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Resilience-Oriented Urban Planning

Theoretical and Empirical Insights

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Preface

Resilience is a topic of interest to researchers, planners, and policymakers as they prepare to face consequences and complex risks posed by a broad range of natural and man-made disasters. The concept has gained prominence in the literature, and scholars across a broad range of disciplines, including psychology, ecology, engineering, and social sciences, have utilized resilience as a guiding concept in research and practice. Since the turn of century, resilience has emerged as a complement to, and even a substitute for, sustainability. Urban researchers, planners, and policymakers are increasingly paying attention to this concept. Resilience is widely considered as a quality required for meeting various Sustainable Development Goals (SDGs) that have recently been set in order to develop communities that are more equal, safe, livable, and sustainable.

In the context of urban planning, resilience thinking can be used to enhance coping capacity of both existing and future developments and to help them maintain their essential operations. Resilience thinking furthermore advocates considering disastrous events as windows of opportunity for significant improvements in the existing conditions and for bouncing forward through transformative adaptation.

Over the past three years, the Global Carbon Project (GCP), as a core project of the Future Earth initiative, has organized several meetings to discuss various issues related to urban resilience (http://www.cger.nies.go.jp/gcp/activities.html). In December 2015, GCP organized a workshop on "Tools and Indicators for Assessing Urban Resilience" at The University of Tokyo, Japan. A strong scientific network was established following this event to support future collaborations and foster dissemination of research findings. As an initial step, the workshop participants were invited to revise and publish their presentations as chapters that can be used by a variety of stakeholders, ranging from graduate students to researchers, planners, and policymakers. It is our great pleasure to see this book as one of the first outputs of this scientific network.

The book has three parts, each addressing a specific area of concern for the development of resilient urban environments. The individual chapters cover a broad spectrum of issues related to enhancing the ability of cities to "plan and prepare for," "absorb," "recover from," and "adapt" to potential adverse consequences of climate change and other threats. The specific focus of the three parts will be on the following three main themes, respectively:

– ***Planning and decision-making process***: Contributions related to this theme are focused on various innovative methods and processes needed to incorporate resilience thinking into urban planning. Among other things, this will include discussions on improvements and/or modifications that need to be made in how cities are managed and paradigm shifts that are necessary to meet the challenges of climate change. In addition, various issues related to assessment of urban resilience and effectiveness of resilience improvement plans are also discussed under this theme.
– ***Case studies***: The book also features several case studies from around the world. These cases show how theoretical aspects of urban resilience are put into action, what the success stories are, and what challenges need to be overcome in order to enhance resilience of urban communities. The success stories presented under this theme signify the ever-growing role that cities can play in improving their resilience and addressing the challenges of climate change.
– ***Urban form and typologies***: Here the focus is on how different urban forms respond to potential threats posed by climate change. A conceptual framework is introduced that can be used for assessing resilience of urban form. This conceptual framework covers issues related to resilience of urban form elements at macro-, meso-, and micro-scales. The part related to this theme also includes contributions that provide theoretical and empirical evidence related to resilience of some of the urban form elements that were mentioned in the conceptual framework.

We would like to thank all colleagues who gave up their time to contribute to this project. We would also like to appreciate the partial financial support from the Asia-Pacific Network for Global Change Research. We hope you will enjoy reading this book and hope that the strategies proposed in this book will be used to bolster resilience and sustainability of cities in the face of climate change and other threats.

Tsukuba, Japan

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Highlights

- Innovative planning tools and methodologies (bottom-up and top-down) are introduced.
- Urban form and its association with urban resilience is investigated.
- Various criteria and indicators for assessing resilience of urban form are introduced.
- Tools and methodologies for urban resilience assessment are explored, and their integration with the planning process is discussed.
- Several case studies on urban resilience building activities are presented.

Contents

Part I
Integrating Resilience Thinking into Urban Planning

Chapter 1
Resilience-Oriented Urban Planning

Ayyoob Sharifi and Yoshiki Yamagata

1.1 Introduction

Cities across the world are increasingly exposed to a wide variety of risks. Many of these risks are environmental (e.g. extreme weather events, water shortage and pressure on other natural resources, biodiversity loss, failure of climate change mitigation and adaptation, etc.) (WEF 2017). Climate change and environment-related risks are tightly interconnected with other risks and, since 2011, have often been ranked among the top five global risks in terms of both impact and likelihood (WEF 2017). Many cities, especially coastal cities, are susceptible to climate change and environment-related risks and hazards (Boyd and Juhola 2015). The frequency and intensity of these risks is expected to increase as climate change continues. Climate change and its impacts may have significant ramifications for the effective management of cities which are engines of economic growth (accounting for over 80% of global GDP) and are expected to host about 66% of global population by 2050 (WB 2015). Based on low estimates, current global average annual losses in cities are about USD 314 billion. Unless cities around the world take appropriate actions to enhance their resilience, this figure may rise to USD 415 billion and even higher (if losses from knock-on effects such as mass human migrations, conflicts, pollution, epidemics, economic collapse, etc. are also considered) by 2030 (WB 2015).

The concept of resilience is increasingly used as an organizing principle to frame scientific and political discourses on cities. Its importance has been emphasized in United Nations (UN) documents related to cities. In the newly adopted New Urban Agenda a wide range of stakeholders, across multiple scales, make commitments to

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develop policies, programs, plans, and actions for building urban resilience (Habitat_III 2016). The importance of building urban resilience is also echoed in the UN Sustainable Development Goals (SDGs): SDG 11 asserts that cities should adopt plans to build their resilience in line with the Sendai Framework for Disaster Risk Reduction 2015–2030; SDG 9 is focused on developing resilient infrastructure to support sustainable development (UNSDG 2015).

Integrating resilience thinking into urban planning and design is essential for building urban resilience. The significance of achieving such integration is emphasized in many policy documents such as the Hyogo Framework for Action 2005–2015, and the Sendai Framework for Disaster Risk Reduction 2015–2030. For several decades, resilience has been a popular subject in field such as physics, ecology, and psychology. It is, however, a comparatively new concept in the field of urban planning and design and was introduced about two decades ago (Sharifi and Yamagata 2016). Since the turn of the century, resilience has received increasing attention within the field of urban planning and design. This can be attributed to the fact that, as mentioned above, cities around the world are, more than ever, facing the impacts of a board range of hazards.

Despite efforts to integrate resilience thinking into urban planning [e.g. see (Wilkinson 2012a, b)], there is still no consensus on the implications of resilience thinking for urban planning theory and practice (Sharifi et al. 2017). This chapter aims to shed more light on this issue by analyzing literature on urban resilience and discussing how resilience can be used to provide the planning theory and practice with new conceptual grounds. It elaborates on the main components and principles of the resilience concept that should be incorporated into the theory and practice of urban planning and discusses paradigm shifts that should occur during the integration process.

This chapter is organized as follows: Next section provides a brief literature review on the resilience concept and its underlying principles. In Sect. 1.3 implications of these principles for urban planning are discussed. Section 1.4 concludes the chapter by providing suggestions for future research.

1.2 Resilience and Its Underlying Principles

Resilience is a polysemic concept that has been interpreted in a variety of ways within and across disciplines (Norris et al. 2008). Groups with different research and policy interests provide different interpretations of the resilience concept and use it to frame and conceptualize their own agenda. Some may use resilience in the context of climate change adaptation and mitigation, while others utilize it in the context of human development, disaster risk reduction, and international development (Lu and Stead 2013). As mentioned earlier, the concept of resilience has its roots in disciplines such as physics and psychology. Originally, it was used to measure the capacity of systems, objects, or individuals to survive disruptions by maintaining acceptable levels of functionality and returning to pre-disruption levels of functioning in a timely manner (Sharifi and Yamagata 2016). This could be considered as an equilibrium approach to defining resilience and was the dominant approach until concepts such as ecological resilience and adaptive resilience were introduced in the second half of the twentieth century (Gunderson and Holling 2002). The single-equilibrium theory was challenged by the emergence of these new concepts that introduced multiple-equilibrium and non-equilibrium approaches to resilience.

Planning scholars have mainly borrowed the concept of resilience from ecology. Three major approaches to defining urban resilience can be distinguished in the literature. These are, namely, engineering resilience, ecological resilience, and adaptive resilience. Engineering resilience theories emphasize minimizing vulnerability to disasters by enhancing resistance and robustness of the physical infrastructure. Based on this interpretation of resilience, disruptions and disasters can, to a large extent, be predicted and prevented. In other words, cities and their infrastructures should be fail-safe (Ahern 2011; Sharifi and Yamagata 2016). If stressors exceed the safety thresholds and the system (or parts of it) experience failure, engineering resilience will enable rapid recovery to pre-disruption conditions (equilibrium). Reliance on engineering methods for building urban resilience may, however, give planners and decision makers a false sense of security.

Extending the theory of adaptive cycle (that was originally developed to understand ecosystem complexities and dynamics) to the urban system (as a social-ecological system), it can be argued that cities and infrastructures regularly go through the four phases of ‘exploitation’(r), ‘conservation’ (k), ‘release’(Ω), and ‘reorganization’(α) (see Fig. 1.1) (Gunderson and Holling 2002). Transition from the exploitation to the conservation phase takes place over a considerably long time period during which changes occur slowly and the system is relatively predictable. However, shift from the release to the reorganization phase often represents a short period of chaotic change and high uncertainty. This alternation between long periods of normal functioning, slow change, and relative stability and briefer periods of chaotic change (due to cumulative accumulation of small-scale events that can lead to major transformations over time) and sudden increase in unpredictability might result in occasional exceedance of critical limits of (urban) systems (Gunderson and Holling 2002). Under such circumstances, overreliance on engineering resilience and system robustness may result in irreversible changes and cause significant loss in system performance.

Ecological resilience entails a more dynamic and flexible approach that recognizes inadequacy of resistance and robustness characteristics for building urban resilience. It promotes building safety margins into the design of the system in order to absorb initial shocks, retain functionality, and minimize overall losses. An ecologically-resilient system may experience transition to new equilibrium states during the recovery process. However, the basic structure and function of the system remains unchanged (Sharifi and Yamagata 2016).

Driven by the growing understanding that future changes are hard to predict, disasters are not always preventable, and urban systems should learn how to live with risk; a more recent approach has emerged and gained widespread popularity in

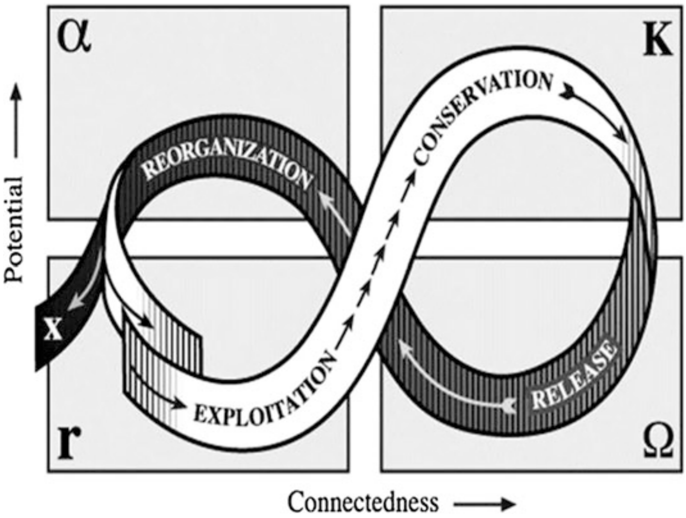

Fig. 1.1 A representation of the adaptive cycle theory. *Source* http://www.resalliance.org/adaptive-cycle

recent years. Highly influenced by the above mentioned 'adaptive cycle' concept, adaptive resilience[1] conceptualizes urban systems as complex and dynamic socio-ecological systems. A nested set of adaptive cycles can be used to model the performance of urban systems over time and across space. Adaptive resilience facilitates appropriate interactions between slow and fast variables. This allows the system to smoothly alternate between long periods of stability and short periods of chaotic change, without losing its integrity and functionality. Social-ecological memory, self-organization, and learning from the past are essential characteristics for achieving adaptive resilience. Overall, adaptive resilience strengthens short-term coping and long-term adaptation capacities and enables the system to sustain functionality over time. Since urban system is nested in a hierarchy of adaptive cycles, it does not necessarily return to (new or old) equilibrium states following adverse events. Adaptive resilience enables building "safe-to-fail" systems that not only bounce back from disasters, but also bounce forward and constantly enhance their performance and adaptive capacity (Ahern 2011; Gunderson and Holling 2002; Sharifi and Yamagata 2016).

The 'adaptive resilience' concept recognizes system complexities and dynamics and lends itself to describing and understanding resilience of urban systems as complex and dynamic social-ecological systems. Inspired by the concept of adaptive resilience, this study defines urban resilience as the *ability of urban systems to continuously develop short-term coping and long-term adaptation strategies- considering,*

[1]Terms such as social-ecological resilience, transformational resilience, and adaptive resilience are sometimes used interchangeably and all refer to the same concept.

and in response to constantly changing system dynamics and complexities over a range of spatial and temporal scales-to mitigate hazards, withstand and absorb shocks, rapidly bounce back to baseline functioning, and more effectively adapt to disruptive events by bouncing forward to better system configurations.

Achieving urban resilience requires incorporation of essential principles and characteristics such as robustness, stability, diversity, redundancy, flexibility, resourcefulness, coordination capacity, modularity, collaboration, agility, efficiency, creativity, equity, foresight capacity, self-organization, and adaptability into the urban system. These principles and characteristics have been defined elsewhere (Sharifi and Yamagata 2016) and will be referred to in describing the major elements of resilience-oriented urban planning in the following sections.

1.3 Integration of Resilience Thinking into Urban Planning

Several fundamental practices and measures for integrating resilience thinking into the theory and practice of urban planning are discussed in this section. These discussions include arguments on the importance and benefits of incorporating resilience into urban planning, as well as, some remarks on how such an incorporation can be achieved.

Before embarking on these discussions, it is worth noting that, traditionally, disaster risk management has always been an essential part of urban planning. However, as will be discussed in the rest of this chapter, introduction of the concept of resilience has given rise to major transformations in approaches to urban disaster risk management. Traditionally, disaster risk management was mainly focused on short- and medium- term emergency planning and mitigation efforts. Integrating resilience thinking into urban disaster risk reduction encourages taking a medium- to long- term approach which is more compatible with phenomena such as climate change that are characterized by slow and steady changes as compared to those that occur abruptly (slow vs fast variables) (Sellberg et al. 2015).

Resilience can be either against abrupt shocks that often occur due to climate variability or against slow and steady changes caused by climate change. In response to abrupt shocks, it is important to enhance resistance, robustness, and absorption capacities of the system, incorporate redundant elements in the system configuration, and develop plans to recover rapidly in case damage is occurred. Changes caused by climate change exhibit different features. Slow and steady variables that continuously change the system may cause irreversible transformations and shift the system into completely different regimes. Under such conditions, only emphasizing principles such as robustness and redundancy would not be sufficient and improvements in terms of coping, adaptation, and transformation capacities are needed (Kim and Lim 2016). Resilience-based planning and disaster management requires continuous and systematic efforts to coordinate the ongoing processes related to exploitation, conservation, release, and reorganization as the four major phases of the adaptive cycle. One point to be mentioned is that the medium- and long-term nature of climate change related phenomena may conflict with the short-term nature of electoral cycles that affect urban policies. Effective strategies, such as raising citizen awareness, need to be developed to address this temporal mismatch.

Traditional urban disaster risk management is mainly centered around vulnerability assessment and developing action plans for reducing vulnerability. Vulnerability is a static concept that provides a snapshot of system conditions and is often evaluated before the occurrence of the event. However, resilience-oriented disaster management recognizes the importance of understanding dynamics and complexities of the system and intends to explain how these dynamics and feedbacks evolve across temporal and spatial scales. Resilience can, therefore, be considered as a dynamic property that is constantly changing and indicates transformations of system vulnerabilities over time (Irwin et al. 2016).

In the following sub-sections, implications of integrating resilience thinking into urban planning are discussed. It should, however, be mentioned that not all planning stages and components are covered here and only selected fundamental points are discussed.

1.3.1 Planning Strategy and Vision

Visioning and strategy making is one of the most fundamental parts of any planning effort. Traditionally, establishing a desirable development pathway and safeguarding it has been at the center of planning efforts. Blueprint plans are developed to provide a clear vision for future growth and development and to deliver guidance for action. Although they can be suitable for achieving the former goal, fulfillment of the latter goal will be challenging. Resilience thinking questions suitability of blueprint planning on the grounds that development pathways need to be regularly updated in order to deal with the constantly changing profile of risks and uncertainties. Due to their rigidity, blueprint plans fail to capture dynamics and complexities of urban systems. Integrating resilience thinking into urban planning requires recognizing the shortcomings of blueprint planning. It is essential to acknowledge that threats cannot always be prevented due to the unpredictability of future conditions. Integrating resilience thinking into urban planning requires stepping away from the "predict and prevent" approach and moving towards understanding and accommodating complexities and uncertainties inherent in the planning for cities as dynamic and constantly evolving social-ecological systems (Reed et al. 2013). Adopting experimental approaches based on "learning by doing" principles (involving co-design and transdisciplinary approaches that engage different stakeholders in urban planning) is an effective social learning strategy for dealing with uncertainties inherent in social ecological systems and achieving adaptive planning and design (Ahern et al. 2014; Reed et al. 2013; Wilkinson 2012a).

It should be appreciated that engineering approaches that emphasize eliminating risk factors, through technological advances and physical planning approaches such as construction of coastal walls and levees, may not be sufficient for safeguarding communities. Instead of eliminating risk, avoiding exposure (e.g. through appropriate site selection) and enhancing resilience to risk should be emphasized (Syphard et al. 2013). Planning authorities should understand the possibility of risk and develop innovative and adaptive planning and design strategies so that the system can experience a safe failure ("safe to fail" instead of "fail safe") (Ahern et al. 2014). For this purpose, a paradigm shift from blueprint planning (linear and static) to adaptive planning that embraces change and involves regular and iterative processes of monitoring, assessment, and scenario making is needed.

Further benefits can also be realized by integrating assessment and monitoring into the planning process. Study conducted in Eskilstuna, Sweden shows that resilience assessment can facilitate brainstorming on uncertainties and complexities and help achieve a "dynamic systems" approach (Sellberg et al. 2015). Through developing longer-term scenarios and analyzing future changes within longer time horizons, resilience-based planning and assessment provides more opportunities for accommodating uncertainties and complexities. The system dynamics are appreciated through integrating changing thresholds into planning and assessment frameworks and taking account of social ecological interactions that occur across time and scale (Sellberg et al. 2015). In addition, assessment and certification can encourage companies and developers to aim for best practices and integrate innovative thinking into their activities.

Earlier, it was mentioned that adaptive resilience promotes a non-equilibrium perspective to system functionality and disaster recovery. This signifies a shift from the conservative mindset that promotes maintaining status quo and returning to equilibrium conditions (traditional urban disaster risk management) to perspectives that embrace change and see disaster (happening or pending) as an opportunity to enhance the overall performance of the system and achieve transformative adaptation.

