated and developed to reach their highest levels of development or growth (Wilber 1996: 311). This assimilation and development is described using the Integral Theory AQAL model introduced in the dissertation in Section 3.6.4. Integral Theory is not without critique. Ken Wilber's interpretations of his sources, assumptions, arguments, methodology and Wilber's own psychological framework are also questioned. However, in spite of the complexity of the Integral Framework, it's perceived 'new age' appearance with subsequent lack of academic scrutiny and lastly the lack of examples where it has been used in practice, the theory still provides benefits to integrate complex issues. The following sections unpack the different stages of development within quadrants (*levels of consciousness*), the paths that comprise this development (*lines*), the transient experiences during the entire process (*states*), and the different styles or 'characteristic flair' that are present in all stages (*types*).

11.1.1 Levels of development – structures producing complexity and depth

While quadrants or *quadrivia* represent the various domains from which reality is viewed, each domain has its own inherent levels of structural development toward greater depth or greater complexity within the terrain. Developmental researchers across many fields agree that biological evolution increases in complexity (De Kay 2011: xxvii). This general path of development starts with greater span, where new levels gradually transcend the limits of previous levels by building on them and subsequently increasing in 'altitude' in the holarchy

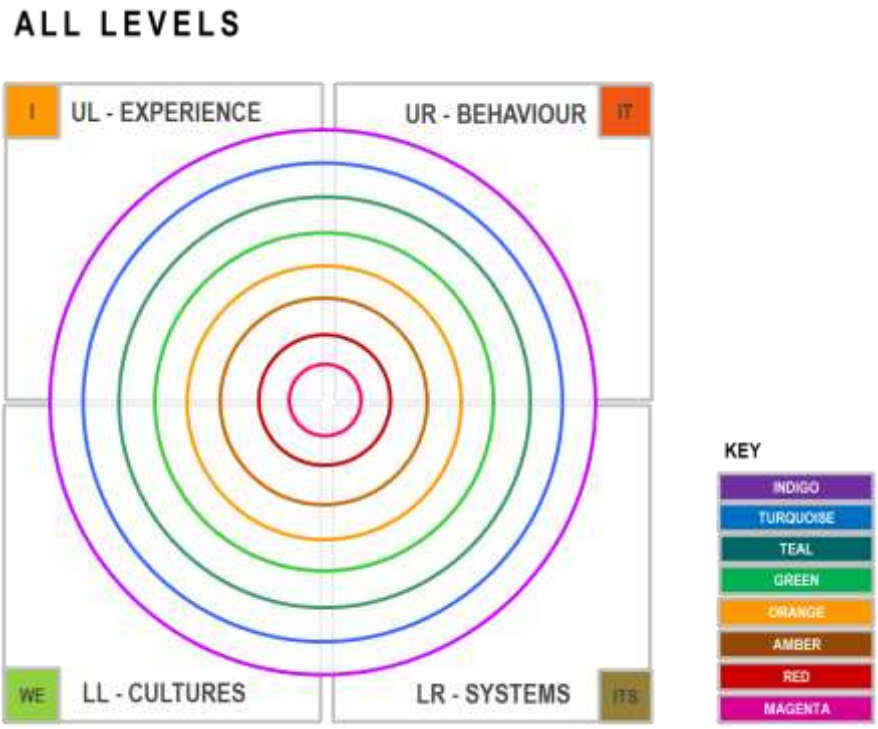


Figure 47 - Transcending levels of consciousness, from red to turquoise, adapted from Wilber et al. (2008) and De Kay (2011)

by embodying less span, but greater depth or awareness (enfolding inward) or complexity (increasing outward).

Developed Left-Hand quadrants (experiences and cultures) embody greater depth, while more developed Right-Hand quadrants are represented by greater complexity. In any holarchy, the levels or stages with greater depth depend on, and organise the structure, of those with less depth. In Figure 48, each distinct level in this progression is represented by a colour – from red to amber, orange, green, teal, turquoise, and indigo – that in turn represents the difference between less (red) to widened (turquoise) depth or complexity, or from 'me' (egocentric or red) to 'all beings' (planet-centric or turquoise). While turquoise is currently the highest level noted, there are other levels above it in the holarchy; however, we are not yet aware of them. These levels of developmental complexity can be summarised into three broad 'waves': in Behaviours (UR) for example, they are gross, subtle, and causal. They correlate to body, mind and spirit in Experiences (UL) (De Kay 2011: xxxi), and represent the "general level or altitude of consciousness" (Wilber, Patten, Leonard & Morelli 2008: 89).

Levels represent structures of consciousness, where consciousness is the space wherein development or growth emerges and unfolds, i.e. evolves. They are permanent conditions or 'traits' that provide a "context of interpretation for wisdom" (De Kay 2011). Awareness unfolds with each level, and once a certain level of awareness and wisdom has been attained, it cannot be lost. Development in one domain/ quadrant correlates with the other quadrants. In other words, if the average permanent development of an individual is at the Red level (instinctual self) in the Experiences (UL) quadrant, then the centre of gravity in the other domains will also reflect Red in the Behavioural, Systems and Cultural quadrants (De Kay 2011: xxxi). Skipping levels is not possible as this would result in a break in the progression of development, and would lead to a return to a level with less depth closer to the centre of gravity of the individual, society or enterprise (Wilber 1996: 127). However, it is possible to facilitate the process by promoting the qualities at the next level of consciousness.

Levels inform decision-making regarding the priority of and relationship between greater and lower levels of complexity, especially where global structures have competing worldviews. As global structures evolved from Pre-Modern or traditional (all-level, but not all quadrant), to Modern (all-quadrant flatlands with no levels) to Postmodern (further fragmented pieces) (Wilber 1996: 309), the complexity budget increased. Integral Theory weaves levels of consciousness together and builds on their inherent knowledge. Intervening within a system should engage the consciousness level or 'centre of gravity' of entity under observation. The AQAL framework initiates a multi-perspectival view over any situation;

however, the wisdom to act depends on an understanding of the consciousness levels represented, since it is "not enough to just be aware of the quadrants – you must also work with the depth and complexity within each domain" (Esbjörn-Hargens 2012: 7-8).

