Urban Transitions Conference, Shanghai, September 2016

Unpacking a sustainable and resilient future for Tshwane

Edna Peres[a], Chrisna du Plessis[a], Karina Landman[b]

a Department of Architecture, b Department of Town & Regional Planning, University of Pretoria, Pretoria 0002, South Africa

Abstract

This paper examines the important yet largely misunderstood relationship between resilience and sustainability and the gap between these theoretical constructs and the practice of urban development. It explores how these two separate constructs, each with its own theoretical framework, complement and support each other as approaches to the complex issues arising from fast-changing urban conditions and unprecedented pressures on the urban social-ecological system.

The City of Tshwane metropolitan urban system, which includes Pretoria, the administrative capital of South Africa, forms the exploration ground for this study. As a metropolitan area undergoing rapid urbanization along with increasing resource depletion, service delivery issues and social injustices, Tshwane provides a number of extreme urban design and planning problems of varying scales within a single urban system that are directly related to the constructs of resilience and sustainability. The paper uses the example of gated communities, a common spatial response to the sustainability goal of security, to examine and elucidate a broader understanding of the relationship between sustainability and resilience attributes and their application to spatial development practices.

It is proposed that the understanding of the structure and dynamics of the city provided by resilience thinking, combined with the normative positions offered by sustainability offers, a) a way for urban design and planning interventions to constructively engage with the realities of a fast-changing city; and b) a new understanding of resilience within urban design and planning fields which includes interpretations that extend beyond climate change mitigation or rapid urbanization adaptation, seeing its potential as means of informing transformative development across scales through establishing mechanisms for the development of spatial resilience.

© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of the Urban Transitions Conference

Keywords: sustainability; urban resilience; spatial resilience; Tshwane; social-ecological system.

1. Introduction

Although there is an increasing interest in resilience within the urban context, resilience is often being used as a substitution for sustainability. In addition, both concepts are frequently used as directives to guide policy-making and urban development and management, but without a clear understanding of the theoretical underpinning required in order to translate these concepts into clear actions for development within the city. For example, in the City of Tshwane, our exploration ground, the city's 2055 Vision document, describes the future city as being livable,

inclusive and resilient [1]. However, within the historically segregated design of the city perpetuated by almost three decades of uncoordinated private development, there are no clear spatial strategies in place to allow for these qualities to manifest. The problem is perpetuated by built environment practitioners who do not understand how these concepts, which have been readily adopted, firstly relate to each other and secondly, translate into city-making. This paper aims to explore the relationship between resilience and sustainability as complementary and supportive theories in order to provide more clarity in terms of their application in urban systems. Three main attributes of resilient systems are explored spatially, leading to the proposition that spatial resilience offers a mechanism for bridging the gap between the theoretical constructs and their application in the practice of urban planning.

2. Contextualizing the City of Tshwane

The City of Tshwane metropolitan urban system, which includes Pretoria, the administrative capital of South Africa, is located in the Gauteng province, the smallest yet most populous and most urbanized province. Described in Fig. 1, its 6 289km^2 municipal area is home to 2.9 million people, of which 24% are unemployed and 135 640 households receiving no annual income [1]. However, the city recognizes to the need to move toward an improved state that would be substantially different from the undesirable status quo. A large deal of future government investment is set to change the character of development in the capital, as identified in the municipality's *Tshwane Vision 2055* [1]. 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 reverse the spatial effects of apartheid [1].

Given the desire for the City of Tshwane to rebrand itself as "liveable, resilient and inclusive" [1], there likely 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 [2].

As the popularity of the term resilience increases within development and municipal circles in Tshwane, so does its use as a substitution for sustainability. Resilience is progressively being used as a normative position espousing the same urban planning principles as those set forward by the sustainability movement. However, this is a misunderstanding of the role of resilience as a characteristic of a social-ecological system (SES). Resilience as a characteristic of an SES merely represents that capacity of an SES to adapt over time to changing circumstances in order to maintain its functionality. It cannot be the goal for urban development since it is both a constantly changing condition and a neutral concept which can hold both positive and negative consequences for the city. To suggest that

Fig. 1. Contextual map of Tshwane within the African continent, the Republic of South Africa, and Gauteng Province

the city must be resilient could imply that the status quo be perpetuated, including many flawed aspects such as crime, poverty, environmental destruction and ecological injustice which are resilient features within the City of Tshwane itself. Rather than suggesting that Tshwane must be resilient in 2055, which in many ways is a pointless endeavor because the city is already resilient by virtue of the persistence over time of both its functions and flaws, the proposal is that the city begins to define the well-being goals for the Tshwane SES. These goals should speak to the needs and aspirations of the social system, as well as the carrying capacity of the ecological system, which together fall under the umbrella theme of sustainability.