1.3.2 Public Participation and Capacity Building

City is a social-ecological system where humans and environment are tightly interconnected. Stewardship of human-environment interactions and management of natural resources lie at the core of resilience concept (Wilkinson 2012a). Resilience-oriented planning acknowledges these interactions and puts people at the center of planning efforts and activities. Participation should be an integral part of the planning process, during both pre- and post-disaster periods. It should involve as many stakeholders as possible and start as early as problem definition in the planning process (co-design) (Schauppenlehner-Kloyber and Penker 2016). Public participation and citizen engagement in mitigation and risk communication efforts is a social learning practice and improves social capital which is widely believed as an essential component of urban resilience (Prior and Eriksen 2013). It is also important to promote communal actions and common practices (again important for enhancing social capital). The citizens should acknowledge that achieving urban resilience may require enhancing preparedness of all households and community members and this may require communal actions. For instance, vulnerability of one household to fire hazard may have consequences for neighboring households too (spread of fire) (Prior and Eriksen 2013).

Stakeholder engagement should also be prioritized during the post-disaster period. Getting people (and not just property owners) involved in the reconstruction process is considered as an important step to build their capacities, empower them, and enhance their resilience and adaptive capacity (Schilderman and Lyons 2011). Participation of people in the reconstruction activities also results in better overall satisfaction with living conditions following the completion of the reconstruction process (Schilderman and Lyons 2011). Furthermore, through capacity building activities, participation in the reconstruction process improves self-organization capacities and reduces community dependence on external support (Schilderman and Lyons 2011).

1.3.3 Equity and Empowerment of Poor and Marginalized Communities

Resilience planning efforts should be aimed at protecting poor and marginalized groups from the negative impacts of disasters through enhancing their economic conditions (Peyroux 2015). Rapid and unregulated urbanization in many cities in the developing world may lead to the formation and growth of informal settlements and poor communities. These communities are often more vulnerable to the impacts of disasters. There is ample evidence demonstrating that low income and marginalized groups are disproportionately affected by the impacts of climate change and other disasters. For instance earthquakes of higher magnitude have resulted in less damage and casualties in cities of developed countries such as the US and Japan as compared to earthquakes of relatively lower order of magnitude hitting cities of developing countries such as Haiti, India, and Iran (Schilderman and Lyons 2011). Many cities in the developing countries are polarized and poor. Marginalized groups in these cities cannot afford complying with required building and construction standards (Schilderman and Lyons 2011). High prices of land and properties in such cities leave the poor groups with no option but to build their settlements on highly vulnerable sites such as steep slopes and alluvial and fluvial plains. This further increases their vulnerability (Schilderman and Lyons 2011). It is, therefore, essential to integrate social justice into resilience planning activities.

To protect poor and marginalized groups from being disproportionately affected by the impacts of disasters, imposing limitations on development in disaster-prone areas is essential. This can be achieved by developing risk maps that clearly identify risk-prone areas that should be protected, preventing new developments in those areas, and developing strategies to incrementally relocate existing properties in risk-prone areas. Occurrence of disasters provides opportunities to take actions that more effectively prevent persistence of vulnerabilities by restricting return of people and businesses to disaster areas. However, if relocation is necessary, care should be taken to ensure that livelihoods of communities are not negatively impacted. Relocation should not negatively impact access of communities to ecosystem services essential for their livelihood (Villagra et al. 2016). For instance, relocating a fishing community to inland areas that are far from the sea can have significant livelihood impacts (Schilderman and Lyons 2011). Evidence from Korail, Dhaka shows that people may prefer living in risk-prone areas that provide them with better livelihood opportunities over comparatively less risky locations with unsecure livelihood opportunities (Jabeen et al. 2010). Therefore, relocation from risk-prone areas should be coupled with mechanisms to provide alternative livelihood opportunities in the short run and diversify livelihood strategies in the long run.

Disproportionate impacts on poor and marginalized groups can also be reduced by developing empowerment strategies. Meta-analysis conducted by Oberlack and Eisenack (2014) identifies income insecurity, restricted availability and accessibility to critical infrastructure, low standard housing conditions, land tenure insecurity, and lack of access to education and health services as major barriers undermining adaptive capacity of communities. Evidence from Korail, Dhaka suggests that tenure instability adversely impacts inhabitants' willingness to enhance their living conditions and levels of preparedness (Jabeen et al. 2010). Obviously, lack of tenure can erode inhabitant's coping capacity. Therefore, empowerment should include enhancing sense of ownership and developing strategies for securing land and home tenure, especially in informal areas (Jabeen et al. 2010). Empowerment should also involve municipal support for development of collective insurance and saving schemes for poor urbanites living in informal areas of developing countries. These efforts could also be complemented through development of innovative municipal insurance plans for further support of urban poor (Jabeen et al. 2010).

Social inclusion is tightly tied with social cohesion and contributes to urban resilience (Peyroux 2015). Enhanced accessibility to infrastructures, safety nets and services in the community, empowerment initiatives to enhance capacity of low-income and marginalized groups, creation of jobs and employment opportunities for diverse community groups, and engagement in the decision making process are examples of efforts that can be taken for improving social inclusion (Peyroux 2015).

1.3.4 Traditional Local Knowledge

Many cities have been inhabited for centuries. Over their histories, residents have learned how to deal with disturbing events and pass on design and construction techniques to later generations. Modern planning efforts should not deny existing planning culture. It should be considered as an asset that needs to be improved as the nature of disasters evolves over time.

The significance of utilizing traditional ecological knowledge for building resilience is emphasized in the literature (McMillen et al. 2017). Planners should understand how coping strategies and capacities of communities to adapt to climate change and variabilities have evolved over time (McMillen et al. 2017). Studying this evolution process will provide valuable lessons about how to adapt to future changes. For instance, traditional ecological knowledge can be used in selecting species suitable for the local climate (e.g. drought-tolerant species in water-stressed areas) (McMillen et al. 2017).

Other benefits can also be accrued from understanding traditional local knowledge. It strengthens social capital, enhances modularity, and contributes to local economy. For instance, awareness of local building technologies and tapping into them reduces dependence on external support and contributes to local economy (Schilderman and Lyons 2011). Respecting local building technologies and applying vernacular architecture principles in modern construction can also provide other co-benefits in terms of energy resilience and thermal comfort (Sharifi and Yamagata 2016).

1.3.5 Institutional Reforms

The structure and functionality of urban systems is characterized by complex and dynamic interrelationships and interactions between a broad spectrum of actors, institutions, sectors, infrastructures, norms, networks, and processes that operate at multiple spatial and temporal scales. Therefore, achieving urban resilience requires developing institutional mechanisms that transcend spatial, temporal, and sectoral boundaries. These institutional mechanisms should be guided by an adaptive management strategy that facilitates collaboration between different stakeholders and gets them involved in continuous processes and feedback loops of learning and adaptation (Crowe et al. 2016). According to Crowe et al. (2016), adaptive management should start with understanding the system through collecting data, generating information, and making the information accessible for different actors to better understand factors that drive change. In terms of the system operation, it is needed to reduce bureaucratic hierarchies, adopt co-design and co-production approaches, capitalize on social and community capital, and emphasize incremental approaches based on learning by doing. Adaptive management should also improve the overall efficiency of the system through instigating behavioral changes, establishing support networks between resources, and optimizing system performance.

It can be argued that devolution of power to local communities, building a culture of collaboration, developing effective communication strategies, appropriate financing of disaster risk management, establishing public-private partnerships, and enhancing institutional transparency and accountability are critical for streamlining adaptive management strategies in urban planning efforts.

Decentralization and devolution of power to local authorities is essential for enhancing local capacity. Successful adaptation and resilience building requires direct participation and input from the local community. Achieving this objective is difficult in highly centralized political systems that lack integrated management at the urban level (Villagra et al. 2016). Strong local authorities with stable and sustainable budget resources are better capable of enhancing community resilience and responding to disaster risks (Villagra et al. 2016). A paradigm shift from top-down and "command and control" approaches towards recognition of bottom-up community-based efforts is needed. Such a shift improves adaptability and flexibility of urban systems and recognizes significance of factors such as human behavior, stakeholder interactions, social networks, etc. (Prior and Eriksen 2013; Reed et al., 2013).

Promoting a culture of collaboration is one way to achieve decentralization. Different forms of collaboration, ranging from cross-sectoral collaboration, through collaboration between cities, to inter- and trans-disciplinary collaboration are needed.

A challenging, yet critical, task would be stepping away from sector-based planning toward recognizing that urban issues are often interconnected. Collaboration between different actors, sectors, and agencies is needed to better understand interdependencies, minimize conflicts and trade-offs, and maximize synergies. A case study of Rotterdam shows that collaboration across different governmental and non-governmental stakeholders, with diverse interests, is essential for enhancing urban resilience. Collaboration networks should be established to coordinate between groups with different interests. Operationalizing such coordination networks requires a shift from top-down and infrastructure-based planning to decentralized planning that acknowledges significance of various social, economic, and environmental forces (Lu and Stead 2013). Networking should not be limited within the city boundaries. It is increasingly recognized that building global networks for promotion of city-scale collaborations can be an effective way for gaining support and sharing knowledge and experiences (Lu and Stead 2013). This is specifically important for supporting cities in the Global South. Cities in the developing countries often have less adaptive capacity to combat the impacts of climate change. Since developed countries are responsible for a significant share of cumulative atmospheric Greenhouse Gas Emissions (GHGs), it is the historical responsibility of cities in the Global North to collaborate with those in the Global South through transfer of knowledge and technologies (Oberlack and Eisenack 2014). Inter- and trans-disciplinary collaboration is also needed because no single discipline is capable of appropriately capturing complexities and dynamics involved in inert-linkages between different social, environmental, and economic factors related to urban resilience. The increasing interest in addressing urban complexities from the perspective of food-water-energy-carbon nexus is a good example in this regard.

Applying appropriate communication strategies is essential for facilitating collaboration between actors with different interests and backgrounds. Drawing on urban flood risk management case studies in several cities in Denmark and the

Netherlands, Fratini et al. (2012) argue that a multitude of stakeholders, including, water professionals, urban planners, landscape architects, natural scientists, laypersons and politicians should be engaged in the planning process. These stakeholders may have different values and communication techniques should be employed to create a common vision and a common understanding among them. Appropriate communication strategies should clarify the interrelationships between various social, natural, and technological aspects of the issue and possibly develop multifunctional strategies and action plans that can benefit various groups of stakeholders and, at the same time, enhance urban resilience by improving citizen awareness and system flexibility. When communicating climate change resilience strategies and action plans (and results of vulnerability and resilience assessment) with stakeholders, it should be noted that highly technical language may not be easily understood by all community groups. Communication using a commonly understandable language is needed for promoting shared learning experiences that can improve social capital (Reed et al. 2013).

Access to financial resources is essential for maintaining the planning, absorption, recovery, and adaptation abilities of urban systems. Availability of sufficient financial resources enhances preparation efforts and can expedite the recovery process following a disaster. Maintaining financial reserves, establishing mutual aid agreements with neighboring communities and regions, establishing microfinance mechanisms in collaboration with vulnerable communities, insuring properties, issuing “catastrophe bonds” and “contingent credit contracts”, developing microinsurance plans, and establishing public-private partnerships can provide authorities with resources needed during the recovery process (Johannessen et al. 2014). Urban authorities should provide opportunities and incentives for involvement of the private sector. Unlike developed countries, share of private investment in urban infrastructure management in developing countries is limited. This needs to be changed to improve resilience of cities. Public-private partnerships provide learning and innovation opportunities for both sectors and can, therefore, be regarded as social learning practices that as mentioned earlier are critical for enhancing urban resilience (Johannessen et al. 2014). Nongovernmental Organizations (NGOs) and Nonprofit Organizations (NPOs) can play an effective role in the immediate aftermath of disasters, as proved following Hurricane Katrina. These groups will also facilitate better rebuilding in the later stages. Therefore, public-private partnerships that also engage NGOs and NPOs are considered essential for disaster preparation and provide communities with increased resources available to respond to disasters (Carpenter 2015). It should be mentioned that only relying on private sector can cause problems, especially in terms of providing services to low income and marginalized groups such as slum dwellers. Private sector tends to avert financial risks and this may lead to exclusion of marginalized communities that are often in a financially precarious situation (Johannessen et al. 2014). In some informal settlements, services are provided by “small-scale independent providers(SSIPs)” which are often informal entities. Urban authorities should develop strategies for formalizing such providers and integrating and engaging them in decision making processes (Johannessen et al. 2014).

In order to ensure proper application of the above-mentioned institutional measures, enhancing transparency and accountability of urban management activities is critical. Compliance with transparency standards enhances trust in authorities, encourages stakeholder participation, reduces the possibility of corruption, and ensures proper expenditure of municipal funds.

1.3.6 Social Networks and Social Support

Early human settlements were often spatially divided into neighborhoods that were characterized by the presence of strong social networks. These networks have functioned as sources of social and economic support during adverse situations (Sharifi and Murayama 2013). As urbanization intensifies and virtual communication networks gain increasing strength, concerns about the decline of social networks in cities become salient.

Social networks provide opportunities for having access to mutual support when needed. They enable individuals, households and communities to seek support (e.g. financial aid, resources, emotional support) from other groups at the time of disaster (Jabeen et al. 2010). These networks are also vital for information flow and for sharing experiences. Social networks are often established within and/or beyond neighborhoods and include groups with shared identities (e.g. faith-based, commercial, linguistic, etc.) (Jabeen et al. 2010). In addition to the above-mentioned benefits, these multi-scale networks can improve the self-organization capacity of communities (Wilkinson 2012a).

Bolstering social networks should be prioritized in planning for urban resilience. It is especially important to employ effective strategies for preserving functionality of social networks when preparing plans for urban renovation and gentrification in historic neighborhoods. Razing old neighborhoods and districts can destroy social relationships that have been in place for a long time (Wallace and Wallace 2011). Drawing on insights from the destruction of some New York neighborhoods (Harlem, South Bronx) in the late twentieth century, Wallace and Wallace (2011) argue that post-destruction policies that promote ethnic segregation undermine resilience of communities and their capacity to respond to negative social and health-related impacts. They argue that the massive destruction projects have resulted in homogeneous neighborhoods (white or black) with small social networks that do not interact properly to establish social ties. Diversity in terms of ethnicity, socio-economic status, and age can contribute to strengthening social networks (Wallace and Wallace 2011).

Sense of place is an integral component of urban resilience and is essential for formation, maintenance, and growth of social networks. Sense of place improves urban resilience and reinforces social networks by strengthening feelings of trust and reciprocity, providing incentives for collective action, and facilitating pooling of skills and resources in the community (McMillen et al. 2017). It also improves household's willingness to take preparation measures against potential future hazards (Prior and Eriksen 2013). Development and preservation of place attachment and sense of community should be prioritized in development of urban renovation and regeneration projects. Sharing knowledge and experiences and engagement in social learning and communal activities may be more difficult in communities with higher rates of turnover, as the process of creating social bonds and trust in neighbors may take time (Prior and Eriksen 2013).

Survey conducted in Australia (Hobart, Tasmania and Sydney) showed that sense of community and attachment to place improves social cohesion, knowledge and information sharing, and tendency to collective action which are important factors in enhancing community preparedness to wildfire hazards (Prior and Eriksen 2013). Social cohesion is essential for transferring response knowledge to community members. In cohesive societies, residents find their neighbors and community members reliable to provide them with support when needed (Prior and Eriksen 2013). Cohesive societies that feature collective action exhibit higher levels of coping capacity and are likely to better self-organize to address irregularities and uncertainties involved in disaster risk management. The propensity to get prepared to respond to disturbing events is also expected to be higher in socially cohesive communities (Prior and Eriksen 2013). Social cohesion enhances collective memory (i.e. lessons learned from previous experiences) which can facilitate a better response to future risks (Prior and Eriksen 2013). It can also be important for implementing adaptation strategies such as collective savings in the community and community-driven infrastructure management.

1.3.7 Dimensional, Spatial, and Temporal Interrelationships and Interlinkages

Conventional urban planning has achieved limited success in addressing interlinkages between different sectors and different socio-economic and environmental factors that shape cities and affect their performance. There is also a lack of understanding about the spatial and temporal dynamics of urban functions, processes, and changes.

Traditionally, plans for urban development have been prepared based on silo-based approaches and each city department has been responsible for preparing plans related to specific sectors (i.e. water, energy, housing, economy, etc.). This approach is not appropriate for understanding how different sectors are interconnected. Sustainability-oriented approaches have for long been in search of solutions to tackle this shortcoming. However, development and operationalization of such solutions has proved to be challenging. Since dealing with interconnections is inherent in resilience theory, resilience concept is useful for strengthening the shift from silo-based planning to understanding and taking account of interconnections (Sellberg et al. 2015). Integrating resilience thinking into urban planning provides opportunities for capturing the interactions between different sectors and understanding the nature and complexity of interlinkages between social, economic, and ecological factors. Achieving such integration is essential for better understanding the dynamics of urban systems and their potential future trajectories (Peyroux 2015).

A major attribute of social ecological resilience is that components of the system are interlinked and interconnected. Urban system is a social-ecological system and thus its underlying components exhibit multiple linkages across spatial and temporal scales (Wilkinson 2012a). Planning efforts for enhancing urban resilience should not be only restricted to the city boundaries. Several risks such as flashfloods have roots in upstream land use changes and human interventions in the environment (e.g. deforestation). Failure in upstream landscape planning can cause several socio-economic and health impacts and trigger secondary risks such as water-borne diseases downstream (in case of flooding events) (Johannessen et al. 2014). For instance, deforestation is believed to be one of the factors contributing to the 1988 flooding in Greater Dhaka. The flooding also impacted city's drinking water system and affected the lives of about 11 million inhabitants through water pollution and water borne diseases (Johannessen et al. 2014).

Resilience planning should also consider dynamics and feedbacks across temporal scale. Traditionally, planning efforts aimed at vulnerability assessment for disaster risk reduction have focused on providing a snapshot in time of the rapidly evolving state of cities. However, path dependencies are important and understanding the temporal continuum within which the dynamic processes and system transformations occur is indispensable (Sharifi 2016). Some simple strategies for incorporating temporal dynamism into resilience planning include longitudinal analyses to evaluate the degree of effectiveness of action plans and interventions in absorbing shocks and expediting recovery process and also using scenario-making and projection techniques for anticipating potential future changes and dynamics (Sharifi 2016).

Overall, different stakeholders across multiple scales influence dynamics of cities as social ecological systems and multi-level adaptive networks are needed to take account of interactions across temporal and geographic scales (Boyd and Juhola 2015).

1.3.8 Resilience-Oriented Land Use Planning

Land use planning should emphasize minimizing exposure to risk, facilitating timely response, and maximizing absorption capacity. To minimize risk exposure, land development should be prevented in certain locations such as ecologically sensitive and risk-prone areas (e.g. flood-prone or earthquake-prone areas). Controlling and regulating development in risk-prone areas is already well-recognized in the field of urban disaster risk management. To integrate resilience thinking into urban planning and urban disaster risk management, ecosystem protection should also be further strengthened. Urban planners should appropriately consider various services provided by the ecosystem and acknowledge that ecosystem planning and conservation can also provide buffers that can mitigate impacts of flooding, tsunami, and other disasters (Villagra et al. 2016). Specifically, urban development should not encroach on valuable ecosystems such as wetlands and greenfields and should not disrupt the natural drainage flows that are critical for flood mitigation. Protection of ecosystem services and avoidance of development in risk-prone areas may require relocation of some existing urban areas and infrastructures. However, as earlier mentioned, relocation should not negatively impact access of communities, living in those areas, to ecosystem services that are essential for their livelihood.