11.1.2 Lines – the multiple intelligences comprising the quadrants

Lines are specific areas of development that "describe the distinct capacities that develop through levels" (Esbjörn-Hargens 2012) in each quadrant or domain. The levels of consciousness and their growth have sequential correlates in each of the four quadrants that reflect the similar centres of gravity of development across all quadrants; growth in some quadrants is a prerequisite for growth in others. However, consciousness does not develop monolithically in all areas or facets of life at the same time (Wilber *et al.* 2008: 81). Each quadrant has a combination of various 'developmental lines', paths or 'intelligences' at different levels of development, i.e. streams which are evolving, growing or progressing independently from each other (Wilber *et al.* 81) and which reflect different rates of growth and development.

Lines represent facets of the quadrants under a similar theme. For example, under the Experiences domain (UL), one would develop multiple yet separate intelligences along the lines of cognition, morals, needs, self-identity, values, emotions, interpersonal and aesthetics. For a person, the development on each line can be represented by a unique *psychograph,* while for social groups it is represented by a *sociograph* (Esbjörn-Hargens 2012). A person or society (or city for that matter) might have highly developed cognitive and kinaesthetic lines (turquoise) and yet have underdeveloped spiritual (red) and moral (amber) lines; together, development along each line refers to the altitude from which life is engaged, problems tackled or solutions derived.

The level or altitude that a line is at can in certain reactions predict behaviours and perceptions. For example, a politician with a highly developed interpersonal line (turquoise), but with underdeveloped cognitive, moral, emotional and spiritual lines (red) will most likely have rapport with the larger public, and will likely promote traditionalist or conservative politics (Wilber *et al.* 2008: 84). The graphs also indicate the strengths and weaknesses in the individual or group to understand how to work within those to effect positive change.

11.1.3 States – structures of temporary forms of awareness

States of being are either normal or altered, and no two states can be experienced at the same time. Described as temporary or transient forms of awareness (lasting anything from a

few seconds to years), they include waking, dreaming, deep sleep, meditative states, and peak experiences (Wilber *et al.* 2008: 70). Human beings are capable of experiencing "a variety of states of consciousness that arise and disappear, blending and changing from one to another to another" (De Kay 2011: xxvii). The system or self at any stage or level of consciousness can experience altered states at any level of consciousness; these are however temporary experiences and not yet long-term 'traits'. Peak experiences at higher altitudes are temporary, as the centre of gravity of the system or self has not yet actually developed through the stages or levels of consciousness (Wilber 1996: 183). Since reality is always shifting and changing between different states, being attentive to the shifts between states can enable proactive engagement with the process of change (Esbjörn-Hargens 2012), to harness its transformative potential rather than block its fluid, on-going nature.

11.1.4 Types – patterns of difference

Within the process of development, two things can exist that are radically different from each other, but which have the same role in the holarchy, i.e. neither is above the other. These 'horizontally different' typologies are called 'types' in Integral Theory and can include differences in genders, yin or yang, personalities, music, languages, or relationships (Wilkinson *et al.* 2010; De Kay 2011). They represent "consistent styles that arise in various domains and occur irrespective of developmental levels", and are very stable and resilient (Esbjörn-Hargens 2012). Types allude to preferences; for example, a preference for jazz or classical music, no matter how great the personal preference, does not mean that one type is better than another; each is a different expression with its own unique characteristics.

Types are present at any level in the development process. For example, masculine and feminine types will be present in the self line in every person. Awareness at greater altitudes of their presence will enable the integration and union of type in a holistic expression of self (De Kay 2011: xxxi). Every person (man or woman) has a gender type (either masculine or feminine) that "describes the texture, not the structure of developmental growth" (Wilber *et al.* 2008: 107). The 'less dominant' type should not be ignored in an integral study.

Types typically remain the same regardless of their position in the process of growing consciousness – a left-handed person in red remains left-handed in turquoise and across different lines (Wilber *et al.* 107). However, in complex scenarios such as personalities, types are less static and can shift. Awareness of the role of types, and by accommodating common and consistent styles in an intervention, "you are more able to infuse sustainability into your efforts by linking to existing enduring patterns" (Esbjörn-Hargens 2012).

11.2 The intangible (Left-Hand) qualities of an Integral City

While this dissertation focuses on the tangible qualities recognised as resilient in a city, there are also intangible qualities that emerge from individual and collective beliefs, cultures and practices. This section touches lightly on a few topics related to the intangible aspects of urban resilience. Cities emerge from collective, self-organising, fast paced, bottom-up networks of people responding to pulse disturbances, as well as from top-down authoritative decisions by institutions and their leaders, which usually take a long time to develop and the effects of which persist for a long period. The internal perspectives (LH: experiences and cultures) of these self-organising networks and their institutional authorities match the external perspectives (RH: behaviours and systems) that form the physical basis of our experience of urban areas (Hamilton 2008: 16).

The beliefs and mindfulness of those in power contribute largely to the resilience of a city and its potential to bounce back, adapt or transform toward an alternative state that would improve the integrity of the system (Hamilton 2008). Focusing entirely on external perspectives in the design and resolution of different problems does not reach or ensure the buy-in of the people who will be implementing and steering the course of the proposals.

In response, collective and individual notions about the purpose of life need exploration. This is important because, fundamentally, the city is the unique physical extension of the collective and individual purpose that evolves over time, as society and its constructs within the city change. However, in the 'hyper-individualised' world we live in, it is rarely asked of citizens to reconnect with their purpose, to engage in their contribution to the city or with their responsibilities to each other. Subsequently, "we live at a time where the lack of conscious purpose at the scale of the individual and the scale of the city create ricochets of side effects" (Hamilton 2008: 110).