3. Resilience thinking and sustainability

The long-standing definition of sustainable development as meeting the needs of the present without compromising the ability to meet the needs of future generations [3] has over years been expanded, through international agreements such as Agenda 21[4] and more recently the Sustainable Development Goals, to aspirations of an idealized society where everyone has adequate shelter, clean water, electricity, a safe and healthy social and physical environment, a dignified job, a decent education, protection from all kinds of injustice and the freedom to pursue their religious and political convictions and their lifestyle of choice, while at the same time being good to the natural environment.

Satterthwaite [5] suggests that the goal of urban sustainability is not to "sustain cities or urbanization, but to meet human needs in settlements of all sizes without depleting environmental capital". Sustainability therefore aims to achieve two things: a) improve human well-being and quality of life, and b) protect the natural systems that support and enable this quality of life. However, as the sustainability of cities has become fully entwined with the health of global biophysical and socio-economic systems, with cities not only being dependent on, but also playing a major role in the continued functional integrity of these systems, sustaining cities by ensuring that their functional integrity is maintained may well be a critical goal of urban sustainability. Resilience is thus closely tied to the qualities of a sustainable city, as a resilient social-ecological system has "a greater capacity to continue to provide us with the goods and services that support our quality of life" [6]. What exactly constitutes 'quality of life' is hotly debated, and the determinants for an acceptable quality of life are very difficult to define, as these depend on the context, the prevailing culture and the synergies between different determinants [7]. However, there is general agreement that health, safety and security, and mobility (which provides access to services and opportunities), are key performance qualities of a sustainable city. More recently, the definition of sustainability has been expanded to also include those qualities and relationships that give rise to a thriving and regenerative urban system in which the relationships within and between social and ecological systems are healed and renewed [8].

The resilience of the city or aspects of the urban system can only be analyzed in relation to specific normative goals, such as those of sustainability, which determines what characteristics should persist in order for the city to flourish. In turn, resilience thinking allows us to understand the best ways to engage with the complexity of an urban SES in order to achieve the higher order goals of sustainability. This then introduces the notion that resilience and sustainability have a complementary relationship. Combined, these theories help to provide a framework with which to restructure the city toward transformative goals. However, in order to attempt such a complementary state, it is important to define broadly what is meant by these concepts.

Resilience thinking allows us to redefine sustainability as a normative position that is based on the aim to restore connections in the living system by healing and then regenerating social-ecological systems (SES). Urban resilience is the capacity of a city as an SES to maintain its core purpose and integrity [9] as a life-nurturing environment for collective and individual fulfilment [10, 11] in the face of dramatically changed circumstances [12] or, if so required, to transform in response to disturbances in order to maintain its functional integrity [13]. This capacity is built up from three attributes in a system, namely diversity, network modularity and redundancy. In resilience thinking, diversity relates to the varied number of functions within a system and the responses to those functions across various scales. In the event of a crisis, a system with more diversity of responses can continue to perform its functions even if one of the responses collapses. Modularity in an urban system relies on the need to create flexible and loose connections between subsystems that can operate independently or swarm together in times of need. Lastly, redundancy could be likened to backups in a system, 'more of the same' reserves that can be called upon during crises when one or many sub-systems collapse. Together, investing in these attributes within a city system

builds up the capital reserves of the system and consequently increases its adaptive capacity, while seeing where these attributes are not present provides clues as to where the city might be more vulnerable to change. To summarize, resilience thinking in a city is an approach to understanding and determining where the strengths and weaknesses within the urban network lie in relation to tangible (spatial), as well as intangible (social, economic and cultural) reserves of urban capital that determine the adaptive capacity of the city in response to cross-scale change and perturbations.