Density, mix of uses, connectivity, accessibility, permeability, and multi-functionality are some other basic attributes and criteria related to land use planning that influence resilience and vulnerability profiles of cities. These criteria have implications for evacuation planning, flood risk management, energy and water consumption, urban heat island effect, social justice, etc.

Choosing appropriate density thresholds has major implications for urban resilience. Increasing density up to a certain point can reduce per-capita energy consumption. It can also provide environmental benefits, as low-density development may result in the loss of valuable greenfield areas and the ecosystem services that they provide. Low-density development can also be associated with other issues such as increased commuting distances, diminished accessibility of emergency response teams and services, and increased vulnerability to natural disturbances such as wildfire. For instance, research shows that low housing density and leapfrog development (isolated development clusters) increase vulnerability to wildfire risks (as compared to infill development that increases overall housing density in inner urban areas) (Syphard et al. 2013). It should, however, be noted that high density may have adverse impacts on the response and absorption abilities of communities. Open spaces needed for evacuation and temporary sheltering may be more limited in high-density areas. High-density urban development can also increase flood risk by increasing impervious surfaces. Incorporation of green infrastructure into urban development plans will also be more challenging in high-density areas.

Green corridors are recognized as important elements for connecting people with nature and providing landscape connectivity. The latter facilitates movement of species (species traversing landscape patches) and provides ecosystem services to the urban dwellers. Urban ecosystem services can also be maintained through protection of natural habitats in the city. As mentioned above, ecosystem protection is vital for regulating temperature, mitigating extreme events such as flooding and heat waves, and protecting livelihoods of inhabitants. The connectivity criterion has also implications for street networks. Highly connected and porous urban areas facilitate better movement of people and vehicles. Street connectivity is essential for effective emergency response and safe and timely evacuation following disturbances. If coupled with well-designed pedestrian areas, street connectivity can also encourage walking which has substantial implications in terms of energy saving, mental and physical health, and social interactions. It is argued that walkable and mixed use neighborhoods provide more opportunities for strengthening social networks and enhancing social interactions among neighbors, thereby enhancing social capital and sense of attachment to the community (Carpenter 2015). In a study about resilience of communities along the Gulf Coast, it was found that intersection density has the highest effect on enhancing resilience. Other noteworthy factors include residential density, density of historic sites, and land use mix. It is argued that such urban form features can create opportunities for more social encounters and interactions and strengthen social networking among citizens which is believed to be critical for enhancing resilience (Carpenter 2015). As explained in Sect. 1.3.6, more social encounters and strengthened social networks can also contribute to building urban resilience by enhancing sense of community.

To integrate resilience thinking into urban planning, paying attention to multi-functionality of land use is critical. Diversity and redundancy attributes can be incorporated into the urban system by creating land use patterns that facilitate achieving multiple technological, social, economic, and ecological functions. For instance, open spaces and parks can be used for stormwater management and also provide other services such as evacuation space and playgrounds for children (Fratini et al. 2012). The multi-functional car parks in Rotterdam provide an underground space that includes water storage tanks or reservoirs and can be used for stormwater retention (to take some pressure off the drainage system), peak flow reduction, and temporary water storage if needed (Balsells et al. 2013). Such alternative systems can be used in case the excess water runoff exceeds the capacity of the drainage system (Balsells et al. 2013).

1.3.9 Resilient Urban Infrastructure

Critical infrastructures such as communication infrastructures, educational centers, energy and water systems, financial institutions, fire stations, health centers, and transportation networks are the backbones of modern cities. All these systems are susceptible to a diverse profile of risks, including the potential impacts of climate change. For instance, many centralized energy plants are located in low laying areas that will be affected by sea level rise; dry spells and droughts have negative impacts on the capacity of hydropower facilities; and extreme events such as hurricanes and typhoons can bring to a halt communication and transportation systems.

To achieve urban resilience, these principles and characteristics should be incorporated into infrastructure planning: robustness, diversity, redundancy, flexibility, efficiency, modularity, and innovation (creativity). Updating existing urban regulations, buildings codes, zoning codes, and design guidelines will be a first step towards incorporating these principles into infrastructure planning. Most urban infrastructures have a long lifetime. Compliance with these principles is critical to avoid lock in into inefficient and unsustainable development trajectories. Location of critical infrastructure is an important factor that has implications for the robustness criterion (Armenakis and Nirupama 2013). New infrastructures should not be built in risk-prone areas and should comply with strict building standards so that the urban system can maintain its stability under high-risk scenarios. Strategies should be developed for relocating existing buildings and properties from risk-prone areas. Existing buildings and infrastructures located in other areas should be retrofitted to meet the requirements of the most updated building codes and regulations. In addition, proper infrastructure maintenance is needed to ensure its functionality over time. Technical and financial knowledge at the local level is needed for maintaining operationality of critical infrastructure (Johannessen et al. 2014).

It should be noted that overreliance on enhancing resilience and reducing vulnerability through enhancing infrastructure robustness can create a false sense of safety. An example of such a sense of security was experienced when Hurricane Katrina hit New Orleans and there was overreliance on dams and levees built for flood risk management and coastal protection. Failure of such hard infrastructures caused unprecedented catastrophic losses in the area (Johannessen et al. 2014).

Traditionally, providers of urban services such as water, waste management, energy, and food have managed infrastructures in a centralized way. This tendency towards centralized systems is explained by the belief that management of centralized infrastructure is less complicated and more efficient (Sharifi et al. 2017). However, there is a growing recognition that decentralized infrastructure is more resilient and provides benefits in terms of diversity, redundancy, and modularity.

Decentralization of infrastructures makes it possible to utilize a diverse array of resources. For instance, various technologies such as nuclear, coal, natural gas, hydroelectric, biomass, solar photovoltaics, and wind can be used for electricity generation. Redundant infrastructure systems are needed for achieving such a diversity. This may affect the efficiency of the system, but is essential for distributing risk, improving modularity of the system, and minimizing its vulnerability to disruptions in the supply chain (Sharifi et al. 2017).

Decentralization of infrastructure is also considered an essential strategy for minimizing the knock-on effects that may spread throughout the system due to the fact that different sub-systems of the urban system are interconnected and disruption in one system can trigger disruptions in the others (Sharifi and Yamagata 2016). Decentralization of infrastructure should be considered as an opportunity for incorporating clean and renewable technologies into the urban system (e.g. developing micro-grids that are fed by solar panels and mico-turbines) (Sharifi and Yamagata 2016). Such a system needs to be co-designed and co-managed by different community stakeholders. Participation in such co-design and co-management efforts provides opportunities for creating social bonds in the community and can result in improvements in terms of social cohesion. It can also be considered as a social learning exercise that may result in societal transformation. For instance, decentralized water, food, and energy systems are important for enhancing citizen understanding of the resource cycle and origin of the resources. Decentralization of these systems may, therefore, have a positive influence on their consumption behavior (Rauland and Newman 2011).

Benefits of decentralization can be maximized by incorporating blue and green infrastructures into the urban system. Over the past few decades, a large body of literature has been published on a diverse group of green and blue infrastructures that can enhance resilience of cities against disturbing events such as flooding, drought, and heat wave (van de Ven et al. 2016). There are also tools such as "Climate Adaptation App (www.climateapp.org)" that can be used by various stakeholders to guide them on how to incorporate climate sensitive and resilient strategies into urban planning and design. In the reminder of this section, only a brief explanation of blue and green infrastructures is provided.

Green and blue infrastructures are essential for regulating urban microclimate, reducing heat island effect, and mitigating flood risk. A wide variety of green infrastructure technologies, such as green roofs, bioswales, rainwater harvesting systems, and permeable pavements can be incorporated into urban development. For instance, a combination of underground (e.g. drainage canals) and above ground (e.g. permeable surfaces) techniques should be used for flood risk management (Fratini et al. 2012). Current drainage systems have been designed to accommodate certain amounts of waste water and rainwater discharge and surcharge. These systems are designed based on the requirements of specific flooding return periods. Resilience-based planning should enhance capacity of drainage systems to meet the needs of large flood volumes with (potentially) large return periods. It should also incorporate sustainable urban drainage systems (SUDSs) and water sensitive urban design measures to enhance adaptive capacity of cities to mitigate flooding (Fratini et al. 2012). Water sensitive urban design principles and strategies such as permeable pavements (instead of sealed surfaces that increase the severity of flash flooding and reduce groundwater recharge rate), green roofs (for peak flow reduction through water retention), retention ponds, bioswales, etc., should be applied in order to get prepared for the potential impacts of changing rainfall patterns that will overwhelm the capacity of existing drainage systems. These strategies should be coupled with other actions such as solid waste management. Effective management of solid waste is necessary to avoid clogging of the drainage system in the event of extreme flooding events. Such clogging can further intensify floods and also trigger health-related risks (such as the spread of water-borne diseases) (Brown et al. 2012).

It should be noted that there are also other types of infrastructures (e.g. transportation and communication) that have not been discussed here, but need to be considered in resilience-oriented infrastructure planning.

1.4 Conclusions

Urban planning and design theories, discourses, policies, and processes are increasingly framed using the resilience concept. This signifies the increasing recognition that, unless cities build their resilience, a broad host of risks and threats including, but not limited to, extreme weather events, sea-level rise, droughts, wildfires, economic crises, and pressure on natural resources can disrupt the functionality of urban systems.

To help cities build their resilience, it is essential to integrate resilience thinking into urban planning and design. This chapter provides some fundamental discussions on how such integration could be achieved. Inspired by the theory of adaptive cycle it is argued that urban planning should not be considered as a static process. Urban systems are dynamic entities characterized by non-equilibrium dynamics and constantly go through the four phases of ‘exploitation’, ‘conservation’, ‘release’, and ‘reorganization’.

It is argued that resilience thinking gives planning new perspectives that enable it to frame and address complexities and uncertainties inherent in the understanding and analysis of urban systems. Change, dynamism, uncertainty, adaptability and self-organization are at the core of resilience planning. This is in clear contrast with the traditional interpretation of planning as an effort to mainly resist disturbance and build ‘fail-safe’ cities. Integrating resilience thinking into urban planning theory and practice is necessary for taking account of uncertainties and complexities-scale and scope of which can be increased due to climate change- inherent in urban systems (Albers and Deppisch 2013). Resilience-based planning should acknowledge the dynamics of urban system, step away from static blueprint planning, and shift towards adaptive planning that involves regular and iterative processes of monitoring, assessment, and scenario making. It is also emphasized that a paradigm shift from ‘command and control’ approaches towards recognition of bottom-up approaches and social learning practices is essential for achieving resilience-based planning.

The chapter provides specific discussions on how to utilize resilience thinking for transforming planning culture and methodology in the following thematic areas: planning strategy and vision; public participation and capacity building; equity and empowerment of poor and marginalized communities; traditional local knowledge; institutional reforms; social networks and social support; dimensional, spatial, and temporal interrelationships and interlinkages; land use planning; and urban infrastructure. A summary of these discussions is provided in Table 1.1. It is hoped that such transformations not only improve efficiency of urban systems and reduce vulnerability, but also provide opportunities for innovation and contribute to achieving sustainable urban development.

The paper argues that key attributes and principles such as robustness, stability, diversity, redundancy, flexibility, resourcefulness, coordination capacity, modularity, collaboration, agility, efficiency, creativity, equity, foresight capacity, self-organization, and adaptability underpin the concept of resilience. Throughout the chapter, it has been discussed how planning interventions aimed at integrating resilience thinking into planning contribute to promoting these principles. Table 1.2 illustrates potential contributions of different planning themes to meeting the resilience principles. It should be emphasized that this does not intend to be an exhaustive illustration and further research is needed to be able to provide a more detailed and precise account of potential contributions of different planning actions.

It should be mentioned that not all principles can be easily applied to urban planning in every city. For instance, as cities around the world increasingly become more interconnected and interdependent through the flow of information, energy,

Table 1.1 A summary of the main features of conventional and resilience-oriented approaches to planning

Planning theme	Conventional	Resilience-oriented
Disaster risk management	- Focus on short- and medium-term emergency planning and mitigation efforts - Target fast variables, and chaotic and abrupt changes - Static vulnerability assessment	- Medium- to long-term approach - Suitable to address both abrupt and slow and steady changes - Recognize the importance of dynamics and complexities and evaluating transformations across temporal and spatial scales - Capacity to respond to constantly changing risks and to expand the response margins and capacities of the system
Planning vision and strategy	- Blueprint planning (linear and static) - Engineering approaches that emphasize eliminating risk - Equilibrium approach to disaster recovery - Predict and prevent approach	- Adaptive planning (regular and iterative processes of monitoring and scenario making) - Acknowledge the unpredictability of future conditions and difficulties in completely preventing risks - Non-equilibrium perspectives to system functionality and disaster recovery
Public participation and capacity building	- Environmental determinism - Limited public participation - Local authorities are responsible for providing services (command and control)	- People-oriented design (putting people at the center of planning efforts) - Co-design, co-production, and co-implementation - Importance of communal actions and self-organization (capacity building)
Building equity and empowering poor and marginalized communities	- Failure in upgrading conditions of low-income urban areas - Emergence and spread of wealthy enclaves in cities - Loose control over development in risk-prone areas - Limited insurance of properties in poor neighborhoods	- Integrate social justice into resilience planning efforts - Reduce urban inequalities (e.g. through affordable housing policies) - Regulate development on risk-prone areas - Ensure that relocation does not affect livelihood prospects of communities - Empower and enhance the sense of ownership - Utilize innovative municipal insurance plans (e.g. collective insurance and saving schemes)

(continued)

Table 1.1 (continued)

Planning theme	Conventional	Resilience-oriented
Learning from traditional local knowledge	- Overreliance on modern planning and design strategies - Spread of standardized building techniques	- Due attention to traditional coping capacities - Awareness of vernacular architecture and local building technologies
Institutional reforms	- Sector-based planning - Communication using a highly technical language - Top-down planning - Limited share of private investment in urban infrastructure management (esp. in developing counties)	- Interactions between sectors (interconnected and interdependencies) - Decentralized planning - Promotion of the culture of collaboration - Incremental and learning by doing approaches - Recognize the significance of behavioral changes - Transparent decision making process - Communication using a commonly understandable language - Strong public-private partnerships
Social networks and social support	- Renovation and gentrification policies affect functionality of social networks	- Community-based social networks are bolstered - Enhance place attachment and sense of community
Sectoral, spatial, and temporal interlinkages	- Failure to address interlinkages between different sectors and dimensions - Silo-based - Lack of understanding of spatial and temporal dynamics	-Not carried out in silos - Efforts to understand interconnections between different sectors - Emphasis on understanding spatial and temporal dynamics
Resilience-oriented land use planning	- Limited success in protecting ecologically-sensitive areas - Functional zoning	- Ecosystem protection - Mixed use development - Due attention to other attributes such as density, connectivity, accessibility, permeability, and multi-functionality
Resilient urban infrastructure	- Overreliance on robustness - Large, centralized infrastructure	- Recognition of other attributes such as diversity, redundancy, flexibility, efficiency, modularity, and innovation - Small-scale, decentralized infrastructure

Table 1.2 Contribution of the selected planning strategies to meeting resilience principles

	Robustness	Stability	Diversity	Redundancy	Flexibility	Resourcefulness	Coordination capacity	Modularity	Collaboration	Agility	Efficiency	Creativity	Equity	Foresight capacity	Self-organization	Adaptability
Planning vision and strategy	■	■			■			■		■	■	■		■		■
Public participation and capacity building			■			■		■	■						■	■
Building equity and empowering poor and marginalized communities		■	■										■			■
Learning from traditional local knowledge						■		■			■				■	■
Institutional reforms			■			■	■		■		■		■	■		■
Social networks and social support		■				■			■	■					■	■
Sectoral, spatial, and temporal interlinkages							■		■					■		
Resilience-oriented land use planning			■	■	■					■	■		■			■
Resilient urban infrastructure	■		■	■	■	■		■	■		■	■	■		■	■

and matter, the relevance and applicability of the modularity principle becomes more restricted (Albers and Deppisch 2013). However, some principles such as diversity are more applicable and have already been integrated into plans of many cities (Albers and Deppisch 2013). Further context-specific research is needed on the relevance, applicability, and priority of different resilience principles.

Overall, this chapter emphasizes that major paradigm shifts in conventional planning approaches are needed for integrating resilience thinking into urban planning and design. Further work needs to be done to provide more details about each planning theme that was discussed in this study (Sect. 1.3). Furthermore, it is essential to examine other planning themes and discuss how they should be evolved and transformed based on the principles of resilience thinking. Finally, challenges and constraints in integrating resilience thinking into urban planning and design should also be investigated.

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Chapter 2
Resilience Matrix for Comprehensive Urban Resilience Planning

Cate Fox-Lent and Igor Linkov

2.1 Introduction

The US Army Corps of Engineers (USACE) has a long standing mission and tradition of protecting people and property from flood damage for the safety and commercial success of the nation. Although this work began as protection from riverine flooding, it has grown to encompass coastal flooding from both tide and storm surge. Throughout the 18th and 19th centuries, local landowners built levees and dams to hold back flood waters and protect their own investments, but after several destructive floods and intermediate legislation, the Flood Control Act of 1936 (Arnold 1988) made it clear that national flood protection would be a responsibility of the federal government. For several decades the USACE sought to control floods through large-scale structures and centralized governance; though, eventually, the government recognized that these engineering approaches alone had a limitations and that the cost of constructing and maintaining massive projects was enormous. Thus the USACE ushered in an era of decision making based on a combination of probabilistic risk analysis and benefit-cost analysis (Moser 2011). Risk was defined as the "likelihood of occurrence and the magnitude of the consequences of an adverse event", effectively the equation: risk = probability × consequence (Moser 2011). In adopting this practice, the USACE and other federal agencies could now set a risk standard. If it is impossible—physically or financially—to prevent every possible flood threat, what level of risk is acceptable? The Federal Emergency Management Agency (FEMA) has used the 100-year flood as the "base flood", implying that lower probability events are beyond

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the government's responsibility to manage. The events that fall below this threshold are "residual risk." Federal risk management focuses on reducing or mitigating the unacceptable risk and but leaves residual risk largely overlooked. The existence of residual risk is also often poorly communicated to local communities. However recent low-probability high-consequence events—Hurricanes Katrina and Sandy in 2005 and 2012, the South Asian floods of 2007, the Sumatran earthquake of 2004, the Fukushima-Daiichi disaster in 2016—have forced a re-evaluation of this approach to risk management.

2.2 Challenges of Traditional Risk Analysis

In contemporary times we face several major challenges with respect to risk analysis and management for flooding and coastal storm events. The modern risk analysis process—as it is rigidly based in the calculation of hazard × vulnerability × consequence (HVC)—has several limitations. One, the current methodology is threat-specific; it does not include assessment measures for general capacity to respond to unexpected threats or integrated threat scenarios. Two, the risk analysis HVC calculation requires quantification of each of those three components. In an era of climate change and globalization, the data does not always exist to adequately describe the potential precipitation and storm conditions or the potential consequences. Three, the HVC calculation has no temporal component, no flexible way to account for how consequences migrate or compound over time if the recovery period is prolonged. Fourth, the methodology does not include any aspect of human behavior for the population that lives in the affected area. While some general demographics may be included in the calculation of vulnerability and consequence (how many potential lives are at risk), there is no understanding of the risk perception held by a community and their willingness or economic ability to put up temporary protections, to evacuate when notified, or to repair any damage. Thus, while the HVC calculation can and does reliably yield a risk value, it can also lead to a false sense of certainty, when in fact the extent to which the computed value reflects today's reality is increasingly questionable.