Rapidly changing cities like those of the Global South often emerge in the form of new rural subsistence cities, and represent places of opportunity for millions of people. In these instances, the purpose of the city varies as significantly as the cultures, beliefs and backgrounds of those entering it for the first time on a daily basis (Pieterse, 2008). Their first experiences of the city, whether a slum, a thriving CBD or a luxurious precinct, will determine the values they will hold that will inform their purpose, mindsets and worldviews; this understanding makes identifying what people pay attention to and need, much easier.

11.2.1 Leadership – evolving city design along with conscious leadership

We have a unique opportunity to learn from the errors of past societies (Diamond 2011: 324). Given the potentially life altering changes facing society (Hes & Du Plessis 2015), urban systems will require the guidance of enlightened leaders in the form of authorities and self-organising networks. There will have to be a willingness to change the status quo, and consensus on what the changes should entail and for whom they should be implemented. In a holarchy of city leadership, strong leaders (councils, mayors, ministers, presidents) depend on the co-operation of all the holons which they envelop (citizens and resources). In this sense, municipalities truly are at the service of all their holons.

Some leaders embrace their power to change locked-in, stagnant, or self-destructive systems by merging bottom-up networks with top-down approaches. Examples include Jaime Lerner of Curitiba (who created a mass transport system linked to high-density areas) or Gregor Robertson of Vancouver (the world's green capital). Their actions ripple through other facets of urban life. Their personal values (aside from their politics) change the environment to influence the experiences and reflect the values of the citizenry, since "the capacity of the community and leadership are co-determined" (Hamilton 2008: 112).

Citizenry who interpret the values and functional boundaries created by top-down authorities, catalyse or mobilise responsive action in embracing and driving values further. As Hamilton suggests, "the biggest challenge is a failure to have sufficient conscious 'altitude' to see the potential of the system-shift from single leaders who manage boundaries to shared leadership who define and hold the boundaries" (Hamilton 2008: 114). Leaders operating at higher levels of consciousness support integral policies that profoundly affect every individual. In other words, these leaders have the capacity to "enable the emergence and evolution in people, organisations, cities and the world simultaneously" (Hamilton 2008: 119).

11.2.2 Integral urban resilience: a pathway to robust, adaptive or transformative cities

The usefulness of Integral Theory is noted across multiple disciplines, and in many cases has bridged specialised and traditionally not co-operative professions to engage in meaningful transdisciplinary work (Esbjörn-Hargens 2012). The built environment is no exception. Extensive research has been undertaken to apply Integral Theory to urbanism and architecture (Hamilton 2008; Esbjörn-Hargens & Zimmerman 2009; Du Plessis 2009; de Kay 2011; Esbjörn-Hargens 2012; Buchanan 2013). In both fields, the practical requirements for a holistic sustainability practice may be attainable if an integral, whole system approach is

applied to the problem. For example, Ellin explores the need to practice integral urbanism for a sustainable human habitat to flourish (Ellin 2006). Ellin's thesis is not extrapolated from the meta-theory or the AQAL model developed by Ken Wilber (see Section 3.6.4.1), but rather focuses on five key qualities required in an 'integral city': hybridity, connectivity, porosity, authenticity and vulnerability (Ellin *2006*). In contrast, Hamilton explores in her book, *Integral city: evolutionary intelligences for the human hive,* the usefulness of using the AQAL model by charting qualities that create optimal conditions for urban human habitats and which, she posits, reflect the complex networks in a 'human hive' (Hamilton 2008).

In *Integral sustainable design: transformative perspectives,* De Kay advances a detailed exploration of the AQAL model, translating it into architectural design and practice, with the aim of creating a meta-framework for (truly) sustainable responses that transcend current practice as well as 'superficial' green trends, and make sense of many competing theories and methods (De Kay 2011). A recent *Architectural Review* campaign saw Peter Buchanan call for a 'big rethink' in the face of major urban issues endemic to Modernity (that detract from sustainability). He advocates integrating AQAL-based urban design thinking into architecture training and practice, to shift from the "City of Doing … to the City of Being" (Buchanan 2013). These researchers explore Integral Theory to move closer to a complete built environment theory that does not ignore perspectives.

The AQAL model is dynamic and does not put forward checklists with 'solutions' – it is a process that reveals information along the way. It has three simultaneous functions: a map of reality, a framework for working within and across disciplines, and a practice to promote awareness (Esbjörn-Hargens 2012). AQAL provides a framework to look at a situation from multiple perspectives in order to delve into the particularities, complexities and nuances of the subject and arrive at a solution that is potentially more 'truthful'. This framework provides a basis for an integral investigation into urban resilience of an urban focal system.

Current sustainable development practices focus on monitoring and awarding exterior paths and exclude interior development paths. An integral urban resilience approach moves away from restrictive checklists toward a holistic way of thinking about change. Integral urban resilience requires that practitioners ask the right questions – for future generations and all life forms (interior paths). Responding requires an understanding of the system and its empirical conditions (exterior paths). A roadmap with a goal, an integral urban resilience approach embraces life, which can enable an evolution toward built environments driven by a holistic imperative to promote good practice systemic regeneration: to do more good, and do it truthfully and beautifully.

ADDENDUM C

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Reference number: EBIT/13/2015 10 April 2014

Ms EM Peres
23 Hanover Gate, c/o 5th Street & 2nd Avenue
Killarney
2193

Dear Ms Peres,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Ethics Committee refers.

1 I hereby wish to inform you that the research project titled "The translation of ecological resilience theory to an urban system" has been approved by the Committee.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Codes of Research Ethics of the University of Pretoria, if action is taken beyond the approved proposal.