Studying the resilience of an urban system can inform decisions to strengthen or weaken capital reserves within the urban system, and by extension the resilience of urban sub-systems, in order to transition the city toward the healing goals and a dynamic regenerative state that is proposed by sustainability. These transitions are easier to identify, monitor and make suggestions for in the physical environment than transitions required in the social domain. However, due to the long-term nature of infrastructural investment, a physical environment designed in a way that does not promote the regenerative resilience of a sustainable system, could be extremely difficult to adapt and transform afterwards.

If the argument is that sustainability is the goal for urban development and that resilience thinking provides the pathway to achieve these goals, it becomes critically important to understand what the devices and tools within resilience thinking are that can make sustainability goals attainable. However, one of the stumbling blocks in applying both urban sustainability and resilience thinking in practice, is that both of these concepts operate in the field of theoretical investigation. They have both constructed valuable and detailed theoretical models, however, when these models are presented to industry practitioners, there is very little depth of thinking taken through to practical applications. For example, sustainability gets watered down into green technologies (at the expense of a redesign of the systems of degeneration and regeneration), while resilience thinking gets simplified as climate change mitigation strategies (at the expense of the attributes of resilience that can lead to transformative urban restructuring). Increasingly, sustainability experts are calling for new ways of practicing sustainability and resilience thinking that can be used to meaningfully navigate the fundamental changes that will be faced in this century, and to design cities that function beyond mitigation toward regeneration [8].

In the quest toward this type of practice, there appears to be a gap between the theoretical dimensions in which both sustainability and resilience thinking operate and the more practical tools and devices required by built environment professionals to apply resilience in the design and management of cities like Tshwane.

In trying to bridge this gap between theory and practice, it is useful to focus on developing the practical tools for investigation. With sustainability being the normative position and goal, and resilience thinking forming the framework that allows for the investigation into how near or far the city is to achieving the goal, there needs to be a clarification of what the goal actually is (the performance qualities) and secondly, what the attributes of resilience are that can used to restructure the urban form of the city.

4. Exploring sustainability performance qualities and resilience attributes within Tshwane

Over the past 25 years there has been significant development taking place in the peripheries of the city with a large increase in the sprawl of the eastern and southern suburbs of Tshwane. The areas chosen for observation are experiencing high levels of change, bringing conflict, concern, and at times condemnation. The east of the city signals the pull of large-scale private development and investment in the city, whereas local government is focussed more on redeveloping the CBD, the north and west. Ad-hoc private development without a unifying vision or approach has already significantly altered the fabric of the city.

The increase in suburban development to the east of the city has made it possible for an increase in the manifestation of interesting phenomena within the urban realm that affect its resilience such as the interweaving of informal settlements and gated-communities, and increasingly limited road networks. The suburban model with its focus on physical boundaries facilitates these phenomena and in many ways, the physical scars of apartheid-era separate development planning policies and suburbanization are still noticeable in the long distances that need to be traveled to places of employment, the large tracts of land that form undeveloped or green 'buffers' between residential areas, and the unequal quality of amenities present in different neighbourhoods. These spatial systems display interesting examples of diversity, modularity and redundancy attributes, which will now be discussed.

4.1. Exploring diversity and redundancy

A healthy, resilient and sometimes stable system has diversity built into its DNA [11, 14]. According to Walker & Salt [6] "a lack of diversity limits options and reduces your capacity to respond to disturbances. Increasing efficiency inevitably leads to a reduction in diversity".

The identification of the physical, structural components that create functional diversity within a city can be interpreted as the functional groups that physically make a city function as "a city", namely infrastructure, buildings and resources (which include waste). 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, water systems, and communication systems. 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. Within an urban system, many variables or components have specific functions that they provide. To each function there are different responses for different aspects of the system. 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.