The risk management practices that result from risk analysis are equally challenged by these deficiencies. First, the process of risk management is enormously expensive for integrated complex systems. As we have already invested in many of the easy and affordable risk reduction measures, attempting to further reduce the risk of localized consequences is increasingly cost-prohibitive in light of the fact that humans, technology, basic utilities, and economic markets are so interconnected. Furthermore, as infrastructural changes are accomplished, the only remaining measures for risk management are more and more through organizational and behavioral changes, which carry long time horizons to complete and often face extensive resistance. Second, while the nature of some known threats are changing, such as coastal storm surge given sea level rise, there are also emerging threats, such as increased heating days and potential failures of technology (through intentional attack or delayed maintenance) that can compound more traditional threats. Third, risk management is focused on capital investment-based threat reduction and mitigation however, many governments or NGOs find that collecting and expending large amount of money to develop preventative measures against what are described as only "potential" events is politically or socially unpopular.

2.3 Resilience: A New Way Forward

Figure 2.1 describes the function of a generic system over time. The initial horizontal line describes business as usual. At the point that a disruptive event occurs, the system function rapidly decreases, and then once the threat has passed, the recovery phase begins. The level of functionality that is recovered depends on several factors; limited resources may prevent the system from full regaining its initial functionality, or conversely, ample resources and wise application of lessons learned may enable a greater level of functionality. Effective system management should aim to flatten out this entire curve, eliminating the disturbance basin, which would effectively indicate that performance holds constant despite an event. Risk analysis does not lend itself to this management goal because it really only describes the potential for initial loss, or maximum Δy. Risk analysis does not consider the sufficiency of the initial functionality (y_0) to provide for the community, or any component of time (Δx) including the shape of the recovery curve, or the final steady state achieved in anticipation of the next event (y_f).

In recognition of the shortcomings of risk analysis, the US National Academy of Sciences declared in "Disaster resilience: A national imperative" (Cutter et al. 2013) that a new paradigm is needed, and that this approach, resilience, is "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." Former President Obama echoed this need for considering a system's

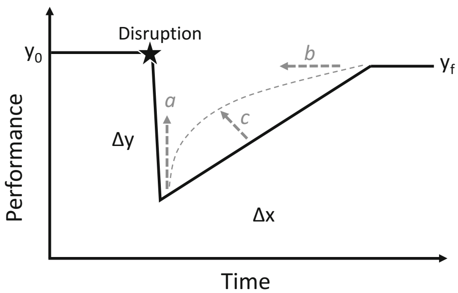

Fig. 2.1 System performance over the event cycle. Following a disruption, the initial performance (y_0) undergoes some change (Δy) but then recovers to a new steady state (y_f) of performance. The time period of recovery following the disruption (Δx) is a critical component of resilience. Resilience can be improved by reducing the magnitude of the disruption (**a**), reducing the time period of recovery (**b**) or changing the shape of the recovery curve (**c**)

entire functioning in a Policy Directive, stating that "'resilience' means the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recovery rapidly from disruptions" (The White House 2013). The European Commission followed by adopting a definition that says "resilience is the ability of an individual, a community or a country to cope, adapt and quickly recover from stress and shocks caused by a disaster, violence or conflict" (European Commission 2016). The emergence of these descriptions clearly indicate that traditional risk assessment must be augmented because it is not expansive enough to address the needs of modern societies for resilience (Linkov et al. 2014). Risk analysis only describes passive vulnerability of, or effects on, a system. The above definitions of resilience require understanding of a system's capacity to perform throughout a disruptive event: anticipate, prepare, plan, absorb, withstand, cope, respond, recover, adapt. Although many of the resilience assessments that have emerged in recent years cite these definitions, they unfortunately fail to explicitly address the temporal component of the event cycle (Bakkensen et al. 2016) into the methodology, instead opting for methods that closely resemble enhanced risk or vulnerability assessment. Indeed, the several past decades of risk management have worked only to reduce and mitigate the risk, shown as arrow (*a*) in Fig. 2.1, and risk management is an important component of resilience. However, the remaining opportunities to contribute to resilience through risk-based mechanism are often technically challenging and costly. As we see, the aspects of resilience that have not been adequately addressed by previous work are through reduction in the overall recovery time (*b*) and/or change in the shape of the recovery curve (*c*) to re-establish higher performance at an earlier point after the threat has passed.

2.4 Development of the Resilience Matrix

In developing the resilience matrix (Fig. 2.2), Linkov et al. sought a way to explicitly capture the capacity of a system across the timeline of a disruptive event. In doing so, they drew on the doctrine of network-centric operations developed by

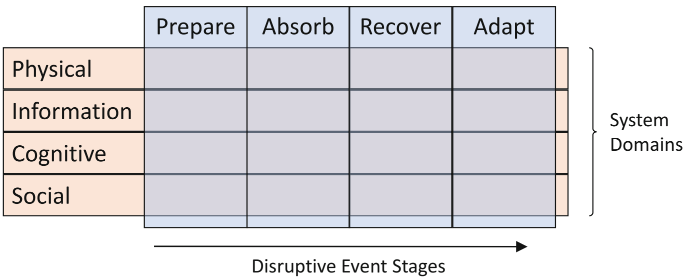

Fig. 2.2 Overview of matrix construction with the event cycle in the horizontal direction and system domains listed vertically

the US military's Command and Control Research Program (Alberts and Hayes 2003). This doctrine describes how a highly networked system is governed by domains that organize system components into measurable aspects. Organizing a system into these domains helps determine what the essential components of a system are and how they interact among themselves. The four domains are:

The **Physical domain** includes performance of the physical aspects of a system in space and time, dominated by the system infrastructure and equipment.

The **Information domain** includes the creation or collection, analysis, and dissemination of information. This can include sensor information about the health of the physical domain, demographic or behavioral information about the social domain, and methods for both gathering and sharing data in real time.

The **Cognitive domain** includes the organizational and institutional components of the system, specifically as they relate to decision making: who is empowered to make decisions and on what information are they basing decisions. This domain includes assessment of the degree to which plans and strategies exist, have been communicated and accepted throughout the organization, and if practice exercises have taken place to test and refine the plans.

The **Social domain** includes the human dimension of the system, especially those individuals not connected to the management and governance of the system. This includes individual citizens' and community groups' interaction, collaboration, and self-synchronization (Alberts and Hayes 2003).

A matrix emerges to facilitate a process for considering how each of the four system domains performs during each of the four stages of an event—prepare, absorb, recover, adapt—based on the National Academy of Sciences' definition of resilience.

The resulting matrix consist of 16 cells, each of which can be populated with metrics or other evaluations of performance. Most resilience assessments justify the inclusion of the various components of their assessments but few attempt to confirm that all of the relevant components have been captured. The 16 cells of the matrix capture how the system in question performs in the four general domains over 4 broad time steps of an event cycle. Collectively they describe the full system over time. By addressing each cell, users can be assured that they have not overlooked any major aspect of the system and that they have assessed the potential for an event to impact areas of the system that have not previously experienced problems. The process of utilizing the matrix to implement a resilience assessment and the ways in which each cell can be populated are described in the next sections of this chapter but some initial examples (Linkov et al. 2013) are:

- For a natural disaster, the capacity of the social domain to recover may largely depend on the financial resources of the community, diversity in the economy, and sense of place among residents.
- The cognitive-adapt cell can be used to capture how readily the existing regulatory and governance systems allow for the adjustment of current processes (such as building codes, critical services funding mechanisms, etc.) to accommodate the changing nature of the system and potential threats.

- In information-prepare cell, users can assess not only how well they can detect emerging threats and the state of knowledge that allows us to predict the timing, location, and severity, but also how well leaders understand the preparedness of the community and willingness to participate in mitigation activities.

The use of the matrix is based on a few key concepts of resilience. (1) Resilience is a property of a system, not a property of a component. For example, in this conceptualization, there is no meaning to a "resilient dam", as the purpose of the dam is not to exist in perpetuity as a structure. Instead, the dam provides a service to the community such as flood protection, electricity generation, or maintaining water supply. What should be considered is the way in which the dam contributes to the resilience of the community system. (2) The focus of resilience is on maintaining functionality. Whereas risk assessment attempts to calculate the potential for losses and then prevent or mitigate those specific losses, the mindset driving resilience should be thought for what the critical requirements of the community are and how can those be maintained. This will be an important frame for generating resilience improvement plans. (3) As indicated in the definition of resilience previously cited, there must be an assessment of performance over an event timeline, and as such, (4) it will require collaboration across local, state, and federal partners, many of which are currently siloed into groups such as public works, emergency management, housing and economic development, and environmental protection. Lastly, (5) there must be elicitation and consideration of the values and preferences of the citizens and stakeholders. In a disaster, there will necessarily be trade-offs in performance between one area of the system and another. For example, roadways could be cleared more rapidly by pumping standing water and debris into nearby water bodies but this will reduce the water quality, affecting local habitats or environments that might be economically important (fisheries, tourism activities) or antithetical to local values. It is critical to engage stakeholders to understand their perspectives and generate acceptable solutions for improvement.

The goal of the resilience matrix is to provide a guiding framework to initiate conversation and engagement about resilience and to identify critical areas of poor performance for further investigation. As will be seen in the next section, the first steps are to define the system and the threat of concern, but independent of any assessment, the matrix can be used simply to identify and organize the relevant stakeholders and entities that have responsibility, authority, or capacity to perform in each of the cells. For an example, in Fig. 2.3 we examine a school seeking to assess its resilience to a tornado, an event that occurs with an annual season in the south-central plains of the United States.

In the physical domain, an engineer and the maintenance department are necessary to understand the current condition of the facilities and the potential performance during a tornado while the city department of transportation and/or publics works will need to be involved to understand the process of how roadway or pipeline damage will be repaired to restore access and service to the school building. The principal, superintendent and school board should be present to develop a common understanding of who is responsible for making the decision to

	Prepare	Absorb	Recover	Adapt
Physical	**Building Manager** Engineer	**Building Manager**	**Building Manager**	**Building Manager**
Information	Local Weather Forecast	Superintendent	School Board	Superintendent
Cognitive	**Principal**	**Principal**	School Board	School Board
Social	Teachers Students	Teachers Students	**Parents** Students School Board	Teachers **Parents**

Fig. 2.3 Resilience matrix populated with entities involved in each sector of a school anticipating a tornado event

initiate emergency procedures, based on what information, and how they will be implemented. In a tornado, it is generally best practice to shelter in place, therefore it will be critical to have teachers and students provide input on the current level of understanding and preparedness and the way in which directives are likely to be carried out in an emergency situation. In the past decade, the growing ownership of cell phones by students means that they can, and do, receive outside information, often before the school might have reached a decision point. Some students will individually choose to leave the classroom, causing disorder and reorganization of priorities for action among school officials. The school board will also have an understanding of what conditions any recovery plan must have to ensure that the education provided meets minimum standards. Representatives of parents and students should be able to indicate under what conditions and timeline they might choose to permanently move to another school. This will also be important to provide the district with information about the potential economic consequences since taxes on local homeowners provide the funds for the school budget. In sum, while the principal is usually the first to be identified as the leader of a school, there is a much broader net of stakeholders and experts involved in the system.

The matrix challenges the way the Corps of Engineers and the US federal government often approach problems and projects. While there is a general understanding that most community issues are interdisciplinary, a risk-based approach allows each agency to work on risk reduction within its mission and authority. For example, to prepare for a flood event, it could be that local leaders will work on educating residents and filling sandbags, states and counties will work on emergency shelters and supplies, and federal agencies, such as the Corps of Engineers, or the Federal Highway Administration will work on large infrastructure protection for their respective assets. The activities can be carried out largely independently; however, the recovery process necessitates much more interaction and communication. The emphasis of resilience on the effectiveness of the recovery and adaptation stages will require new organizational strategies.

2.5 Using the Resilience Matrix

The resilience matrix can also guide community leaders through a screening-level resilience assessment in a six-step process (Fox-Lent et al. 2015), as outlined below:

Step 1 Define the system. As demonstrated in the example above, a system may initially seem easily definable by its physical borders (e.g. a school building), but the integration of physical environment with other infrastructure and the humans who inhabit it, along with the various formal and informal decision making processes at play can rapidly expand the system boundaries. It is imperative that the user clearly select and define what will and will not be considered part of the assessment.

Step 2 Define the threat. Many approaches to resilience assessment attempt to offer an "all-hazards" approach. However, it is frequently clear by the metrics selected that the developer has used some internal set of threats to drive the development of the tool. For example, the methods that assess efficiency of emergency evacuation routes are not considering events like a tornado, where practice is to remain in place or terrorist attacks that occur without warning. In contrast, the method here simply asks users to define the threat, or suite of threats, under consideration to provide direction in the assessment and improve transparency of results.

Step 3 Identify critical functions. In this step, the resilience assessment process begins to differ from a risk analysis process. All systems perform functions, and while ranking them can be difficult, organizing them into tiers is often less challenging. Tier 1 functions are often those services directly related to securing life safety for inhabitants and can include shelter, fresh water, food, sometimes medical services, and sometimes electricity. These are the critical functions and are frequently necessary to ensure that Tier 2 functions can be re-established. Tier 2 functions are those that can acceptably experience decreased functionality during a disruption, but are important to return quickly in order to aid in recovery. While electricity and access to fresh water are only Tier 2 functions during the short duration of a tornado, their necessity to provide cooling during a heat wave make them Tier 1 functions for that scenario. Transportation may be a Tier 1 function during a forest fire to allow evacuation as the fire moves, but may be a Tier 2 function for a hurricane as it is not advised to travel during the hurricane, but many people many need to get to medical services afterwards. Education is mostly like a Tier 3 function for a community at large, but the school building itself may provide Tier 1 functions of shelter and a temporary medical triage site. While the environment or local ecosystem is rarely a Tier 1 function for most users, it can be an important Tier 2 function if the local economy is dependent upon environmental tourism (tourism, water sports, fishing) or is residents rely on the ecosystem for livelihood (organic agriculture, aquaculture, well water). A separate matrix will be completed for each critical function. To pare critical functions down to a manageable number for assessment, the list may be tailored based on the end purpose of the assessment. While it may be good to understand how well the electrical grids perform, these are largely managed by independent agencies therefore community leaders or state leaders will not be directly involved in making future investment decisions.

Step 4 Select performance indicators. The goal in this step is to select one or two measures that generally indicate the ability of the system to perform in each domain-phase (matrix cell). The goal is not to try to incorporate measures of every single process that occurs "on the ground". As a screening-level tool, the interest is in describing relative behavior amongst the cells to generate an overall picture of the system.

Previous work in the resilience field has led to the identification of several properties associated with resilience, among which are redundancy, flexibility, modularity, robustness, resourcefulness, rapidity, reliability, diversity, and adaptive capacity (Bruneau 2006; Norris et al. 2008; Renschler 2010). These principles can be used to generate performance indicators to populate each cells of the matrix. In general, the prepare phase will consider aspects of robustness within the system; similarly, the recovery phase will likely focus on rapidity or the timeliness of performance. However, there is no one-size-fits-all answer for pairing properties with components of a system. Some threats may warrant distributed and modular resources but centralized decision making while other system configurations may perform ideally with distributed decision making but centralized resource warehousing.

Some examples of indicators (Eisenberg et al. 2014) are:

- Information-Recover for bridge structure: Time required to gather—via visual inspection or sensor technology—necessary data to assess the extent of damage and develop a plan for appropriate repairs.
- Social-Prepare for an ecosystem: Measures of the initial species diversity, habitat, and diet.
- Physical-Adapt for a cybernetwork: Capacity of existing equipment to handle system-wide configuration changes, or, perhaps, given the business requirements, the fraction of hardware that can be physically separated from the global internet.

This step also allows the integration of "big data" to provide very specific metrics of performance over time. Yet as one point of caution, it is tempting to aim to incorporate all available data into the assessment despite some of it not being appropriate. Unfortunately it can often be the case that multiple measures in the data capture the same phenomenon or process. Forcing everything into the assessment can, at a minimum, be time consuming but more problematically can lead to over-weighting specific processes within the assessment (although the cellular structure of the matrix will minimize that effect).

Early on, the most useful data may not be available. In this case, the process of completing the matrix will help the user identify the need for any new data collection efforts. In the meantime, the framework allows for the incorporation of qualitative data. This can take the form of an expert assessment such as an engineer's "best professional judgement" or rubric used to select performance from a ranking scale such as "poor" to "excellent." To add rigor to qualitative measures, it can be useful to have several authorities with relevant experience make these judgements independently in order to gauge the variability or level of confidence in the result. In particular, it can be difficult to find indicators for the cognitive domain. More than likely, no objective measure for the quality of cognitive performance exists and a simple 'yes' or 'no' evaluation is not particularly useful. One option is to develop a checklist of increasing sophistication in the planning and decision process and use a count of the number of checkmarks as the indicators. For example, checklist items could include: does a plan exist? Were stakeholders involved in the development? Is the plan documented? Has the plan been disseminated to partners? Has there been a table-top exercise to practice and test the plan? Has there been a large-scale exercise in collaboration with other relevant agencies or groups? Is there a process to regularly revisit and revise the plan? This is similar to approaches used for assessment in the field of emergency management. Other examples of indicators, both qualitative and quantitative, are discussed in the latter case study sections.

Step 5 Calculate Scores. In this step, the indicators of performance are transformed into performance scores using established decision-analytic techniques (Linkov and Moberg 2011). This process establishes how the previously identified measurement falls within the context of locally acceptable performance. In most cases, a linear value function will be appropriate: the user defines two end points of unacceptable performance and ideal performance. The lower end point is set to 0 and the upper end point to 10 so that linear interpolation can be used to calculate the normalized value of the selected indicator. This is the most important step during which to engage with stakeholders, as setting the bounds establishes what the community considers to be good or poor performance and will drive priorities for new investments. For example, a metric for the social-prepare cell may be the percent of people who have participated in a community preparedness training. The worst possible end point would be 0% but while the best possible endpoint could be 100%, organizers may recognize that it is not achievable or cost-effective. Instead, it may be determined that 80% is an ideal target, under the assumption that the majority of citizens will then live in a household with someone who has taken the training and can share the knowledge. Continuing with this example, if 0% equals a score of zero and 80% equals a score of 10, and the actual measure is that 28% of community members are currently trained, then the cell receives a score of 3.5. Other value functions could be used; for instance, it may be justifiable to use an exponential curve for a value function if the measure selected clearly generates greater marginal benefit from each additional unit of improvement. Though, for a screening level tool, a linear value function is often adequate.