2 According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of any member of the Faculty Committee who will deal with the matter.

3 The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof JJ Hanekom
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

ADDENDUM D

This dissertation contributes toward a larger research project named the Think tank on Resilient Urban Systems in Transition (TRUST). This research project was formed and is administered by Prof. Chrisna du Plessis (current HOD at the Department of Architecture at the University of Pretoria), in response to a call by the National Research Fund (NRF) requesting strategies for the resilience of aspirational African cities. The proposal put forward by the University of Pretoria highlighted three research streams with three additional themes aimed at unpacking the tangible and intangible aspects of resilience. These included understanding the application of resilience theory to urban systems, developing appropriate interventions, and changing mindsets to build capacity for resilience. Research would occur across scales, from buildings to metropolitan areas within the City of Tshwane.

The proposal was awarded in 2012 and six students were initially appointed to conduct research; one Architectural PhD student (the author), four Town Planning Masters, and one Landscape Architect. These students are dealing with the application of resilience theories and one Town Planning Masters student in particular is dealing with the intangible aspects of resilience, specifically those emerging from the mindsets of people living in a particular area in Tshwane. These students are still to graduate.

In 2013, five additional MArch (Prof) students were included into the group and prepared research dissertations for new regenerative design buildings and urban interventions in Tshwane. All five students graduated in 2014. A number of staff at the University of Pretoria are involved in this research group and the name TRUST emerged as a means of giving identity to their work. In 2015, a book was published by Prof. du Plessis and her co-author at the University of Melbourne Dr. Hes (Hes & Du Plessis 2015), in which many of the intangible issues relating to the resilience of cities were discussed as well as many proposals for alternative approaches to sustainable design. A new application for funding has been lodged at the NRF and it is hoped that this research group will continue.

ADDENDUM E

Examiner's Report and candidate's responses

Prof. Ann-Margaret Esnard

Comments		Action		
		Minor edits.	Revised in document.	Defend existing at oral defence.
1	Please consider using the final chapter to make an even stronger case for the practical benefits of the dissertation, perhaps by adding some more on your thinking about the findings for professionals, practitioners and government officials. Another approach might be to select two or so core urban practitioner tasks and illustrate how the findings from the study areas and be used or applied.		Please see new section 9.4.5.	
2	How would concepts such as the intentional collapse of some systems in order to transform the larger system into a more positive state (C3) play out in reality?		Please see section 3.2 where the following has been added: An example in South Africa occurs through the (in this case unintentional) deterioration of existing coal-fired power stations through lack of maintenance, upgrades, fewer cheap coal resources and limited system capacity leading to instability of electrical supply and consequently an increase in the costs of coal energy. This time of transition offers an opportunity to shift the dependence on coal-fired power stations toward renewable energy sources like solar or wind where applicable, with an adaptation of the electricity grid toward decentralised, at-source energy production. In the South African context, this transformation of the variables in the system (not the electrical system itself) toward a renewable resource is positive in that it reduces the environmental impact, increases job opportunities in the long-term, reduces risk and contributes to the development of the local economy.	We see transformation happening often when some systems give way to more resilient systems. The way to instigate change in a system depends on two things. First, the resilience of the conditions toward which the system should move. Second, the nature of the perturbation that will need to be powerful enough to shift the system (otherwise, it may only entrench the system).
3	What are the implications in the translation to practice? For example who gets to choose		Please refer to the discussion in a new section, 8.6.7.	
4	Chapter 2 – Make a stronger case for the choice of the City of Tshwane study area and focal areas. Parts of the justification are spread out in sections 2.7, 2.8 and 2.9. The description used on page 52 (eg. Densification of low-density areas; peripheral townships emerging in higher-income areas) is very insightful and allows a reader to quickly imagine how the finding are transferrable to other/ future transitioning cities in South Africa.		Please see section 2.8.	

5	Chapter 3 – Expand on the point you make in section 3.6.1 (page 69) that "It is self-evident that the City of Tshwane is an SES with close relationships and networks flowing between human-nature systems." Assume the reader is not familiar with the City.		The following has been added: The impact of social decisions and processes on the environment primarily through development has shifted the flows between flora and fauna, which at times significantly affected social systems in return. The description in section 5.5.3.3 further illustrates this close relationship.	
6	Chapter 6 – Perhaps I missed something but the regime example does not seem to be fully tied into the content of the chapter.		Clarified within 6.3 that the example refers only to section 6.2 in this chapter.	Being able to observe how a city changes within a research framework (this chapter covers two frameworks), becomes an important tool for gaining insight into the drivers of change in a city as well as related opportunities. The example used to explore thresholds looks at a Pretoria East neighbourhood as a defined regime that has undergone significant shifts in physical form. It then tracks how certain drivers caused these shifts and explores how there were thresholds between the driver and the change in which the change might have been avoided or redirected.
7	Chapter 7 – Section 7.4.1 – The statement about decentralisation as a possible way to increase autonomy and reduce their risk of collapse, citing Harrison et al (2014), is great food for thought, and is worth perhaps discussing in a final section or leaving for a publication when you can discuss more vis-à-vis professional practice and politics. Otherwise I am left really curious about your thinking on these type of potentially contentious issues.		The following has been added: This brings to light issues around politics and power and the impact that some systems and entities will hold over others. While decentralisation may be useful for management and governance of independent municipalities, it may also further disempower those entities with weak resilience. This risk is discussed further in section 8.6.7.	BRI paper and publications to further explore this. Political issues involved with decisions around this and who gets to make them.
8	Chapter 8 – Some discussion of the 100 Resilient Cities initiative/ framework needs to be referenced in this Chapter; perhaps somewhere on pages 212-213 – see http://www.100resilientcities.org/#/-/		The following has been added to 8.6.1: In the 100 Resilient Cities initiative pioneered by the Rockefeller Foundation (100 Resilient Cities: 2015), valuable research is being conducted in creating awareness for the need to be resilient toward the physical changes being faced in the urban world today. However, the initiative risks oversimplifying a complex research area (by omitting deeper questions around intangible value systems for example) and furthermore setting resilience up as a goal for cities.	
9	Chapter 9 – More is needed in the "Areas for future research" which currently reads like a list of findings		Each of the four areas for future research identified in 9.3 have now been qualified.	