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), industrial (production) and civic space (amenity). Subsequently, residential or shelter responses (Fig. 2) might see informal responses like a homeless person appropriating the edges of an abandoned building with a very fast rate of change enabling quick responses to perturbations, to structures like shacks, with more formal responses like sectional-title houses or apartment blocks, and low-density luxury estates with full-title houses with very slow rates of change and response to change in the larger system [15].
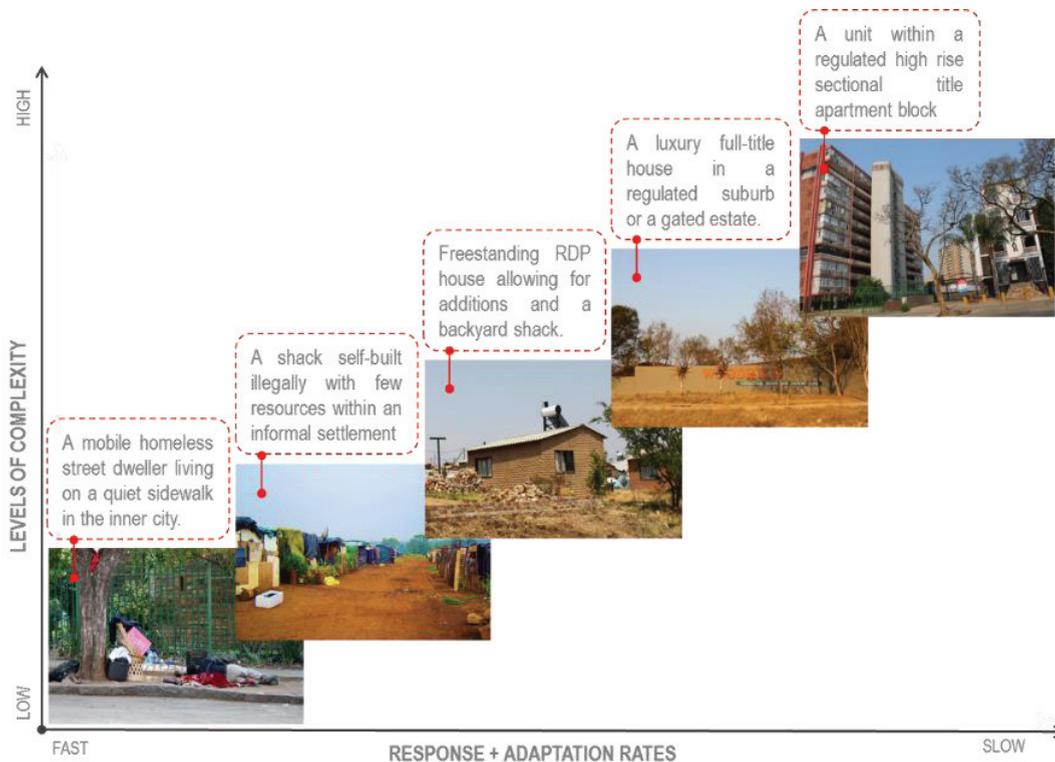

Fig. 2. Functional response diversity for shelter, across scales

Redundancy within the response diversity of a functional group can be described as an "insurance plan" or a "backup" [12] for the system at a time when things go wrong. These concepts of diversity and redundancy can also be applied spatially. By examining the focal system of a small, gated estate south of Tshwane illustrated in Fig. 3, we can look at the value of building in redundancies from the perspective of the road network so as to decrease its vulnerability. Currently, the neighbourhood is dependent on a single point of entry and exit for the estate off a busy, high-speed road. Traffic congestion and accidents have placed pressure on the regional road network to adapt, resulting in 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. While the gated community was established in response to one of the goals of sustainability, namely to provide a safe and secure urban environment, the lack of redundancy in the function of "entrance/ exit" not only impacts on the resilience of the community, but also on other sustainability goals of the city such as mobility and accessibility; and the resulting internal traffic jams at peak traffic times increases the amount of greenhouse gases released by idling vehicles.