Step 6 Identify gaps and prioritize efforts. The final step is to examine and interpret the matrix results. At this point, the user will have generated a matrix for each critical function, each of which contains 16 scores. There is no single resilience score. Instead, these matrices collectively describe the performance of the system. In a first pass evaluation, the lowest scoring cells should be noted in order to highlight areas of overall lower performance. Since the four time stages comprise a cycle, and the four domains are integrally interconnected, resilience arises from strong performance across the system. This effort will be demonstrated in first case study. In a second pass, the matrix can then be used to evaluate and prioritize any proposed action plans by determining which cells of which critical functions should be targeted by the plans. Often, plans evolve to favor the most vocal representatives, the most visually apparent improvements, or the cheapest opportunities but these actions will have limited benefit if they do not address the lowest scoring cells. This process will be demonstrated in the second case study.

2.5.1 Case Study 1: The Rockaways, NY

In April 2014 an initial case study was undertaken by the USACE Risk and Decision Science team to test the application of the matrix. Hurricane Sandy made landfall in New Jersey as a post-tropical cyclone on October 29th 2012, generating a storm surge of 2.4–2.7 m along the southern coast of New York (Blake et al. 2013). The Rockaway Peninsula is a strip of land that extends between Jamaica Bay to the North and Atlantic Ocean to the South (Fig. 2.4). The Rockaway communities experienced the greatest effects of the storm in this region and in the post-storm activities several reports were published that provided data and community perspectives on the event. These reports were leveraged by Fox-Lent et al. (2015) to perform a retrospective pilot of the resilience matrix framework.

The system boundary was selected as the Rockaway Peninsula and the threat considered was a hurricane/tropical storm with significant storm surge. The area is largely residential and so for the pilot, a single critical function was selected (housing/shelter). The authors relied on several interviews with local community leaders, city after-action reports, and reconstruction plans to identify indicators. Indicators included “percent threatened population that report likely to evacuate before storm” for social-absorb, “time required to reconstruct beaches with dunes” for physical-recover, and “years for the Corps of Engineers to perform feasibility study, design, appropriate funds, and construct new flood risk reduction plan” for cognitive-adapt. As described in the previous section, the goal is to obtain an

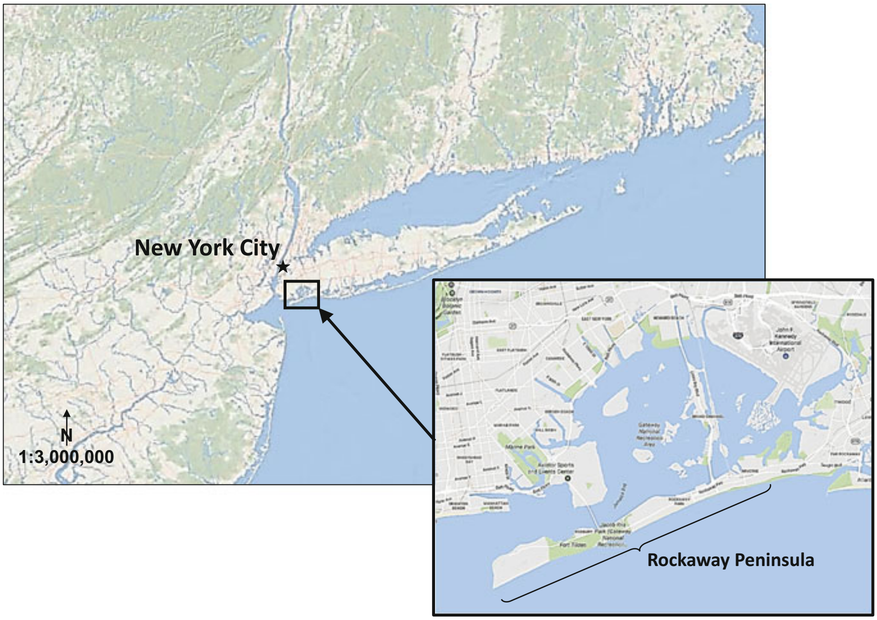

Fig. 2.4 Location of the Rockaway peninsula, New York City, United States. Map data: ESRI, Google

overview of the system by selecting indicators, not exact metrics or performance for each cell. Consequently, the matrix, shown in Fig. 2.5, summarizes the results using a relative color scale so as not to mislead users about the precision of the screening tool, but instead allow the identification of important trends.

The previous decades of effort at risk reduction and emergency management have led to stronger (or stronger perception of) performance in the prepare and absorb stages, while there is relatively weaker performance in recovery and even less for adaptation. The social domain appears to have adequate performance, perhaps in part due to the insular nature of these communities residing on a strip of land surrounded by water and with limited transportation connections. Although the indicator selected for the information-absorb cell shows weak performance, the

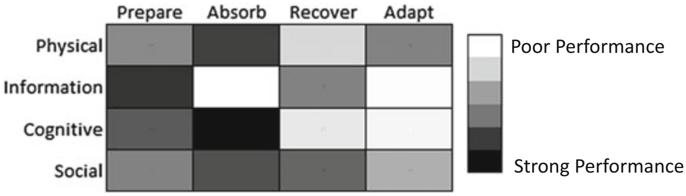

Fig. 2.5 Matrix results for the Housing/Shelter critical function at Rockaway. Adapted from Fox-Lent et al. 2015

cognitive and social domains exhibit strong performance during this stage. This may be a testament to the degree to which the preparation activities can support good performance even in the absence of good real-time information, or it may indicate the need to further investigate what non-traditional information pathways are being utilized. One goal of the matrix as a guiding framework is to organize data collection and facilitate communication. The act of performing the assessment can be an important learning process independent of any results. For example, in the execution of the above steps, the authors uncovered jurisdictional information that governs decision making in the study area. For example, the western end of the Rockaway peninsula hosts a private community, which means that they have sole responsibility for their land and neither state nor federal entities access the area. In direct contrast, on the eastern end of the peninsula, the majority of the residents live in city-owned public housing, which means that as individuals, residents cannot take the initiative to make any enhancements or investments in the physical infrastructure on their own. Thus, for more specific planning, it may make sense to create two separate matrices.

2.5.2 *Case Study 2: Mobile, AL*

On September 29th 1998, Mobile, Alabama experienced a Category 2 hurricane, Georges, that inundated the area both with rainfall and coastal flooding. Although Hurricane Katrina in 2005 eventually made landfall in New Orleans, earlier estimates of the storm track forecasted that the storm may have hit Mobile instead. In addition to the very present hurricane threat, Mobile is expected to experience up to 2.5 feet (0.76 m) of sea level rise over the next 100 years. As a result, area leaders have been keen to understand the region's resilience and in March 2015 a workshop was convened in Mobile through a collaboration of the National Oceanic and Atmospheric Administration (NOAA) and USACE to test and provide feedback on different research approaches to resilience assessment for the Mobile Bay region (Touzinsky et al. 2016). The resilience matrix was introduced to the workshop as an initial screening-level assessment to be considered by a panel of representatives from county and state planning and emergency management, environmental restoration, port management, and local commerce and construction.

The city of Mobile sits at the head of Mobile Bay (Fig. 2.6) and hosts both a large regional medical center, aerospace industry, and an active seaport, supported by growing populations on the eastern bank of the Bay. In addition, the Bay hosts fisheries and oyster beds and the barrier islands at the mouth of the bay area are a major regional destination for tourism and beach house investment (Swann and Herder 2014).

For the Mobile study, four critical functions were identified: housing/shelter, shipping, tourism, and the bay ecosystem. Although the workshop participants identified telecommunications and electricity as critical functions, these systems are privately or independently owned and operated and thus beyond the ability of the

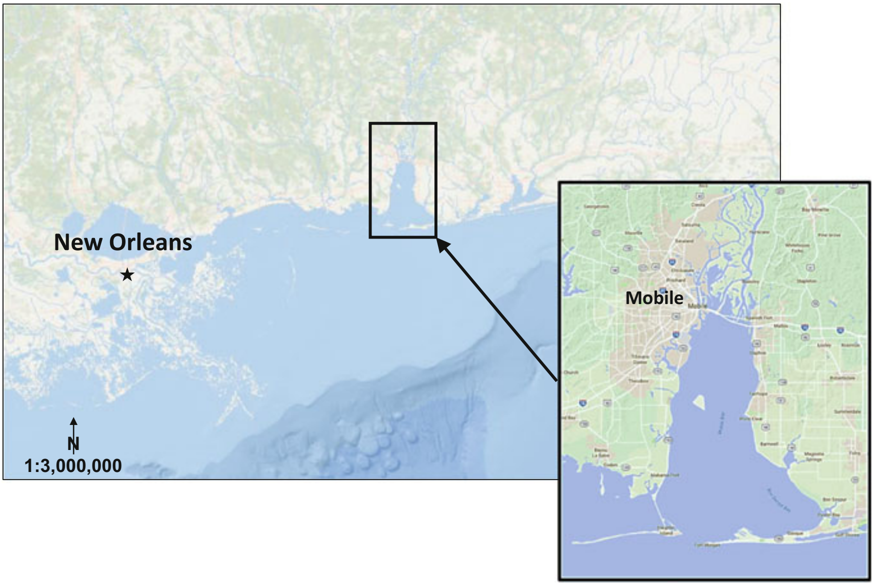

Fig. 2.6 Mobile Bay, AL. Map data: ESRI, Google, INEGI

local leaders to accurately assess. Participants were split into groups around each of the critical functions in order to discuss past performance, key issues, and ideal improvements. This activity was intended to benchmark the mental models of each participant to the same concept of what levels of performance constituted acceptable and unacceptable limits within the region. Next, each participant individually completed a survey asking about the capacity of the system to perform in each cell of the matrix. Figure 2.7 shows an excerpt from the Housing survey regarding the physical-adapt cell.

In this way, steps 4 and 5 of the resilience matrix method are combined to generate a score of strong or weak capacity to performance in each cell. The results of the workshop assessment are shown in Fig. 2.8. Initial observations reveal that the region has overall better capacity in the information and cognitive domains than in the physical and social domains. The tourism industry, as assessed, has strong

Physical Domain	Not at all	Slightly	Moderately	Mostly	Very	Not Sure
4) Adapt: How adaptable is the Mobile Bay Region community's housing/shelter assets to new storm conditions? Consider: • Ease and cost of adapting or moving housing/shelter assets to be more resistant • Room to add increased coastal protective structures as needed (increase dune height, add seawall, etc.)	○	○	○	○	○ → Increasing adaptability	○

Fig. 2.7 Example resilience matrix elicitation survey question for the Physical-Adapt cell of the Housing/Shelter critical function

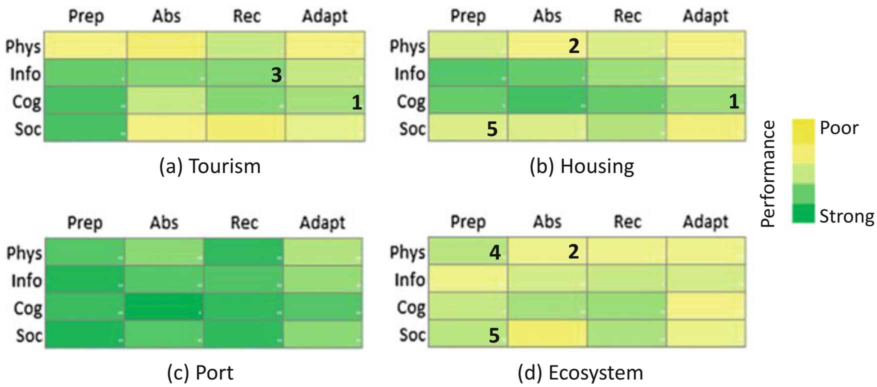

Fig. 2.8 Completed resilience matrices for four critical functions associated with Mobile, Alabama: **a** tourism to beaches, **b** housing for residents, **c** shipping activities at the port, and **d** ecosystem of Mobile Bay. Numbers indicate the cells which proposed improvements will affect

capacity in the prepare phase, but this does not appear to translate into supporting actual improved capacity to absorb. The sufficiency of the preparation activities may need to be reconsidered through community engagement. The port representatives reported a highly resilient capability for their part of the system to deal with immediate threats, but somewhat lower capacity to adapt to future conditions. Ecosystem advocate report that the historic focus has been on clean-up and recovery of the bay after storm events rather than efforts to prevent or minimize damage and this is borne out in the assessment.

To demonstrate the further utility of the resilience matrix in decision making, a selection of proposed resilience enhancements are evaluated by noting which cells of which critical functions each action will address. Five proposals are:

1. Building code improvements and enforcement for coastal structures, especially on the barrier islands.
2. Replace bulkheads along the bay with natural revetment and living shorelines to mitigate erosion.
3. Develop a network of licensed contractors certified in coastal storm damage mitigation techniques for businesses to access when making repairs.
4. Reduce impervious surfaces in new upland developments to retain natural drainage.
5. Continuing education on ecosystem services, fragility and human impact on ecosystem health.

The matrices in Fig. 2.8 have been marked with numbers 1 to 5 to indicate the parts of the system each project with affect. Even without attempting to quantify the extent of improvement in each cell, the matrices can yield information to help prioritize. Efforts to generate resilience improvement ideas suffer from some common challenges. It is difficult to generate fully new and innovative strategies so proposals tend to follow actions taken before. Depending on whom is involved, solutions can be overly focused on structural investments or other visual changes. By comparing the proposal to the assessed capacity of each cell, the user can determine whether the proposals meet the largest needs of the system or whether there are aspects of the system for which no proposals have be brought forth. Although the matrix methodology does not include a consideration of exactly how components of the system are related and interdependent, the default assumption is that in modern environments, any threat will have cascading effects throughout the system. To address this reality, the matrix can be used to assess proposals and select a portfolio of projects that collectively address the areas of the system with the lowest capacity for performance. In meeting this challenge, projects that address more than one critical function (or more than one threat), as do projects 1, 2, and 5, can be prioritized above those acting in the same areas but on only one function. This type of project evaluation can be used to describe qualitatively the benefits of any portfolio of projects and trade-off against cost, time, and other factors.

2.6 Lessons Learned

Urban environments often suffer from a tragedy of the commons. The density of inhabitants and the numerous public agencies can all to hope or assume that someone else is addressing looming threats. Landlords may assume that individual tenants will evacuate in some flooding events or otherwise take emergency measures while tenants may assume that the landlord has invested in protective measures for the building as a whole. Similarly, local governments may assume that the state or federal government will step into manage major disruptions, while the larger governments may expect local governments to be pro-actively preparing to manage themselves. The resilience matrix provides a framework to identify and bring together relevant players for urban planning, community development, disaster risk reduction and emergency management for structured conversations about performance expectations and responsibilities.

The two case studies described herein have gone further and attempted to assess local and regional resilience with both quantitative (Rockaway) and qualitative (Mobile) measures. There are several benefits of the matrix for resilience assessment. One, the use of qualitative measures allows communities to rapid screening level assessment even in the absence of qualitative data and funding. It is important to perform at least this initial level of assessment to avoid stagnation when there are a large number of unorganized stakeholders. The actual process of completing an assessment and examining the results can support further decision making in numerous ways. The gap analysis helps identify easy improvement actions that are broadly beneficial and the matrix itself is documentation to justify the shared use of funds between groups for these projects. For other actions, the assessment process can help explicitly bound the scope of collaboration so that agencies and community organizations can move forward independently, assured that their efforts are not redundant to or undermining others. Traditional risk analysis is often performed independently by each agency or organization and would fail to facilitate collaboration in this way. At the same time, risk analysis can still be an important component of a resilience assessment and the matrix can integrate the results of previous analyses as metrics within the cells.

In developing, testing, and sharing the resilience matrix the authors have revealed several challenges to this level of assessment. While a screening level assessment can help identify quick wins and other actions that are broadly useful, it likely cannot help differentiate between the benefits provided by similar alternatives. For example, with respect to coastal flooding, more detailed analysis will be needed to determine whether constructing a 3 m protective dune and purchasing 2 back-up generators provides more or less benefit than constructing a 3.5 m protective dune and purchasing only 1 back-up generator. Additionally, while the assessment process will reveal numerous relationships between different systems within a community, the matrix lacks a formal assessment of any interdependencies and their effects of overall resilience. As a consequence, the assessment can only consider components in the system with static properties. More advanced—though time-intensive—modeling, such as agent-based or network approaches, is necessary to identify emergent properties.

Two final limitations currently apply to all resilience assessments. First, the premise of resilience that the recovery period, beyond the immediate emergency response, is a critical component of resilience. However, to date, there are very few community or infrastructure systems with sufficient data on recovery processes. The matrix is able to incorporate estimates from professional judgement or rough indicators that can be drawn from public records (e.g. number of days until schools re-open, percent of homes still unoccupied at one-month after a disaster). The other limitation is that understating the performance of some public services such as electricity distribution and telecommunications is often crucial to helping a community recover. However, these are also often run by private or semi-private entities who keep performance information and emergency plans closely guarded both to protect a competitive edge in business and to protect knowledge of vulnerabilities for security purposes. The paucity of these data is a common challenge to urban planning, risk reduction, and resilience in general, but has been brought to the fore again in academic discussions due to the specific designation of the mid- to long-term recovery period as a focus of resilience.

Lastly, we return to the idea that resilience is about maintaining functionality rather than preventing specific losses. Traditional risk management results in investments or processes that are specifically intended to prevent some loss. Conversely, a resilience framework, such as the matrix, allows users to assess the contributions to the system as a whole for any proposed investment. A great example taken from the first case study is a neighborhood in East Rockaway that is constructing solar-powered street lights at the public library (NY Rising Community Reconstruction Rockaway East Planning Committee 2014). These lights will improve safety year-round and also will provide a lighted community gathering space with solar-power that can be tapped into for emergency operations.

The key component of the resilience matrix that supports this type of resilience decision making is the value function. Considering alternatives with respect to the value functions provides an assessment of marginal benefit that can be included in more traditional cost-benefit analyses to identify alternatives that not only enhance resilience to a specific disruption but also provides benefits to the community during the intervening times of normal operation. The field of urban planning has long used stakeholder engagement activities to gather input. Integrating the construction of value functions into these existing practices can help streamline the process and capture information in a mathematical formulation that can be used again for future decisions, whether for development, resilience, or risk reduction.

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Chapter 3
Urban Informality and Planning: Challenges to Mainstreaming Resilience in Indian Cities

Minal Pathak and Darshini Mahadevia

3.1 Introduction

The merits of aligning climate change and sustainable development actions in cities are now well accepted with a large body of scientific literature in the past decade and corroborated in IPCC's fifth assessment report (IPCC 2014a). Urban resilience has emerged on the forefront of the urban development agenda globally, more so with the UN Sustainable Development Goals (goals 11 and 13) that exhort urgency to address climate change and its impacts and to make cities inclusive, safe, resilient and sustainable (United Nations 2015). This has now opened up the discussion around the necessary urban planning and policy interventions to achieve this.

As a large developing country, India is experiencing multiple transitions. Amidst increasing trends in population growth, economic growth and urbanization, addressing simultaneous goals of sustainable development and climate change is a daunting task. Synergistic actions would open up the possibilities to exploit the window of opportunity and deliver multiple co-benefits (Shukla et al. 2015). This is well recognized and reflected in India's commitment to sustainability based approach for addressing climate change. For instance, India's National Action Plan on Climate Change (GoI 2008), implemented in a 'missions' mode identifies eight submissions that align climate change actions with sustainable development. Within these, the National Mission on Sustainable Habitat outlines key actions in urban areas to develop climate compatible urban centres that enhance quality of life. Earlier studies demonstrate the possibilities for achieving low carbon sustainable

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development in Indian cities through sectoral mitigation and adaptation actions (Puppim De Oliveira et al. 2013; Pathak and Shukla 2016).