Prof. Raymond J. Cole

Comments (that require action)		**Action**		
		Minor edits	Revised in document.	Defend existing at oral defence.
10	Despite a fair amount of repetition throughout (see below), the dissertation is well-written.			
11	Regarding typos: - P.162 '…so that its		Changed to: "manage to accommodate"	The use of 'an' preceding SES is because the author reads and

	variables **manage accommodate** change…" - Throughout the dissertation, the author uses "an SES". It seems that this should read "a SES".			pronounces SES as the letters S.E.S in rather than a word SES (which when pronounced quickly could sound like 'assess'). The 'an' relates to the sound of the letter 'S' which has a vowel sound 'Es', and uses 'an' preceding it.
12	**Methodology** The author notes that the work presented in the dissertation is part of a larger research project – Think tank on Resilient Urban Systems in Transition. It would have been useful for the reader to understand a little more about the scope of this parallel investigation. In particular, having identified the importance of urban resilience studies engaging both intangible and tangible systems in the dissertation only focuses on the latter. While this is understandable in narrowing the scope of the author's research, to the physical realm, do other aspects of the overall research project address these or is it also out of TRUST's scope? And if so why?		Please see Addendum D	
13	**Methodology** The author makes an important acknowledgement on p52.- "in order to develop the literature study, it was important to test whether the core concepts derived from literature were unbiased and critically engaged. Consequently, participation in resilience theory workshops, writing of papers and presenting at conferences and seminars became an important aspect of the process of analysis." It would be useful to know exactly how the candidate sees such an approach countering any possible biases.			Exposure of the literature findings and their interpretations benefitted from the feedback of parties external to the area of research, usually within different fields and disciplines of study. Urban resilience is multi-disciplinary, it was valuable to expose aspects of the dissertation to different perspectives, to enrich my own perspective and broaden my frame of reference. Since interpretation of a qualitative study is ultimately subjective, exposing ideas to review from multiple and often unexpected sources provides a useful basis for a more considered interpretation.
14	**Literature** One gets the sense when reading the dissertation that many of the ideas within the literature review are restated over and over again. While in most instances this is not so problematic since the author often brings a nuanced emphasis in each reiteration, it does suggest that the work could be tightened. For example: - Is it really necessary to have *Section 8.8 – A (very) short summary of urban resilience*, when the reader has navigated through the key ideas earlier in the dissertation? - In 9.1, the author restates the structure of the dissertation/ chapter content (p223), and then essentially does the same thing in 9.4 (p 225). Here I would ask the supervisor to discuss the removal of this		Combined 9.4 into 9.1.	8.8 serves as a summary of important aspects for those future readers who may not have the opportunity to read the whole document, but would like to access the key points of an urban resilience approach.

	repetition.			
15	**Literature** The author makes several references to Wilber's Integral Theory, stressing very much its positive attributes and possibilities. It would be valuable to know the types and validity of any criticisms that have been directed at the theory.			The positive attributes of Integral Theory as an inclusive method for collating multiple ideas and perspectives was stressed due to its value in the research process and in deriving findings. Since it was not the focus for this dissertation, the author did not find it necessary to expand on the drawbacks. Many criticisms against Integral Theory are levelled against Ken Wilber and his interpretations of key sources. Apart from articles in websites like www.integralworld.net or www.markmason.net, the author could not find published or peer-reviewed academic studies investigating the validity or use of Integral Theory and directly criticising it as a whole. The closest appears to be Jeff Meyerhoff's self-published critique titled, *Bald Ambition: a critique of Ken Wilber's theory of everything* (available on www.integralworld.net) which engages his sources, assumptions, arguments, methodology and Wilber's own psychological framework. Meyerhoff, does however stress that Wilber's "integral vision is an advance over postmodern relativism…" (www.integralworld.net/meyerhoff-ba-intro.html). The author's own criticism is threefold: Integral Theory as promoted by the Integral Theory Institute is a complex framework that is not easily explained nor applied (once you explore beyond quadrants and levels); it seems to be associated with esoteric or 'new age' practices and therefore risks losing its potential for academic rigor and development; and lastly, there are very few practical examples of how the theory is successfully and meaningfully applied in everyday situations.
16	**Literature** Throughout the dissertation, the author draws on the work of Simin Davoudi, referenced as *Resilience Theory: A Bridge or Dead End*, Planning Theory & Practice 13:2, 329-333, June 2012. I think this should be 329-307 since there are several other articles within that issue within the pp329-333 range. It is surprising that the author did not draw on/ reference the subsequent papers, e.g., Libby Porter and Simin Davoudi's critique – *The Politics of Resilience for Planning: A cautionary note*, Planning Theory & Practice 13:2, 329-333, June 2012, which offer other forms of critique.	Page numbers corrected to : 299-307	Libby Porter's paper focused on the politics of who acts on the resilience of what? The politics, or rather the ethics of application was not really the focus of the research. However, it is a risk and I agree there is value in adding this reference to the discussion in a new section, 8.6.7.	The papers by Shaw, Haider et al, Wilkinson and Fünfgeld et al in this edition of *Interface* are valuable in providing insights into the debate for and application of resilience thinking in various scenarios, but were not necessarily seen to be essential in the argument of the dissertation and therefore were not cited.
17	I haven't checked all the references, but two that caught my attention are: - Cole, R. 2012. Transforming from Green to Regenerative	Corrected		