Resilience and sustainability could be improved by incorporating redundancy principles, e.g. by increasing 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).
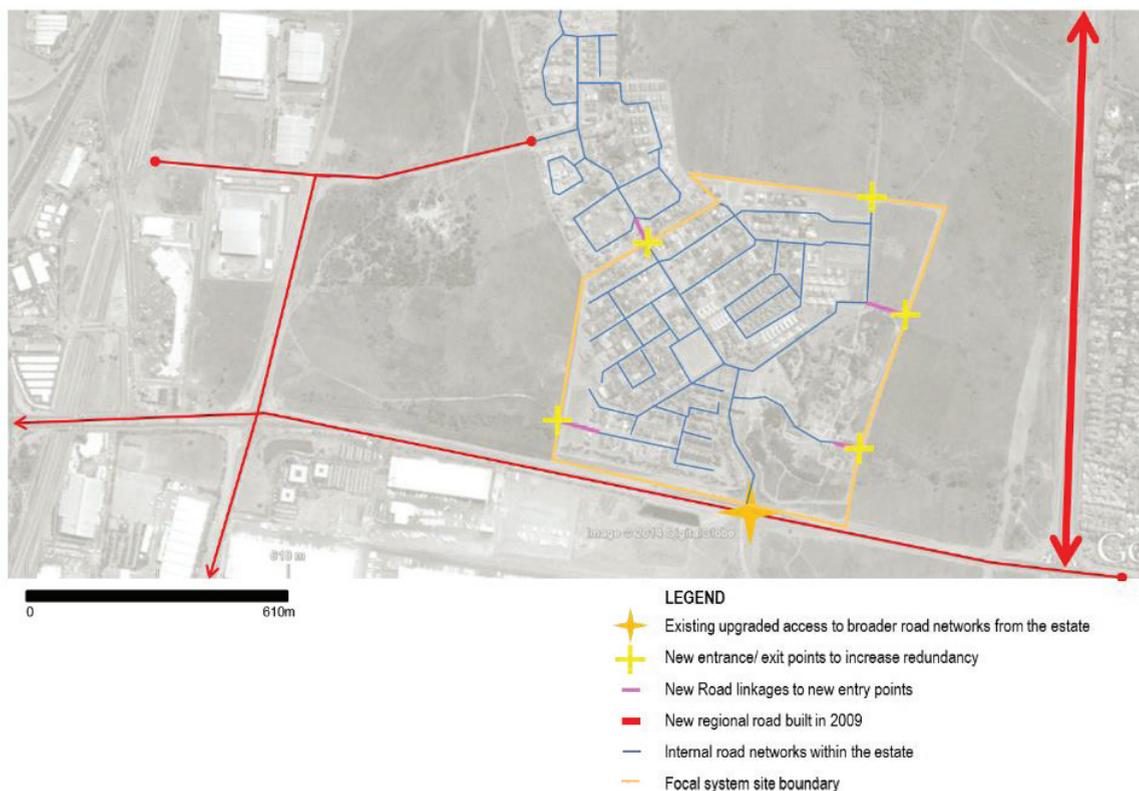

Fig. 3. Redundancy explored through the entrances to a gated estate.

4.2. Exploring the relationship between modularity and resilience

Modularity in a system arises from the relationships between components in the system, the linkages between which create a certain structure or pattern that affects its future performance. 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 localizing 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" [12] and have "subgroups of components that are strongly connected internally, but only loosely connected to each other" [6].

This section assesses modularity in a small sample area, illustrated in Fig. 4. The assessment focuses on the physical road network and excludes possible levels of social or ecological modularity. The security complex or estate residential typology has a very significant layout. This pattern repeats irrespective of the scale of the development. While the local road layout (shown in blue in Fig. 4) may represent a well-connected internal layout of vehicular roads and pedestrian routes, on a broader scale (shown in red in Fig. 4) these complexes are limited to one monitored access point (or two to three in very large developments).