Indian cities are developing sustainability plans. However, as evidence from global cities shows, stand-alone plans lack the integration necessary for a networked approach to planning that may be necessary to address future risks (Childers et al. 2015). It is well accepted that conceptualizing urban resilience should go beyond the classical definitions of post-disaster recovery and integrate sustainability over spatial and temporal dimensions (Sharifi et al. 2017). The paper does not delve into new conceptualization of resilience. Instead, we adopt the definition of the Intergovernmental Panel on Climate Change (IPCC) where 'Resilience is the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation' (IPCC 2014b, c). Therefore, resilience would mean response to and recovery of urban systems and people in response to climate related extreme events.

Mainstreaming information on climate risks, policies and interventions in existing decision-making has been proposed as a way for more sustainable and efficient decision making compared to designing and managing climate policies separately from ongoing activities (Ayers et al. 2014). For Indian cities, building in climate change resilience actions could possibly involve higher costs in the short term relative to addressing only the immediate goals of providing shelter, basic services and local economic development. At the same time, addressing these immediate goals will support climate change resilience actions.

The architecture of urban planning and governance in India are both enabling and challenging to resilience building. An additional complexity is the nature of urbanization in India which is largely informal (Roy 2009). With 102.4 million (or 26.4%) urban population living below the poverty line of INR 1407 (USD 29.38) per capita per month in 2011–12 (GoI 2014), continued poverty has posed a chronic and persistent challenge to policymakers addressing urban sustainability.

Within this context of dynamic urbanization and informality, resilience includes the capacity of the urban poor to respond to and cope with climate change events. In the second and third sections (Sects. 3.2 and 3.3), the chapter looks at how urban governance and planning influence resilience management for Indian cities. Using the case study of Ahmedabad city's Heat Action Plan, the paper highlights the key challenges to mainstreaming to climate resilience in Indian cities.

3.2 Urban Planning

India is currently at a low level of urbanization; according to the most recent population census, 32.7% (377 million) population lived in urban areas in 2011. The population is unevenly distributed across different size classes of cities and towns. Forty-three per cent of the urban population resided in the metropolitan cities (million plus cities) in 2011, while about 38% lived in towns and cities below 200,000 population in 2011, (Mahadevia and Sarkar 2012). In the decade between 2001 and 2011, the urban population shifted towards metropolitan cities while the small towns registered a steep decline in population growth. By 2050, over half of India's population will live in urban areas (United Nations 2014). Based on the current trends, the challenges of achieving urban climate resilience will also play out differently due to India's unequal urbanization pattern, with a possibility of the large and metropolitan cities attracting more attention compared to their small and medium sized counterparts.

Urban development falls under the purview of the state government. Urban development, as defined here, includes land use planning through statutory Master Plan or Development Plan; Comprehensive Mobility Plan, Infrastructure Investment Plan, Environmental Protection Plan and Housing Strategies. Of these, the preparation of Master Plan or Development Plan[1] is statutory. In some cases, sectoral (transportation, infrastructure, environmental protection and housing) plans form a part of the Master/Development Plan. At the state level, town planning and/ or urban development legislation specifies the approach to land acquisition and development for urban use, zoning, and road layouts. Zoning decides activity locations and road layouts broadly indicate the direction of development of the city.

At the next level below the Master/Development Plan are the smaller area plans, referred as zonal plans/district plans/town planning schemes. Each of these plans has a different mechanism of deciding on land use allocation and layout of the roads. In some states at the third level are the local area plans, which also include three dimensional designs of spaces. The different urban planning components, the scale at which these need to be planned, elements or measures of building resilience and institutions/ actors involved for the building resilience required in the Indian city contexts are presented in Fig. 3.1 and detailed in Table 3.1. This table also identifies the existing state/local policies or programmes in which these resilience measures could be dovetailed.

3.3 Urban Governance Structure as It Relates to Urban Resilience Planning

Revi et al. (2014) recognize governance as an important element for climate adaptation and resilience and emphasize importance of multilevel risk and multi-scalar governance frameworks for addressing these. Table 3.1 mentions scales of interventions and the existing institutional entities responsible for planning and implementation.

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[1]In some states such as Gujarat the term Development Plan is used while Delhi uses the term Master Plan.

Fig. 3.1 Urban Planning Hierarchy, Ahmedabad

In India, city boundaries are defined by the state government. This is problematic-when a city's growth spills over as 'Outgrowth' but the formal boundary of the Urban Local Body (ULB) remains unchanged. This development pattern led to creation of a separate entity called the urban development authority (UDA), to address physical developments of the city beyond the local government's jurisdictional limits. To put it simply, the UDAs plan and implement projects in the urban sprawl areas. Such a pattern is more commonly observed in case of metropolitan and some large cities (population between half a million to 1 million). The UDAs are engaged in technocratic duties of planning and implementing capital works and land development. With city management being solely their responsibility, ULBs are directly accountable to citizens. Consequently, these authorities are heavily burdened with administration, service delivery and emergency response to disasters. The UDAs are not elected therefore they are not directly accountable to citizens. Their relationship with the ULB depends largely on the powers ascribed to them. In some cities, the UDAs are more powerful than the ULBs and have powers to prepare urban development plans, city transportation plan and city infrastructure plan.

The State governments have the powers to sanction various plans-Master/ Development Plans and other lower level plans. The state governments also hold the powers over legislation. As a result, ULBs are burdened with managing routine urban matters without having independent sources of finance. The problem is particularly severe in smaller cities where the financial and functional capabilities

Table 3.1 Urban Planning and Governance Frame for Resilience-building Measures for India

Elements	Planning scale	Programmes/schemes/ legislation	Entities (to be) involved	Elements/measures of resilience building
Urban built-form				
Land use plan	• Municipal government • Regional as defined by regional development authority	• State town planning and/or urban development Acts • AMRUT for waste management	• Municipal government • Regional development authority • Village Panchayats • State urban development department • Central government, Ministry of urban development • Hawkers' union	• Densities, Floor-space index, Dwelling Unit (DU) size • Zoning • Restricting developments in risk-prone areas • Landfill siting Green spaces demarcation • Street design
Urban design	• Local area/ward • Street • Neighbourhood • Community	• None	• Municipal government (ULB) • Ward committee • Area/neighbourhood/community associations • Non-governmental organisations	• Ward or neighbourhood level • Street design • Building design • Water harvesting/disposal designs, i.e. local channels, recharge pits, soft surfaces, etc. • Green space design
Transport				
Transport plan	• Municipal government (ULB) • Region (in case of metro cities)	• E-mobility mission • AMRUT	• Unified metropolitan transport authority (UMTA) if any • Mode-specific authority, i.e. Delhi metro rail corporation, Indian railways for sub-urban trains, public transport corporations • Auto-rickshaw or e-rickshaw unions	• Climate responsive mobility plan (i.e. for heat impacts, flood impacts, storm impacts • Public transport plan
Water supply, sewerage, solid waste management				
Infrastructure plan	• Municipal government (ULB) • Region	• AMRUT • Capital projects in the domain	• Municipal government (ULB) • Regional development authority • Village Panchayats • State urban development department • Central government, Ministry of urban development	• Water supply network • Water availability augmentation plan in dry regions • Sewerage network • Storm water drainage network

(continued)

Table 3.1 (continued)

Elements	Planning scale	Programmes/schemes/legislation	Entities (to be) involved	Elements/measures of resilience building
		• Swachchh Bharat mission (Clean India Mission)		• Bunding/dikes along coast/waterways • Solid waste management plan • Waste (hazardous & non-hazardous) disposal plan
Energy				
Energy supply	• Municipal government (ULB) • Region • Sub-municipal/ward • Neighbourhood	• National Solar mission • Waste to Energy Mission	• Ministry of New & Renewable Energy, central government • State government	• Energy plan • Decentralized municipal energy Solar PV Municipal Waste to energy
Environment and pollution				
Environment plan	• Municipal government (ULB) • Region • Sub-municipal/ward • Neighbourhood	• AMRUT • Environmental legislation	• State government department of environment • Municipal government (ULB) • Ward committees • Neighbourhood committees/associations • Community-based associations	• Pollution control plan • Non-development zone • Green area development plan • Rain Water harvesting • Water ways (rivers, canals, lakes & ponds) development plan • Wetlands development and conservation • Ground water management
Housing				
Housing plan	• Municipal government (ULB) • Region • Sub-municipal/ward • Neighbourhood	• Housing for All (PMAY)	• Municipal government (ULB) • State level housing & slum boards/authorities • Regional planning authority, i.e. AUDA • Revenue department of the state government • Non-governmental organisations	• Individual house/building level water storage • Individual house/building level toilets • Slum redevelopment plan

Source Authors

are much lower, limiting the local government's ability to respond to any emergencies, and almost negligible capacity for resilience building. This centralisation of urban governance at the state government level and lack of financial powers severely constrain ULBs (Mathur 2013; Sivaramakrishnan 2013). Even in the case of metropolitan cities, the governance is highly fractured and fragmented (Sivaramakrishnan 2014) and city governments largely dependent on the state governments. Mahadevia (2010b) has argued that the earlier autonomy of the municipal governments has eroded over time due to various reasons such as requirements for large investments that make the cities dependent on the state government, interest of the state-level politicians, including the Chief Minister of the state to project the state's important city's development through branding to attract investments (Mahadevia 2011a), financial resource dependency for capital projects and above all political interference of the state level politicians.

Another area under control of the state government is the implementation of infrastructure projects. The state governments have greater interests in their capital and large cities and hence they tend to neglect the small and medium towns (for infrastructure levels in small and medium towns vs metropolitan cities see Mahadevia and Sarkar 2012). The State Level Nodal Agencies (SLNAs) and agencies created for the implementation of the national level programmes, for example, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) further eroded the powers of the ULBs.

Most urban public transport authorities either belong to the state government or are parastatals controlled by the state government. Barring a few cities such as Ahmedabad and Mumbai, ULBs do not have control over them. State agencies also address environmental issues including pollution control, waste management and parks and green cover. Managing water bodies could be controlled by the state government or the local government depending on the jurisdiction.

In summary, the governance structure for implementing plans and projects for urban resilience building is fragmented with jurisdiction of multiple agencies at two levels-local and state government. The municipal government lacks authority to coordinate the activities for a climate resilience plan. The participation of the community and neighbourhoods is feasible only if the municipal government is the main coordinating authority for various necessary climate change resilience actions. That not being the case, community and neighbourhood associations, and NGOs continue to work in their isolated terrains limiting the possibility to scale up good practices.

3.4 Urban Poverty, Informality and Resilience

The previous sections discuss at length the elements of urban planning and urban governance as these influence climate resilience planning. In this section, we discuss poverty and informalisation as the third most significant dimension to mainstreaming urban resilience. Methodology for estimating poverty have changed periodically in India (Mahadevia and Sarkar 2012; GoI 2014) making it difficult to assess the changes in incidence of poverty as well as the total numbers below the poverty line.

Urban poor reside in informal settlements, which generally are illegal. Hence, ULBs do not invest in basic services in these settlements. Residents in these areas lack access to piped water supply, sewerage and storm water drains, paved streets and green spaces. Lack of piped water supply increases the residents' vulnerability to impacts from heatwaves, droughts and floods. Inadequate and poor quality of sewerage and storm water drainage imposes huge risks during floods and storm surges. Unpaved streets are prone to waterlogging during monsoon posing severe health risks from unhygienic conditions such as epidemic outbreaks from the waste mixing with rainwater.

With already low levels of nutrition any post disaster epidemic afflicts the poor the most and cause severe impacts and in several cases even mortality. Within this segment, the children, women and elderly are the most vulnerable. Climate change impacts aggravate poverty as the poor who are the most vulnerable suffer higher damages and get further pushed below the poverty line. The poor households and communities face development constraints including financial and social capital deficits which increase their vulnerability to extreme events. Poverty reduction can support adaptation by increasing individual, household and community resilience for building climate change resilience (Revi et al. 2014).

Land tenure is an important determinant to improving infrastructure and housing conditions in the informal settlements. This is particularly challenging to resolve and has been a long standing impediment to upgrading programmes (Boonyabancha 2005, 2009); (Mahadevia 2010a, b) essential for local-level adaptation action. Further, tenants also are not included in slum upgrading programmes. Thirty per cent of urban households live on rent (National Sample Survey Organization 2010), including in the informal settlements (Desai and Mahadevia 2014). "Tenants and those with the least secure tenure are often among the most vulnerable and exposed to hazards but also are usually unwilling to invest in improving the housing they live in and less willing to invest in community initiatives" (Revi et al. 2014 p. 581).

Informal settlements have largely developed on the urban periphery, without obtaining legal permissions related to land use conversion from agriculture to non-agriculture or non-compliance with the city's Master/Development Plan or the other plans below the city level plan. At the planning stage, large parts tend to be categorised as illegal as these do not conform to the planned use, the Development Control Regulations (DCRs) or building codes. The high cost of conforming to the legal provisions prices out the low-income households from the urban housing markets. There is a historically accumulated housing deficit of 18.8 million houses (NBO 2012). While housing programmes to support low-income households have been in operation, meeting the housing deficit through public housing programmes would be a long term process.

There are no official estimates of informal housing. Calculating from the National Sample Survey data, 67%, or two in every three households in the bottom 40 expenditure percentile of the urban population live in informal housing categorised as independent units (National Sample Survey Organization 2010 p. 67). These independent units could be in slums or informal settlements. To get some broad ideas of numbers; 31.5 million urban households comprised of bottom 40% in 2011, of which 21.1 million lived in informal housing. Hence, the tasks of formalising land tenure in urban India are stupendous. Legalisation of an informal settlement is feasible if the land belongs to the local government or the state government and land rights can be granted to the residents. Land rights cannot be granted without formal legislation, which is absent in many states. More often than not, this option is not chosen by the local government as the finance-strapped governments prefer to auction such lands to generate funds for capital projects (Mahadevia 2010a, b). The large proportion of informal housing is on privately owned lands, making it difficult for local governments or state government to acquire them for formalising tenure of the resident households. Informal tenure then continues to prevail for long periods.

These communities also face the continuous threat of eviction from the governments when lands they are occupying are to be used for more profitable uses, or for city beautification projects or large city level infrastructure projects. It is within these informal settlements that much of the disaster risk is concentrated; thus vulnerabilities and risks faced by the urban poor living in these settlements aggravates during disasters thereby, exacerbating their already precarious living conditions and creating a vicious circle of poverty. Thus, the poor disproportionately bear the brunt owing to their limited capacities to cope with the disasters and their aftermaths (Wamsler 2008; Baker 2011; Satterthwaite 2011).

Urban land markets work such that the poor tend to occupy the most marginal lands such as riverbanks, marshes, railway tracks and hill slopes. Due to the hazardous or ecologically sensitive locations, these slums do not get regularized and hence are deprived of basic services, increasing their vulnerability. The poor convert some of the marginal lands, such as marshy or low-lying habitable by refilling. Such lands attract the attention of land developers or the local government, depending upon whether the lands are private or public leading to a series of episodes of displacement. Private land developers are well aware of the possibility of speculative profits from land and are in a position to influence local policy-making, resulting in slum demolitions. If offered, rehabilitation post demolitions tends to be in urban periphery (Mahadevia et al. 2014; Coelho and Raman 2013). In Chennai, Coelho and Raman have observed that once evicted from the fragile locations, slum dwellers are sent on rehabilitation sites, which are often equally fragile lands such as floodplains or lakebeds. If no rehabilitation is offered, the poor tend to squat in new locations, often in the urban periphery (Doshi 2013).

In summary, the urban poor live in vulnerable housing conditions, vulnerable from all aspects, tenure security, health conditions and climate change. Without access to basic infrastructure, this population is the least resilient. This segment is also less able to influence development plans and public expenditures while the wealthier sections of the populations are the main beneficiaries of public expenditures. The section highlights the issues of informality in Indian cities and argues that resilience plans must incorporate this element if the true goal of building equitable, resilient and sustainable urban habitats is to be achieved.

3.5 Case Study: Ahmedabad Heat Action Plan

As the concept of resilience continues to gain ground globally, Indian cities are increasingly recognizing the need for resilience building. Presently, these plans are limited to piecemeal measures to address specific risks and remain disjointed from the existing urban development plans. As part of the ACCCRN Resilient Cities initiative supported by Rockefeller Foundation, the city of Surat has developed a comprehensive Resilience Strategy. A large number of Indian cities, especially small and medium sized cities lack adequate financial and institutional capacity to assess, comprehend and act on specific climate risks. This section discusses the Ahmedabad Heat Action Plan, which is a first of its kind attempt to address a specific climate risk (heatwaves and urban heat island) for an Indian city. The analysis could draw out lessons that could be useful for enhancing or building resilience plans for other Indian cities.

3.5.1 About Ahmedabad

Ahmedabad city is located in western India and has a population of 6.5 million (2011). It is the seventh largest city in the country and the second biggest trade center of western India (Fig. 3.2). It is also the commercial capital and plays a significant role in the economy of the state of Gujarat. Ahmedabad is also a major financial centre contributing about 14% of the total investments in stock exchanges in India. The economic base of the city is now shifting towards tertiary (service) sectors, which now account for more than 50% of total employment. Ahmedabad is among the top 20 cities to be developed as smart cities under India's Smart City Mission launched in 2015 (GoI 2015).

The city had high population growth rate in 2001–11 (3.1% per annum) compared to the national average (2.5%). Presently, the city covers 466 km^2 and falls under the Ahmedabad Municipal Corporation (AMC) (Mahadevia et al. 2014). Beyond this, the area falls under the jurisdiction of the Ahmedabad Urban Development Authority (AUDA) which prepares and implements the physical plan of the area including town planning schemes, regulating development activities and laying down infrastructure. AUDA controls about 1866 km^2 and activities within this zone are regulated by the Urban Development Plan of Ahmedabad, a statutory plan for 20 years[2].

[2]AUDA. (2013). *Comprehensive Development Plan 2021 (Second Revised Part-1)—Exiting Conditions, Study and Analysis, AUDA, Ahmedabad.* Ahmedabad: AUDA.

3.5.2 Existing Vulnerability and Climate Change Risks in Future

As a rapidly growing megapolis, Ahmedabad faces unique sustainability issues. On one hand, significant investments have been made on showcasing mega projects to enhance the image of the city such as the mass transit[3], a large scale Riverfront Development project, and several lakefront revitalization projects. Conversely, rapid population growth resulted in huge demand for infrastructure and land for residential and commercial spaces. Meeting this demand was at the cost of urban sprawl, reduced green spaces and infrastructure deficit. A large proportion of population in the city lives in informal housing with poor quality of infrastructure. In 2011, 14.3% of the population lived in slums while the unofficial number was over 30% (Mahadevia et al. 2014).

Ahmedabad falls in the semi-arid zone and has hot and dry climate with average summer temperatures reaching 38 °C. The population in the region is at high risk from heat waves, particularly the urban poor residing in informal housing with inadequate infrastructure access. A large segment of this population is employed in informal sector such as street vending, and small businesses requiring them to spend a large part of their day outdoors which increases their vulnerability to heat waves. Future projections for Ahmedabad show a significant increase in the number of hot days with temperature increase over 40 °C. Modelling for the impacts of temperature on mortality Ahmedabad displays a "J" shaped relationship with the rate of mortality projected to increase markedly beyond the threshold summer temperature of 32.2 °C (Dholakia et al. 2014).