	Design, Building Research & Information, 40 (1), 39-53, should read: Cole, R.J. 2102. Transitioning from Green to Regenerative Design, Building Research & Information, 40 (1), 39-53. - Meadows, Meadows and Randers (1972) on p22 should read Meadows, Meadows, Randers and Behrens (1972). This is also the case in the references.			
18	Other cuts could possibly be made to the dissertation other than those related to repetition referenced earlier. I found the use of the High Line park (p187) as a regenerative project is too briefly covered to offer a useful contribution to the dissertation and could be eliminated. If it stays, it probably needs to be supported by referencing James Corner's larger ambition to shift culturally held perceptions of landscapes toward "participative lifescapes", and the analysis that Field Operations undertook related to the anticipated coevolution over time of social and ecological systems on the High Line park.			Given this project was not investigated in depth serving as an illustration of an idea of a reinterpretation of the story of a place and its inherent potential and not as a precedent (and since it was the only international example) it has been removed.
19	Figures and Diagrams to be clarified Figure 5: Flow chart of the main research question & sub-questions. Frist, I am not sure that this is necessary; Second, the sub-questions logically flow from left to right rather than directly from the main research question.	Adjusted to flow from left to right.		
20	Figure 20: Diagram showing the focal system and focal scale in the panarchy…It is not clear to me what the diminishing spiral moving upward and with arrows at both ends conveys.			Figure 20 is an interpretation of a focal system represented as a dynamic spiral which is constantly evolving either in the direction of greater depth and complexity or toward less complex levels of the holarchy. The spiral and arrows represent dynamic change.
21	Figure 26: A diagrammatic representation of the relationships between press and pulse disturbances…Some of the numbers are not legible.	Corrected		
22	Figure 28: An aerial photo timeline of change…There is no key to the numbers, these are only included on the diagrams in Figure 30.	Key introduced from Figure 28		
23	The text (p182) references "in a row of security complexes (1-4 in Figure 40), yet the 1-4 notation seem to be identified in Figure 41, not Figure 40.	Corrected		
24	Use of the City of Tshwane …in comparison to the very comprehensive coverage of the theoretical ideas derived from the literature in the respective Chapters, the depth with which			To a certain extent, it also left the author wanting. The level of coverage is uneven with a greater focus of the dissertation on developing the theoretical framework with the use of Tshwane

	they are translated into the context of Tshwane is somewhat uneven and leaves the reader wanting.			to illustrate how the concepts could apply at a desktop level, being less extensive. With time, more translations could apply, thereby also refining the framework, perhaps making it more localised and less generic. Colleagues undertaking research as part of TRUST delved into extensive and detailed research into the translation of concepts in Tshwane within various sites, and in order to avoid duplication, this study was more theoretical and less practical.
25	In terms of presenting the approach or framework in chapter 9, which the author suggests "has been adapted from an ecological theory base as well as practical exploration in the Tshwane urban system", it is not clear what role the latter has played. Could the framework have been developed solely based on the extensive exploration of the literature.			Yes, to a degree. The framework could be developed (and does find its origin) from the extensive exploration of the literature. To illustrate how the concepts and framework translate into an urban system, Tshwane provided a good example: a. it is a city undergoing rapid transformation (social, political, economic and environmental); b. it offers a diversity of urban conditions that reflect many emerging global issues; and c. as a capital city being defined as 'resilient', this becomes a lens into what resilience actually means.
26	On p143, the author states that "The following exploration examines the physical changes that have occurred in a portion of the Menlyn node, i.e. Waterkloof Glen Ext 4, over a period of 13 years, between 2001 and 2014."The text that follows, however, presents a much longer history. Perhaps the author could acknowledge the importance of this longer history during this introduction.		Clarified by adding: over a period of seven decades focusing on recent physical change occurring during 13 years, between 2001 and 2014.	

Prof. Karina Landman

Comments (that require action)		**Action**		
		Minor edits	Revised in document.	Defend existing at oral defence.
27	Pg.2. paragraph 2, "to establish the a basis for research…" Should it be "the" or "a"?	**Edited**		
28	Why is the resilience of the physical environment more suitable to quantitative research? (p45.). If this is so, this should be explained to support the statement or what is meant.		Changed to: The resilience of the physical environment and the social domain is suited to combined qualitative and quantitative research.	
29	There are several instances throughout the thesis where the candidate reference an author with the date of publication and page numbers and them omit the date later in the paragraph or next paragraph. This seems to be incomplete, e.g. p.47 Hofstee, p.71 Ellin, p.165 Forty, p. 175/196 Walker & Slat, p.215 Eisenstein. Was this done on purpose and is there a reason for it? If not, it should be corrected.			Yes. This is done on purpose. As per Hofstee, E. 2006. *Constructing a good dissertation: a practical guide to finishing a Masters, MBA, or PhD on Schedule.* 11th ed. Johannesburg: EPE, p254, when the same reference is repeated directly, the date is omitted, as it is still referring to the same reference.
30	It is not clear why in 2.5 the heading is "Methodology". The	Change d the		