In a row of security complexes (1-4 in Fig. 4) 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
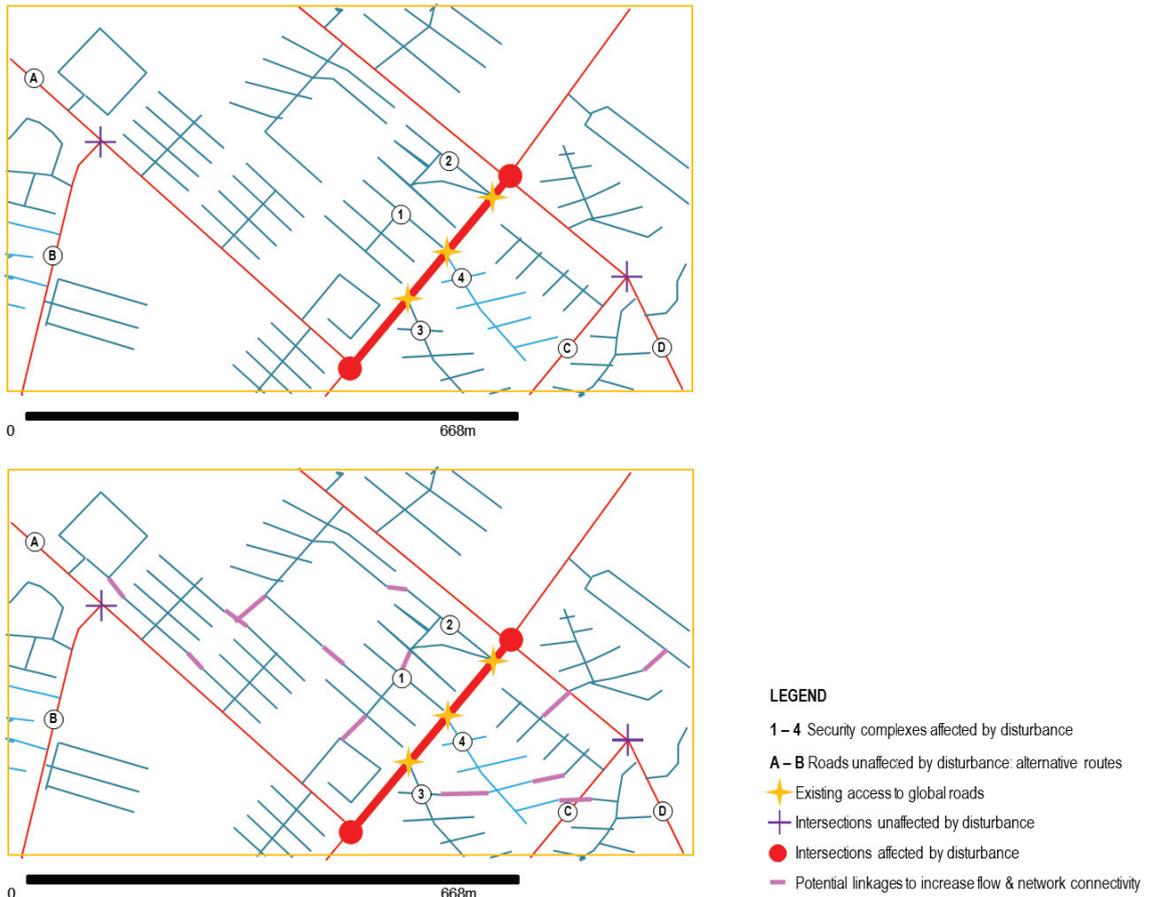

Fig. 4. Modularity explored in the road network around gated-communities

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 larger 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). However, 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 Fig. 4, 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 Fig. 4) 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.

The design of at least one or two connections between each security complex, as illustrated by the lilac lines on Fig. 4, 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.

5. Closing the gap: Spatial resilience as a mechanism for achieving sustainability goals

In the illustration of resilience attributes discussed above, it is clear that resilience arises also from the spatial system properties. Investigating the spatial manifestation of these attributes creates the opportunity with which to explore how the city system can be restructured to achieve the performance qualities of a regenerative and sustainable system. While sustainability and urban resilience theory are important concepts in creating the vision for any city, it is important to build practical avenues for implementation within the built environment professions. We've observed a gap between theory and practice. One of the most important ways to bridge this gap is to engage with the resilience of the physical environment of the city, as the realm that influences both the lifestyle of its citizens, as well as the operational efficiency of the urban system. It becomes a useful entry point that can be observed and measured, and the effects of interventions can be easier to notice than those in the realm of ideas or social behaviours. Spatial resilience is an important aspect of resilience thinking as a pathway to achieving sustainability, since it directly affects what is possible in terms of the operation of the city. By building on the attributes of resilience (diversity, modularity and backups) found within an SES, it is possible to derive mechanisms of measurement for spatial resilience that can gauge of how far or how close the spatial characteristics of a system are from achieving a more sustainable urban form.