The Ahmedabad Urban Development Plan recognizes the increasing urban heat island effect in the city and indicates adopting measures to reduce the impact and enhance resilience to heat waves. These include, among others, measures to reduce dust emissions, improve green cover, and increase permeable surfaces. The plan also specifies incentives to land owners to encourage development of hard and soft surfaces and creation of a citywide network of green streets, parks and open spaces.

Urban resilience is also an integral component of Ahmedabad's proposal submitted as part of India's smart city mission. The resilience component includes i. Climate resilience ii. Disaster planning including floods, droughts, epidemics and iii. Heat Action plan. Table 3.2 outlines Ahmedabad's resilience actions outlined in different plans.

[3]Since 2008, the city has made sizeable investments in new transport systems including the 97 km BRTS network and two metro corridors spanning 36 km, the first phase of which will become operational in 2018.

Fig. 3.2 Ahmedabad in India

3.5.3 Ahmedabad Heat Action Plan

In 2010, Ahmedabad experienced a severe heatwave with temperature reaching 46.8 °C accompanied by a substantial increase in mortality (Azhar et al. 2014). The event drew the attention of policy makers to the urgency of the issue. Subsequently, collaboration between the local government and national and global research organizations was formed to prepare local response strategies. A series of consultations and research studies were carried out to identify vulnerable populations, measures to build individual and community resilience, and improving heat-disaster response planning in the city. The Ahmedabad Heat Action Plan was formally announced in 2013. The plan identifies four key strategies: i. Building Public Awareness and Community Outreach ii. Utilizing an Early Warning System and Inter-Agency Coordination iii. Capacity Building Among Health Care Professionals Reducing Heat Exposure and iv. Promoting Adaptive Measures. A nodal officer was appointed to oversee implementation of the plan and ensure inter agency coordination in the event of a heat wave[4]. The strategies and response actions had a specific focus on including the most vulnerable groups.

AMC initiated implementation of the plan involving state government departments, local government agencies, NGOs, health department, water supply authorities and institutional groups. Policy briefs were issued with special focus on strategies for workers in high risk occupations, communities in slums and women. To prepare for the heat wave, the city issued colour coded alerts through print and electronic media to warn stakeholders including service providers and citizens. Shelters were opened up to serve as relief centres. The messages were disseminated through various means including pamphlets in regional languages, advertisements, public messages, and community outreach programs. The AMC has invested over $100,000 towards implementation including the early warning system[5]. Preliminary evaluations show positive outcomes in terms of reduced health mortality.

The Ahmedabad Heat Action plan is a pioneering initiative at the subnational level. Through this partnership between the project team and the AMC, Ahmedabad leads as the first Indian city to create a comprehensive early warning system and preparedness plan for extreme heat events. The strong leadership of the local government, effective communication and innovative strategies backed by a robust institutional structure enabled efficient delivery of the plan. The engagement of stakeholders at early stages of the process also contributed to its timely and effective execution.

Success of the plan has led to its replication in other cities in India. In 2017, over a dozen cities and states had adopted or developed heat action plans. The plan has a strong element of coordination across various governance levels. It contributes to the State's mission to implement climate compatible strategies and has catalysed the development of new national guidelines and improved heat forecast systems covering over 300 cities (NRDC 2017). The guidelines issued by India's National Disaster Management Authority encourage state and city authorities to formulate heat action plans following the example of Ahmedabad.

While the plan has succeeded in implementation, the existing strategies largely focus on preventive measures that address short-term and immediate impacts of heat waves; it does not include long term measures to build in climate resilience.

[4]For example, in April 2013, a simulation exercise was organised with 50 city officials, key stakeholders and international experts to plan how their agencies would react to a heat wave and to improve inter-agency communication in the city.

[5]https://cdkn.org/project/climate-change-addressing-heat-health-vulnerability-in-rapidly-urbanising-regions-of-western-india/?loclang=en_gb. Accessed 27 July, 2017.

Table 3.2 Resilience elements in existing plans of Ahmedabad

Existing plan/ proposal	Key elements	Institution
Proposal for Smart City Mission	i. Climate resilience ii. Disaster planning including floods, droughts, epidemics and iii. Heat Action plan	Ahmedabad Municipal Corporation
Heat Action Plan	i. Building Public Awareness and Community Outreach ii. Utilizing an Early Warning System and Inter-Agency Coordination iii. Capacity Building Among Health Care Professionals iv. Reducing Heat Exposure and Promoting Adaptive Measures	Ahmedabad Municipal Corporation in partnership with local and global research institutions
Ahmedabad Urban Development Plan	i. Identifies heat effect due to hard and reflective surfaces. ii. Reduce dust pollutants that capture and contain heat iii. Green cover, permeable pavements iv. Incentives to land owners for soft surfaces v. Monitoring of Heat Action Plan	Ahmedabad Urban Development Authority

For instance, the heat action plan does not integrate planning interventions such as increasing green cover and managing water bodies despite these being a part of the city development plan. Additionally, while different plans recognize the importance of resilience building (Table 3.1), these remain fragmented. For instance, in the case of Ahmedabad, the heat action plan of the city should have been linked to the green spaces demarcation, solid waste management plan and urban design proposals in the city's Development Plan. In recent years, the city has implemented water supply and lake restoration projects. These proposals have sizeable opportunity to enhance resilience building, however, due to the limited scope of the Ahmedabad Heat Action plan, the opportunity to embed heat resilience into the urban planning mechanism has not been fully exploited.

Some reasons for fragmented planning include the existence of multiple planning agencies, weak coordination among these and lack of integration among sectoral plans. Political constraints to long-term resilience actions are mainly resulting from the disconnect between the long-term nature of resilience planning with short term political cycles. The absence of communication between policymakers, planners and stakeholders is another challenge. In addition, vertical coordination among national targets and local level plans is weak. Even with strong city development plans, several planning elements do not get translated into local area plans.

As mentioned in earlier sections, the presence of a sizeable population living in informal settlements is a major challenge. However, a successful and equitable resilience plan should focus on providing housing and infrastructure for the urban poor. Ensuring long term resilience will require a coherent vision and integration across plans. As observed by Mahlkow and Donner (2016), the Ahmedabad study also highlights that mainstreaming of a resilience plan into the urban development plan requires coordination across government agencies at different levels and linkages between formal and informal planning and governance instruments. Resilience building will also require continuous stakeholder inputs from the planning and implementation to the post implementation feedback. The implementing authority in turn should continuously engage with different stakeholders before, during and post implementation. Such an engagement would ensure long-term sustainability of the initiatives and promote equity through participation of different groups.

3.6 Conclusions and Policy Implications

As a rapidly developing country with relatively low urbanization (33%), a high proportion of urban poor without access to housing and infrastructure, India faces unique challenges to building resilient cities. National policies, notably India's National Action Plan on Climate Change (GoI 2008), and more recently, the Smart city program (GoI 2015), AMRUT (GoI 2016) and INDC (UNFCCC 2015) frame an integrated vision of aligning climate policy and development objectives for urban areas.

Integrating climate change into city plans at the development stage can help avoid costs in the long run and prevent adverse impacts arising due to lock-ins. Earlier studies on Indian cities (Pathak et al. 2015) show that an integration between climate change and development is possible and desirable. Policy makers see trade-offs between immediate needs (economic growth objectives) and long-term sustainability objectives. Consequently, sustainability or resilience plans exist as stand-alone plans, disjointed from formal urban development plans. In addition, the top down nature of urban planning, and coordination between multiple planning agencies remain significant challenges. The Ahmedabad case study shows that a robust institutional set up and partnerships among local and state organizations is possible. An earlier assessment of literature shows that the heat warning systems are effective in reducing mortality and morbidity however, efforts could be made to improve access for different groups (Toloo et al. 2013). Future work could possibly explore the differential impacts of resilience plans on different vulnerable groups.

Mainstreaming resilience strategies also requires detailed information on climate science and impacts—for e.g. downscaled climate information for local areas, associated climate risks in the long, medium and short run and methodologies and indicators for measuring resilience. Presently, there exist gaps in the available information on the above. Going forward, urban plans need to integrate a comprehensive data assessment of future heat projections under different scenarios, their micro level impacts in different zones within the city and develop methodologies to measure and benchmark resilience across different cities.

The paper highlights the planning and governance challenges for mainstreaming resilience in urban planning. With a large urban population in informal areas, building in informality into resilience planning is a necessary precondition to achieve the vision of 'safe climate resilient cities. The paper argues that resilience should be seen beyond conventional and narrow definitions of disaster response and recovery but be viewed in the longer timeframe and a broader framing, incorporating equity and access as basic paradigms.

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Chapter 4
Designing a 'Fit-for-Purpose' Approach to Tracking Progress on Climate Change Adaptation and Resilience: Learning from Local Governments in Australia

Susie Moloney and Heather McClaren

4.1 Introduction

In the post Paris climate policy context, there is an imperative to effectively monitor and evaluate progress across a range of scales in responding to climate change. In particular the focus on how well we are tracking adaptation progress has been identified as a key challenge (Christiansen et al. 2016; Ford et al. 2015). While this is particularly important for comparing progress across nations in terms of assessing current actions and future needs, this challenge also applies to regional and sub-regional (and urban) scales where the impacts of climate change are most prevalent. Attention turns then to the capacity of cities and regions, constituted as individuals, communities, institutions, businesses and systems, and their capacity to become more 'climate resilient'. This means developing the capacity to "survive, adapt and thrive in the face of climate related stresses and shocks and even transform when conditions require it" as defined by the Rockerfeller Foundation (Gawler and Tiwari 2015: 5). Local governments are playing a critical role in this process of planning for urban resilience and enabling their communities to adapt and thrive. In the Australian context, local government plans and strategies are emerging, however the extent to which municipalities are planning effectively for climate change and whether they are delivering on outcomes is difficult to assess. While there are a number of frameworks for monitoring and evaluating (M&E) climate change adaptation (CCA) and urban resilience, very few have been implemented at the local scale (Turner et al. 2014). It is also recognised that a standardised approach to M&E may not be applicable to different contexts given the

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specificities of location and impacts, institutional context, policies and programs (Mathew et al. 2016). This recognises then the need to develop an approach that is 'fit-for-purpose' in order to evaluate the effectiveness and appropriateness of particular policies and actions for particular contexts. This chapter presents a case study from a group of councils in metropolitan Melbourne, Australia who have collaborated to develop a framework to track how well they are adapting to climate change and improving their resilience. The project process, framework design, indicators and pilot implementation phase will be outlined including an analysis of the challenges and issues that emerged in developing and implementing an approach to monitoring and evaluation. This chapter seeks to contribute to the gap in knowledge around 'doing adaptation' in particular how we can monitor and evaluate progress. Much more attention is needed on how we can better understand the "actual experience of adaptation" which broadly asks "are we adapting"? (Ford and King 2015, p. 506) and in the case of the particular Australian case study presented in this paper, the focus is on how can we assess 'How Well Are We Adapting?'

The case study presented focuses on the work of group of municipalities across the western region of Melbourne. The Western Alliance for Greenhouse Action (WAGA) is comprised of eight member metropolitan/peri-urban councils (see Fig. 4.1) whose role is to coordinate and enable councils to better plan for climate change and to build capacity regionally by working together on regional strategies and projects. The breadth of issues and challenges varies across the region which encompasses over 4700 km^2, 830,000 people and includes agricultural land-uses, rapidly expanding low density suburbs, increasing densities in the inner city including development along flood prone coastal areas. While councils are working together through WAGA, each member Council has its own plans, strategies, priorities, institutional cultures and politics. Victoria is unique in the Australian context of having ten local government alliances across the state, some very active since the mid-2000s (Moloney and Funfgeld 2015; Moloney and Horne 2015). While initially supported by state government funds, since 2008 all alliances are funded by small annual member council contributions largely used to employ a Chief Executive officer to coordinate alliances and generate projects and grants. WAGA, established in 2006, has developed a range of mitigation and adaptation initiatives, regional risk assessments, adaptation and low carbon strategies and is trialling a range of projects.

WAGA released a regional *Climate Change Adaptation Strategy and Action Plan* (WAGA 2013) including the key aims of mainstreaming adaptation across Councils, embedding adaptation planning processes and reviewing progress of adaptation work carried out by WAGA councils. The Plan focused on the 88 identified climate risks in the western region (17 severe) and encompassed all council service areas including: asset and infrastructure, transport, open space and recreation, natural environment, emergency management, health and community, planning and building and business continuity (WAGA 2013). In 2014 WAGA applied for and received three years funding from the Victorian state government to support the development of a 'Framework to Monitor, Evaluate and Report on

Fig. 4.1 Western Alliance for Greenhouse Action councils, Metropolitan Melbourne

Climate Change Adaptation' across the WAGA region. It is the experience of developing and implementing this project titled "How Well Are We Adapting?" that is the focus of this chapter. Both authors have been involved in this project since its inception, one as a project officer and the other as a research partner. Drawing on experiences and insights this chapter outlines the process involved, highlights lessons in developing a 'fit-for-purpose' M&E framework and some of the challenges in implementation. Before the case study experience is discussed, first the context for M&E for CCA and resilience is outlined including some of the key challenges and how these informed the project and framework design.

4.2 Monitoring and Evaluation for Climate Change Adaptation

The climate change policy and planning context focuses around two sets of responses addressing mitigation and adaptation with the latter closely linked in policy and practice to disaster risk reduction (DRR) which is increasingly framed using the concept of resilience (Moloney et al. 2018: 6). Mitigation involves the reduction of greenhouse gas emissions and includes measures at all scales of government and across all sectors of the economy and society. Adaptation measures focus on assessing risks, preparing for and responding to the impacts of climate change in particular contexts and regions. Adaptation actions need to be “locally contextualised and often, customised to local and regional socio-cultural and institutional factors” (ibid.: 5). The capacity to develop and strengthen social and institutional responses to climate change enables local and regional contexts to “build back better” (UNISDR 2015) or “bounce forward” (The Kresge Foundation 2015) in terms of urban resilience. This chapter focuses in particular on climate change adaptation measures and the capacity for local governments to better assess how they are progressing in terms of the effectiveness of their actions to improve adaptation and resilience to ongoing climate events.

In Australia, while there has been some volatility in recent years around national mitigation policy there has been significant investment at the national scale in adaptation research, risk assessment and planning (Webb and Beh 2013) with the National Climate Change Adaptation Research Facility (NCCARF) and the Commonwealth Scientific and Industrial Research Organisation’s (CSIRO) Climate Adaptation Flagship research initiative (Preston et al. 2011). In 2007, the National Climate Change Adaptation Framework was released to address demands from businesses and the community for information on climate change impacts and adaptation options (Council of Australian Governments 2007). Australia initiated a Local Adaptation Pathways program in 2008 which provided grants to local governments to assist with climate risk assessment and adaptation planning. These initiatives have strengthened growth in adaptation knowledge and practice in Australia, placing it alongside countries such as the U.S. and the U.K. in the field of climate change adaptation. Given this progress around developing plans and actions for adaptation, the challenge now is to better understand how effective and how successful these adaptation plans and actions have been and how best to plan for the future. Adaptation can refer to actions taken to adjust to a changing climate (UNFCCC), the process by which such adjustment is reached (UNDP, UKCIP), or the outcome of a process that leads to a reduction in risk (UKCIP, IPCC) (Bours et al. 2014a). Clarity around which definition to use is important for defining what is being evaluated and for assessing what makes good adaptation (Hedger et al. 2008). The following sections draw on a review of literature on monitoring and evaluation for climate change adaptation (Turner et al. 2014) highlighting the key lessons around the purpose of undertaking M&E for CCA, approaches used, key challenges and lessons for developing an approach to reporting.

4.2.1 Purpose

Determining the purpose for doing M&E is a critical first step in the process of embedding M&E into decision-making and improved planning. Embedding Monitoring and Evaluation (M&E) into the adaptation process allows for iterative, ongoing learning and opportunities to modify, change and improve responses to climate change. Spearman and McGray (2011) state that monitoring and evaluation (M&E) plays two critical roles in promoting successful adaptation: to add to the long-term process of learning "what works" in adaptation and; to provide a powerful tool to help practitioners manage their work. Generating new knowledge and facilitating learning is a crucial component of M&E, along with documenting what works (or not), when, where, how, and why and are important steps in improving the effectiveness of adaptation plans. It is also crucial that effort is made to translate M&E learning into continuous improvement to ongoing adaptation. Monitoring and evaluating allows for adaptation activities to be adjusted based on how successful they have proven to be in achieving the intended adaptation objectives and to ensure the plan remains current and is working well (UKCIP 2013).

> Monitoring and evaluation of projects, policies and programmes forms an important part of the adaptation process. Ultimately, successful adaptation will be measured by how well different measures contribute to effectively reducing vulnerability and building resilience. Lessons learned, good practices, gaps and needs identified during the monitoring and evaluation of ongoing and completed projects, policies and programmes will inform future measures, creating an iterative and evolutionary adaptation process. (UNFCCC 2010: 4)

There are many reasons for undertaking an evaluation that are closely related to the objectives of an adaptation initiative, including: to evaluate effectiveness of interventions, assess efficiency of resource allocation, to understand the equity implications of actions, provide accountability, assess outcomes, improve learning, improve future actions or to compare interventions (Hedger et al. 2008; Preston et al. 2011; Pringle 2011; Sanahuja 2011). For example the Global Environment Facility's report on *A Framework for M&E*, states that: "First and foremost, adaptation interventions must be evaluated in order to determine whether they were successful" (Sanahuja 2011). For accountability purposes, this objective might be most important, however defining success, and measuring success is complex in climate change adaptation. Another reason for embarking on an evaluation might be to improve learning; to understand what worked, why and in what context (UNDP 2009), to examine the unexpected outcomes and to inform future decision-making. Using M&E for learning purposes is critical, however, in reality the time invested in learning can vary considerably between evaluations whose purpose is to better understand 'what happened and why' than those focused primarily on accountability in order to answer 'have we done what we said we would?' (Pringle 2011).

Another important consideration in determining an appropriate M&E framework, is to consider the different adaptation activities being addressed which have been categorized into two areas: those that build adaptive capacity and those that deliver adaptation actions (UKCIP 2013). UKCIP state that although the adaptation activity may relate to both of these categories, it is useful to distinguish which adaptation activity is being addressed (Spearman and McGray 2011; UKCIP 2013). Building adaptive capacity involves developing a community's or an organisation's capacity to respond to the impacts of climate change, such as developing a community's awareness of their exposure to flood risk and providing information to enable them to build their resilience in the event of a flood. Adaptation action on the other hand is focused more on taking practical actions to directly reduce or manage the biophysical impacts of climate change (such as increases in heat waves), to address non-climatic factors contributing to vulnerability or to exploit positive opportunities (UKCIP 2013). There is often an overlap between the two, for instance local government may monitor and evaluate adaptation actions identified in a plan aimed at increasing organizational adaptive capacity through staff training or awareness raising programs for instance.

4.2.2 Approaches

Determining the most appropriate approach to M&E is also very important and the four most commonly used approaches are (see Fig. 4.2): Input-output-outcome based evaluations; Process based evaluations; Evaluation of behavioural change; and Economic evaluations.