	discussion seems to relate more to the research process, organisation and analysis of data.	heading to: **2.5 Research process**		
31	It is important to be clear about the difference between 'methodology' and 'methods' and where it would be appropriate to use each term. In 2.6 the word 'method' would be more appropriate than 'methodology'. Yet, the paragraphs seem to be dealing more with what was previously referred to as 'research designs'. Page 50 deals more with the various methods that was used. Furthermore, on p. 53 (section 2.10) the candidate refers to "each method is used…" Does this refer to the methods discussed on p.50 or the research design that are discussed in the previous sentence?		In 2.6 on page 49: Removed 'methodology' In 2.7: The dissertation data were sourced primarily from existing resilience literature and this formed an important informant of the research method In 2.10: this refers to the different research designs discussed previously, which then influenced the methodology	
32	Does the diagram on p75 refer to Peres and Du Plessis 2014a or b?	Corrected	Peres, E. & Du Plessis, C. 2014b. Integral Resilience – an indicator and compass for sustainability. In:*World SB14 Barcelona Conference, 28-30 October, Barcelona*. Barcelona: World Sustainable Building 2014, no. 149. Available from: http://trustsa.weebly.com/uploads/1/3/2/0/13205680/wsbc14_-_integral_resilience_-_peres_du_plessis_final.pdf	
33	To what does "ineffectiveness on p.82 refer (paragraph 2)? This is not clear from the sentence.		Sentenced changed to qualify effectiveness as such: This indicates that the problem does not only lie with inefficient systems (resource use), but also with their ineffectiveness (systemic structure) in being able to thrive beyond new challenges; a different perspective should be adopted.	
34	In diagram 12, is 'transformative and normative resilience' meant to be the same or does the diagram only imply that both falls in that category?			Figure 12 on p85 illustrates the degree of normativity between resilience thinking definitions as put forward Brand & Jax (2007) and Davoudi (2012) and interpreted by the Author. Based on this framework, Transformative resilience is rooted in a normative position and can therefore also be described as 'normative' resilience.
35	The second paragraph on p.86 seems to be out of place and it is not immediately clear how it relates to the diagram on p.85. Perhaps the link should be explained in more detail. It is also not obvious how the meanings of resilience relate to the manifestations and if these all fall within three categories.		Moved the paragraph in question to the first paragraph in section 4.4. Clarification: the meanings or definitions of resilience thinking and their focus may manifest as bounce-back, adaptive or transformative. However, the intent with which different disciplines engage resilience thinking generally aligns descriptive meanings to bounce-back, hybrid meanings to adaptive and normative meanings to transformative manifestations.	

36	"Mooi kloof", should be Mooikloof in Figure 25.	**Edited**		
37	The fourth paragraph on p133 states that "Security estates do not provide on-site staff accommodation..." This is not true of all estates. Mooikloof specifically allow for on-site staff and many houses have additional rooms for this purpose. In some cases residents have built separate small hoses for their workers.		P133 edit: Many security estates or residential complexes do not provide on-site staff accommodation, while previously most homes in South Africa had staff quarters on the property. There are limited facilities for 'temporary' workers working a few days a week in an area.	
38	At the end of p.134 the example refers to a balancing feedback loop and other informal settlements being established, e.g. Malemaville. However, there is in fact one almost opposite the site next to the Woodlands Mall and next to the cemetery. This is very interesting given the limitations to expansion that was put on the Woodlane village. The Newspapers have also started to report about this new informal settlement.		Have added a reference to this as follows: This response was a balancing feedback that aimed to counter the change. But while successful on this site, the confinement of the growth of Woodlane Village has resulted in similar 'land invasions' on other 'empty' sites in the east. In close proximity, 'Cemetery View' is emerging as a fast-growing settlement next to an existing cemetery, which has begun to encroach into the burial grounds (Martins 2014).	
39	P.147 (second paragraph, fourth sentence): "…in an attempt to prevent the community from self-organising…". This should be from and not form.	**Edited**		
40	Why are there small circles on the sides and a larger circle in the centre of the diagram of the adaptive cycle on p.154?		Clarified in the text: However, each phase is separated by a threshold that marks a transition between two system states (as shown in Figure31, represented by the grey circles for flexible thresholds and a red circle for the critical 'collapse' threshold).	The circles represent thresholds. The grey thresholds are themselves flexible where the r-phase can move directly into a Ω and α phase, or an early K-phase into a Ω and α phase. However, once a system move into a late K-phase threshold (red circle), then the chance of a collapse is inevitable.
41	Despite harsh criticism of the Modernist approach to planning, South African cities are still planned according to land use" (p.165). What is meant by this? Land use must be taken into account in planning cities and neighbourhoods, but should not be the ultimate objective. Perhaps this sentence needs to be unpacked to be clear. This is a bit of a general statement that needs clarification to avoid misunderstanding.		The sentence has been revised as follows: Despite harsh criticism of the Modernist approach to planning, principally using land use and geometric form to design new developments (Salat 2011:87), South African cities are planned primarily according to land use without integrating other considerations. Resultant building typologies and streets lack built in flexibility to change. Local examples of the closest 'integrated' land use, mixed-use, lacks the richness and flexibility evident in historical cities (Salat 106) whose typologies have evolved over centuries to absorb transformation.	
42	With reference to Figure 33, p 166 and Figure 34, p.169, it is not clear what is understood under each of the categories of functional diversity. How do the categories relate to the actual functions e.g. of movement and gathering? Infrastructure has a particular meaning in a city and		Please see revised section 7.2, which has additional explanations in between the original text. Primarily this exploration has focused on diversity within the physical structure of a city without which a city could not	Essentially, while the zoning of a site may allow for a variety of land uses simultaneously or over time, the building typology that manifests the physical reality, often limits uses practically only to one or two uses. This therefore directly affects the resilience of the city to adapt to change and to provide the inherent