The two simple illustrations of spatial resilience attributes indicate that this avenue of research into defining the mechanisms for building spatial resilience will yield interesting results. It promises an opportunity to further refine the relationship between sustainability and resilience thinking in a meaningful and useful approach. However, while the authors have begun to conduct various explorations into the definition of and attributes of spatial resilience, as yet these ideas need to be unpacked and tested more rigorously before they will yield any definite results.

4. Conclusion

This paper argues for an expanded understanding of sustainability and resilience as complimentary concepts within urban studies. It suggests that sustainability forms the normative position behind the goals of urban development, while resilience thinking provides the framework of ideas to determine how far the city is from achieving these goals and how best to achieve these goals. However, it also determines that both these concepts operate better as theoretical constructs and that this posed a challenge when trying to transform the spatial reality of the city toward a more thriving and regenerative system. To this end, the attributes of resilience thinking were engaged further in order to attempt to bridge the gap between theory and practice, creating a mechanism for shifting the physical system toward desired goals. Using an example of a typical spatial manifestation within Tshwane, the notions of sustainability, resilience thinking and the beginnings of spatial resilience were briefly explored. It is

proposed that a spatial resilience approach could provide a good unifying approach to synergise future development in rapidly urbanising environments. Within the context of resilience studies, the research outlined in this paper proved useful to clarify certain misinterpretations, but also in proposing a tangible way forward for determining the spatial resilience of the city.

Acknowledgements

References

[1] City of Tshwane, Tshwane vision 2055: remaking South Africa's capital city. Strategy development and implementation, City of Tshwane, Tshwane, 2013. Accessed 3/12/2014 from: http://www.tshwane2055.gov.za/images/vision/online_version-cot_2055_vision-v2.pdf.

[2] G. Rochecouste, L. Pearson, Delivering resilient, sustainable cities is all about people and place, In L. Pearson, P. Newton, P. Roberts (eds.), Resilient sustainable cities, Routledge, New York, 2014, 44-51.

[3] WCED (World Commission on Environment and Development), Our common future, Oxford University Press, Oxford, 1987.

[4] UNCED (United Nations Commission on Environment and Development), Agenda 21: The United Nations Programme of Action from Rio, 2002. Accessed 12/06/2006 from http://www.un.org/esa/sustdev/documents/agenda21/index.htm

[5] D. Satterthwaite, 'Sustainable cities or cities that contribute to sustainable development?' In D. Satterthwaite, (Ed.), The Earthscan Reader in sustainable cities, Earthscan, London, 1999, 80-104.

[6] B. Walker, D. Salt, Resilience Thinking: sustaining ecosystems and people in a changing world, Island Press, Washington, 2006.

[7] C. Du Plessis, K. Landman, A sustainability analysis of human settlements in South Africa. National Department of Housing, CSIR Report BOU/ C368, Pretoria, 2002.

[8] D. Hes, C. Du Plessis, Designing for Hope: pathways to regenerative sustainability, Routeledge, New York, 2015.

[9] B. Walker, D. Salt, Resilience Practice: building capacity to absorb disturbance and maintain function, Island Press, Washington, 2012.

[10] A. Forty, Words and Buildings: a vocabulary of Modern architecture, Thames & Hudson, London, 2000.

[11] M. Hamilton, Integral City: evolutionary intelligences for the human hive, New Society Gabriola Island, Canada, 2008.

[12] A. Zolli, A. Healy, Resilience: why things bounce back, Headline Publishing Group, London, 2012.

[13] K.F. Gotham, R. Campanella, Towards a Research Agenda on Transformative Resilience: Challenges and Opportunities for Post-Trauma Ecosystems, Critical Planning, Summer, 2010, 9-23.

[14] L. Gunderson, L. Pritchard, C. Holling, C. Folke, G. Peterson, A summary and synthesis of resilience in large-scale systems. In L. Gunderson, & L. Pritchard (eds.), Resilience and the behaviour of large-scale systems. Island Press, Washington, 2002, 249-266.

[15] C. Du Plessis, Applying the Theoretical Framework of Ecological Resilience to the Promotion of Sustainability in the Urban Social-Ecological System. In: Smart and sustainable built environments, São Paulo: SASBE, São Paulo, 27-29 June, 2012, Accessed 5/8/2013 from: http://trustsa.weebly.com/uploads/1/3/2/0/13205680/duplessis_sasbe2012.pdf