	planning context and so do resources. This is not clearly defined in the discussion. And how does it relate to services and utilities? Also, what about the spaces in between buildings? Land-use are not linked to buildings but are actually allocated according to plots and some plots can allow for various land-uses. So it could be contested to refer to 'buildings'. Furthermore, some plots are not developed and may be used for other functions, e.g. public open space. Therefore, a park is not just a "green network" under 'resource', but also offers a specific function for recreation etc., which is similar to the middle category. This interpretation needs to be reconsidered to have better value. Furthermore and also referring to the discussion on p.170., the response diversity for "residential" across scales seems to be incoherent. Does scale in these cases refer to the size of settlements or actual housing unit or built form of houses? This is not clear. Also, why is a RDP settlement or neighbourhood (RDP 'typology' does not make sense here) at a different scale to a housing estate or informal area? All of these can occupy larger or smaller sites. Even apartments can occupy different areas ranging from large urban blocks to a small site that only form part of a block.		function or respond at optimal levels. Spatial structure directly informs functional response. This can cause confusion since similar categories to the functional diversity interpretations of species in an ecological system are not being compared. This proposed interpretation forms an expanded understanding of functional diversity in urban systems, but does require refinement. This proposal can be investigated further in future research (both tangible and intangible).	capital for regeneration. Just as land can hold many uses simultaneously or over time, so too can a building. It is important to note that land use has not been substituted by buildings, infrastructure and resources. Instead, the focus has shifted toward looking at the physical components from which the city finds its spatial structure. This is achieved by zooming out and restructuring the first tier of the Functional Diversity map to show the functional drivers or 'keystone' variables in the city; as being structure (infrastructure), form (buildings) and flows (resources). Land uses are integral and embedded in each of these.
43	Also linking to this discussion, one should be careful in placing too much emphasis on just 'road networks'. Salat also refers to "system of public spaces". Where would they fit into the categories? The problem with the Modern Movement was exactly that everything was seen as 'road network' with parks and buildings on in between. Therefore one should be careful that while there appears to be criticism of the Modern Movement's approach, it may come across that this approached is used to come up with a typology.		The author implied a movement network when roads were referred to, that included human movement spaces like public spaces. However, it was not explicit. Small corrections have been made to reflect that: Systems of public spaces overlap between roads and GOS. Where transit of people occurs (vehicular and non-motorised) through a series of streets, plazas, squares would be part of roads (vehicular) and green space (pedestrian), but also focused on the flows of energy of the larger living system…nutrients, flora and fauna etc.	
44	With reference to Figure 36, p.172, why is the apartment complex at the extreme with gated estate below? In fact, a gated estate works very similar to a sectional title scheme (which is also commonly used in [gated] township complexes) where there are strict rules and regulations about what people can do, built etc. This is decided by the Home Owner's Association. Therefore it may make more sense to have these typologies at the tip and a			The table shows differences in the response rate of each unit in different conditions. For example, it is easier for a house in a gated community to install a solar geyser, but not for a unit on the first floor of an 8 storey apartment block.

	'normal' old style suburban area in place of the gated estate where people have much more autonomy on deciding how to go forward.			
45	The Highline is a great example, but one could have also considered the plans for the upgrading and revitalisation of the Apies River in the Inner City of Pretoria, linking all the way north to the new Rainbow Junction Development.		Research for this dissertation could find no *already* built project in Tshwane that encapsulates the extensive social and ecological regenerative qualities demonstrated in the High Line. The Apies River project(s) do not demonstrate the use of story of place of the regenerative agenda to serve as a Tshwane example.	Given the High Line project was not investigated in depth, and since it was the only international example, it has been removed.
46	With reference to the discussion on p.197, what would be the challenge of translating resilience concepts into planning and development policy?		Please refer to the discussion on 8.5 which tackles the challenge involved in translating resilience to policy as well as 9.4.5 which illustrates how resilience thinking might be engaged with in practice.	
47	What is meant with the reference that Integral Theory forms and important avenue for research in urban design toward building transformative resilience (p.204)? It would be useful to explain this a little bit further.		This sentence could be confusing and has been reordered into: While this dissertation posits that Integral Theory forms an important research avenue in the design of urban environments geared toward building transformative resilience, it is not the focus of the dissertation.	
48	On p.213 reference is made to a SACN 2011 report with direct quotes. It would be good to add the page number.	page 140.		
49	While the summary presented on p.218 is good, it would be useful to add the implications for policy development. Can one use these terms/ concepts or not.		Please refer to page 207: This is why the use of 'resilience' as a broad term in development policies is problematic. Firstly, there is no distinction between the use of resilience as a metaphor versus its use as a way of thinking and studying the built environment. Resilience stand to be promoted in policy as a desirable 'goal' without specifying the resilience of what to what (see 8.6.1) and stands to become a trend rather than a useful design and systemic thinking tool. This can easily turn into a rigid dogma that does not have the flexibility to evolve as social-ecological conditions change. Secondly, resilience thinking as outlined in this dissertation cannot directly underpin a policy for three reasons; it is process not outcomes driven, it is too complex to transcribe into a checklist for policy and lastly, resilience is not always desirable. There is a further risk to the use of resilience thinking in policy and that is as an active tool for transforming the urban environment; it can just as easily be used to destroy positive systems as negative ones depending on the outlook of the political party at the time.	

50	On p. 224, does "other areas" refer to areas other than Tshwane?	Other cities.		
51	The use of the term "gated settlement" can be a bit confusing (p.228). To what scale does it refer – a large gated estate, an enclosed neighbourhood or a gated townhouse complex, as was used in the actual example? The morphological implications would differ depending on the type. The discussion also refers to safety in larger sense, but this is not just safety from crime which tends to be the main concern, but safety in case of disasters. So maybe this should be pointed out.		Made the following changes: New gated communities (that of a townhouse complex and a gated estate) at the scale illustrated in this dissertation are showing fewer levels of modularity and redundancy in terms of services, accessibility and building typologies. […]However, within the focal areas studied, the gated settlement examples used indicate a loss of overall resilience in the system both at the local and city scale. […] Further investigations into other gated communities of varying scales like estates and enclosed suburbs may likely show similar results. Urban redundancy was explored from the perspective of a gated estate, using the perspective of accessibility and electricity provision. While a single entrance increases the monitoring of vehicle entry and exit to limit criminal threats, it did not necessarily increase the community's overall safety against service failure or other disasters, nor did it facilitate accessibility to the broader urban network.	

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