The input-output-outcome approach is the most commonly used approach and is underpinned by a 'logic model' (see 'adaptation logic model' in Pringle 2011). Process based evaluations are also commonly used and they aim to define the key

M&E Methodologies	Focus on	Approach	Assumption
Input-Output-Outcome evaluation	Effectiveness	Elements of adaptive capacity/ risk are pre-determined and evaluated against a set of indicators	Increased adaptive capacity will ultimately lead to reduced vulnerability Risk is probabilistically determined and known
Process-based evaluation			
Evaluation of behavioural change			
Economic evaluations	Efficiency	Benefits of adaptation is measured in terms of economic loss	The ability to determine a baseline and projected benefits and losses

Fig. 4.2 Existing approaches and methodologies for the evaluation of adaptation interventions. *Source* Villanueva (2011, p. 20)

stages in a process that would lead to the 'best choice of end point' without necessarily specifying what that end point might be (Villanueva 2011, p. 26). A key message from Villaneuva's analysis of the current approaches and methodologies used for evaluating planned adaptation interventions is that while each approach is useful in assessing and predicting adaptive capacity, they are not very effective at helping understand *how* adaptive capacity develops.

Adopting a 'developmental approach' to evaluation and a 'theory of change' approach have emerged as useful processes for managing the inherent uncertain and complex nature of M&E for CCA (Turner et al. 2014). While we do not have the space here to explore each in detail, we briefly outline both learning based approaches to M&E. Developmental evaluation (DE) is relatively new and not well tested however it has emerged "in response to the need to support real time learning in complex and emergent situations" (Dozois et al 2010, p. 14). The emphasis is on 'adaptive learning' rather than 'accountability to an external authority' (Villanueva 2011). The evaluator is embedded in the initiative as a member of the team and they go beyond data collection and analysis to actively intervening to shape the course of development and decision-making (Dozois et al. 2010, p. 14). Where it may be difficult to develop a traditional evaluation framework with outcomes, targets and indicators, a DE approach helps create a 'learning framework' which Dozois describes as a framework for mapping the key challenges and opportunities, identifying what the group or organization needs to pay attention to as they go forward; and what they need to learn. The purpose of a learning framework is to set direction for learning and project development and helps development evaluators be strategic and intentional about where they should focus their attention. The other (learning based) alternative to the 'logic model' for M&E is the 'theory of change' approach which has become increasingly influential in international development. It is a 'critical thinking' approach to program design, monitoring and evaluation (Bours et al. 2014c). Again without going into detail this approach involves a group of stakeholders defining what the long term goal or outcome is and then works back from that to map the steps required to achieve it. For each step in the process indicators, thresholds and assumptions are outlined resulting in a 'change map' accompanied by a narrative (Bours et al. 2014b, p. 2). It is an iterative process where at each stage, the 'necessary conditions' for achieving the goal are identified. The five steps involve: identifying the goal, develop a pathway of change; operationalize outcomes; define interventions and articulate assumptions. This approach is considered most valuable for designing and evaluating climate change adaptation (ibid., p. 3).

Common approaches to evaluating adaptation are characterized as focusing on defining and measuring adaptive capacity and risk reduction against a predefined set of indicators (Villanueva 2011, p. 31). While there are a number of tools and frameworks, very few evaluations have actually been carried out which makes it difficult to determine what is and is not a successful framework or approach. From Villaneuva's analysis however, there were three key issues that emerged from past and current practice that are important to consider in developing a 'fit-for-purpose' framework: (i) adopt a process-based approach not simply a 'deterministic approach focusing on inputs/outputs; (ii) Ensure the approach is dynamic and reflexive not static; and (iii) Move beyond focusing only on efficiency and effectiveness towards a more learning based approach. Monitoring and evaluating both the 'what' and the 'how' of adaptation processes and actions is critical in order to improve decision making and will necessarily involve both quantitative and qualitative data.

4.2.3 Key Challenges

There are a range of key challenges and issues that have emerged in the literature around M&E for Climate Change Adaptation (Turner et al. 2014; Bours et al. 2014a; Villanueva 2011; Pringle 2011; Barnett and O'Neill 2010; Hedger et al. 2008). While not necessarily unique to adaptation these certainly present a range of issues for those embarking on an M&E process for CCA. The following draws on the eight key challenges synthesized by Turner et al. (2014). The first concerns how to define and determine what 'success' means in climate change adaptation. There is no clear measure that determines the success of an adaptation intervention which means evaluating adaptation often relies on proxy measures that relate to the achievement of broader societal aims. Second, as climate change is a long term process there will likely be significant time lags between the intervention and measurable impacts, making it difficult to fully assess the effectiveness of an adaptation project. Third, the challenge around attributing an outcome to a particular action. That is, it is difficult to measure the impact of an adaptation action if an event does not occur as it is to assess how much worse the event would have been if the intervention or action was not taken. Fourth, there are a lack of concrete definitions for adaptation making it challenging for those involved to agree upon what is being evaluated. The fifth challenge addresses the issue of future uncertainties and changing conditions that result in 'shifting baselines'. This highlights that natural and socio-ecological systems undergo continuous change over time which means that the use of a fixed baseline for comparison may not be sufficient to understand the complexity of the processes involved. Avoiding maladaptation is another key challenge, where the stated objective is not being achieved but also where adaptation actions can increase vulnerability and exposure to extreme weather events and other climate change hazards. Dealing with uncertainty in terms of climate change projections, as well as social, economic and political uncertainty presents a significant challenge to evaluating the success or appropriateness of an intervention at a given point in time. Finally, the eighth key challenge concerns the diversity of adaptation scales and sectors. The multi-sectoral implications of adaptation responses and the need to involve a wide range of stakeholders and government departments and agencies, create significant challenges around establishing indicators and M&E systems that can be applied across multiple scales and institutional contexts (Turner et al. 2014).

4.2.4 Developing an Approach to Reporting

Following the review of reporting approaches and indicators for CCA, there appears to be no single 'best practice' for construction of adaptation indicators, but common concepts which can be useful for the purposes of comparison at appropriate levels. The following draws on the analysis and recommendations of Turner et al. (2014).

Comprehensiveness is not necessarily needed, and an exhaustive number of sectors to be reported on may be counterproductive. The AEA (2012) argues that: "Developing adaptation indicators need to navigate a path between simplification and quantification on one hand, and developing a rich understanding of the complexities which underpin adaptation on the other" (p. 34).

The SMART (i.e. specific, measurable, agreed, relevant, time-bound) (Turner et al. 2014) approach is a useful set of background criteria for the development of all indicator types. This may be incorporated implicitly or explicitly, but offers an early platform on which to develop a suite of M&E indicators.

M&E indicators should strive to ensure a balanced set of indicators in a number of respects:

1. A balance between process and outcome indicators is advised, taking into account the respective advantages and disadvantages of each.
2. Indicators should reflect both the building of adaptive capacity, as well as the reduction of climate change related vulnerability.
3. A mix of both qualitative and quantitative indicators is advised to ensure that reporting practices do not over-emphasize one at the expense of the other.

As several of the approaches recognized, the establishment of baselines for indicators is a necessary step to ensure progress is monitored properly. However, these should remain flexible and capable of being 'shifted' on the basis of changed circumstances and new information.

Indicators should also be checked to ensure they are being attributed to the correct CCA measures. This is particularly the case for quantitative indicators, which often take the form of proxy indicators for circumstances that may only be indirectly related to an adaptation program. The progress of adaptation measures should also be reflective of their degree of implementation, which should be communicated to stakeholders and the community.

Villanueva (2011) sets out the implications for the development of indicators and makes three key points (ibid., p. 18):

- Use of generic indicators to capture underlying causes of vulnerability while specific indicators can be used to monitor the specific measures undertaken to reduce vulnerability
- Evaluation processes snapshot vulnerability and adaptive capacity at the end of a program but this needs to be followed up by constant monitoring over the long-term
- M&E needs to capture the existence of vulnerability and adaptive capacity and those processes that may effect the distribution of vulnerability or how capacity leads to action.

Some of the key lessons used to inform the development of the WAGA framework focused around the importance of M&E as a learning framework which emphasises a participatory approach to engaging a broad range of stakeholders in the process. For M&E to be most useful it must be understood as an ongoing and iterative process over long-term time frames. To ensure that the ongoing learning from M&E can inform key policy and program decisions, it is important to consider the timing of reporting with decision making cycles and how best and to whom to communicate learnings to improve actions.

4.3 'How Well Are We Adapting?'—Developing an ME&R Framework

Following the release of a Risk Assessment (WAGA 2011) and Adaptation Plan (WAGA 2013), the Western Alliance for Greenhouse Action (WAGA) identified the need to better understand how well Councils were adapting to climate change overtime and how as an alliance they could assist councils to track their progress and improve decision making. They applied for and were successful in receiving funding from the state government for a three year project to enable them to develop a monitoring, evaluation and reporting (ME&R) framework for climate change adaptation involving a number of key project partners including three WAGA councils (Hobsons Bay, the City of Greater Geelong and Wyndham City Council), RMIT University, Net Balance Foundation (environmental consultants) and the state Department of Environment and Primary Industries (the funder). The project partners recognised that adapting to climate change risks is an ongoing process of continual improvement and that a process for monitoring, reviewing and evaluating progress and the effectiveness of their adaptation actions was necessary. Rather than taking an 'off the shelf' approach, the WAGA framework needed to be designed with the specific councils and needs of the western region in mind. The framework would monitor the performance of councils in improving adaptive capacity and implementing adaptation actions through a set of indicators. This project sought to build on emerging international research and practice around effective M&E for climate change adaptation (Hedger et al. 2008; UNDP 2009; Pringle 2011; Villanueva 2011; Bours et al 2013, 2014a, b, c).

The framework and indicator sets were developed and tested over three years (2014–2016) and involved a number of key stages which will be discussed in the following sections focusing on: defining the scope; the framework design, indicator development; and the piloting phase.

4.3.1 Defining the Scope

ME&R for adaptation can apply to multiple scales, sectors and institutional contexts, and this key challenge was articulated at the outset of the project (Turner et al.

2014). The project team recognised that even though the M&E framework would apply to a set of similar institutional contexts—local governments in Melbourne's West—those institutions had a range of similar, though not identical, processes and strategies in place and that there was no 'standard' approach to climate change adaptation across Councils. There were also multiple sectors to consider because local government service delivery and asset management applies at a local scale the practices of numerous sectors across emergency management, planning, health, infrastructure, waste collection, environment, leisure services, parks management and community planning. Lastly, the scale at which to pitch the framework was another consideration, due to the regional nature of the project, and the individuality of local strategies and plans to address local climate adaptation issues and hazards. The state and national level contexts also needed to be considered in the early stages, as many adaptation issues are cross jurisdictional.

The project team first defined these different issues determining the scope through a series of workshops involving participation from a broad range of external and internal council stakeholders to capture a diverse range of inputs into the early design of the framework. A literature review (prepared by university research partners—see Turner et al. 2014), a gap analysis of existing council strategies and approaches and a materiality assessment were key processes that informed the scope.

The project team first needed to determine a set of objectives for the framework which were grounded in the particular purpose for this climate change adaptation ME&R framework. This involved discussion around the range of reasons for doing M&E and identifying some of the potential complimentary or conflicting purposes (Pringle 2011). For example, the desire to provide accountability was understood to be in conflict with a focus on improving learning which implied that there would be failures to learn from, and there was reluctance to admit to failures in a political environment that could expose local government to liability claims. The desire to use the framework to compare progress was also challenging as local governments have varied responses to climate change adaptation and are at different stages, so it was difficult to provide meaningful comparison on adaptation 'progress'.

The following lists the key objectives for *How Well Are We Adapting* developed by the WAGA project team (see WAGA 2016):

- Help us track how councils are managing or responding to climate change.
- Monitor the impacts of climate on council operations.
- Communicate with the community about climate vulnerability and council action.
- Assess the effectiveness of actions and inform future actions* (i.e. if there are maladaptive actions occurring) (*Eventual goal).
- Evaluate and report on actions that help manage climate risks (Management).
- Focus on learning rather than measuring success or failure (Learning and Improving).
- Focus on areas of commonality across all WAGA councils (Integration).

The next key steps in the scoping of the framework involved developing a shortlist of priority sectors to apply the framework to and a sub set of issues under each of the priority sectors. These outcomes were informed by the workshops and a materiality assessment. The following four priority sectors were identified focusing on key local government service areas:

(i) Open space and water security
(ii) Community wellbeing and emergency management
(iii) Planning, building and regulation
(iv) Assets and infrastructure.

Drawing on key lessons from the literature review (Turner et al. 2014) and the processes described above, the following framework was developed.

4.3.2 The Framework Design

Some of the key lessons from the literature that informed this framework structure (see Table 4.1) included the need to establish regional scale and municipal scale baselines to evaluate Council performance and to ensure that both vulnerability and adaptive capacity measures were incorporated through the theme components.

Developing baselines was recognised as challenging at both regional and local scales and within a context of escalating climate hazards, which are expected to become more frequent, severe and unpredictable (i.e. shifting baselines). The 'How Well Are We Adapting?' framework responds to these challenges by selecting baselines at a regional scale that monitor climate variables and regional vulnerability or resilience (including socio-economic indicators). At the local municipal service level, the indicators focus on a mix of process and outcome indicators that can be monitored over long time frames and analysed for trends against a baseline of climate hazards.

The theme components were developed as a structure to build the indicators around. Indicators that were developed had to align to the theme components to ensure there was a good representation of the key aspects for adaptation response within each sector, in particular a need to identify indicators that were sensitive to vulnerability and adaptive capacity across local government service delivery and operations. In order to fully develop a set of indicators that could be tested with Councils within the project time frame, it was decided that two of the four priority themes would be focused on—'community well-being and emergency management', and 'open space and water security'. The lessons learned from this process would then inform the development of indicators for the remaining two priority themes.

4.3.3 Indicator Development

Once the framework structure was approved, the next stage involved in depth co-production of the indicator sets with council-based practitioners aligned to the

Table 4.1 How well are we adapting? ME&R framework for WAGA region (WAGA 2016)

Regional baseline indicators
This data gives us the context and highlights regional vulnerabilities that will inform where to target interventions. However, council policies have little immediate influence over these indicators *Climate variables* Climate parameters such as temperature or rainfall will be tracked over time to inform council planning and response over the medium to longer-term *Regional vulnerability or resilience* Indicators that suggest heightened vulnerability to key climate impacts, e.g. socio-economic disadvantage, demographics, physical vulnerability and flood risk, etc., will be monitored
Priority themes Important council sectors affected by climate change Community wellbeing and emergency management Open space and water security Assets and infrastructure Planning, building and regulation
Theme components These indicators are targeted at the individual council impact and intervention level, rather than at the regional scale—the climate impact and adaptation responses described and monitored here are grounded in councils' service delivery and implemented by operational staff Through combining indicators from each theme under these components, the councils and WAGA will have enough information to provide an informed story to council and the community about what is happening 1. **Service vulnerability or resilience** Measure the ability of a service or asset to cope with and recover from the effects climate variability and change (i.e. measures vulnerability but could measure action effectiveness) 2. **Institutional capacity** Measure the existence of appropriate structures, institutions, processes (formal or informal) or legal frameworks to respond and adapt to climate change. For example, appropriate knowledge, staff training, committees, and coordination of risk across the organisation, etc. 3. **Resourcing and budgets** Captures the extent to which actions and processes to address climate change are costed, budgeted for, and financially provided for. (also financial impacts of changing climate) 4. **Participation and Awareness** Assesses the extent to which climate change planning involves all relevant stakeholders and evaluates their awareness of climate change issues, use of climate information, understanding of risks and potential response options, as well as actions to promote awareness in different contexts

sectors under the priority themes. Two workshops were held with local government staff from the eight WAGA councils that deliver services or operations within community wellbeing, emergency management, open space and water security. Through the workshops agreement was reached upon a set of adaptation principles to inform the indicators. These principles defined what good adaptation involves and draws from literature and practice of robust decision making (Hallegatte 2008; Silke and Renouf 2014) (see also https://www.weadapt.org/knowledge-base/adaptation-decision-making/robust-decision-making).

The adaptation principles that informed indicator development for *How Well Are We Adapting* focused on how adaptation implements processes or outcomes that:

- Continue to perform under a number of different future scenarios
- Increase flexibility
- Build in resilience and/or redundancy
- Meet planned budgets
- Don't increase CO_2-e
- Don't increase community vulnerability
- Avoids adverse outcomes (*mal*adaptation).

The workshops also asked practitioners to imagine what adaptation success would look like and developed narratives for successful adaptation for the region. Another important aspect of these indicator workshops was to use a set of indicator criteria to evaluate indicators and practitioners also considered whether to use formative and summative and whether indicators would be quantitative or qualitative. The following lists the indicator criteria used to develop indicators within the framework:

- Must be sensitive to change
- Data collection achievable
- Informative
- Useful more generally
- Council can influence.

4.3.4 Testing a Preliminary Framework and Sets of Indicators—Reflections on Implementation

A draft framework and two sets of indicators—Open space and water security (14 draft indicators) (Table 4.2) and Community wellbeing and emergency management (15 draft indicators) (Table 4.3) were produced following the practitioner workshops and tested during a pilot implementation period in 2015/16. The pilots recruited two of the eight councils to engage further with internal staff and attempt to collect the indicators. The pilots were an important step in finalising the ME&R framework, assisting in the evaluation of indicators against the indicator criteria identified in the practitioner workshops. The pilots originally aimed to test data collection against the indicators; however Indicators were not sufficiently developed to progress to data collection without first refining them through a detailed testing process with staff in the relevant internal teams. This led to a revision of the methodology for the pilots at a relatively early point. Rather than concentrating on data collection as a means to assess the framework, emphasis shifted to internal staff interviews, with a small data collection phase included at the end of the pilots. The pilots were valuable for their in depth refinement of the indicators which resulted in a much more robust set of indicators.

The project officer was able to draw on both the implementation phases including staff interviews to identify further potential barriers to a full

Table 4.2 Open space and water security (14 draft indicators)

	Open space and water security indicators		
		Capacity to report?	Example reporting
		Denotes capacity for optional or limited reporting	
		Denotes capacity of full reporting	Denotes reporting that may be considered high risk
1	**Service vulnerability and resilience**		
1.1A	**Type and volume of water supply used**		
	(a) Report total annual volumes of alternative or non-potable water used by supply type (e.g. recycled water, stormwater) to irrigate open space	Work needs to be done to refine this indicator and capture more reliable data. Difficult to estimate volumes of alternative supplies that aren't metered. Difficult to record the areas watered	About 15% of 68 ha of active open space is irrigated with alternative supply
	(b) Report total annual volumes of mains or potable water used to irrigate open space	Could report volumes without area. Or could hold this indicator over until data issues are resolved	37% active sporting reserves use potable water for irrigation
	(c) Describe any disruptions to alternative or non-potable water supplies observed during the year	Can report qualitative statements of disruptions to water supply	Minor, moderate or major. With description. E.g. Brimbank mentioned a moderate disruption caused by seasonal dryness in Spring 2015
1.1B	**Variation of the gap in water supply compared to demand over time**		
	(a) Report area that was physically unusable during the past year because water supply was unavailable	Can report. Need to standardise qualitative supporting statements	0 ha—No areas were physically unusable due to insufficient water supply
1.2	**Water efficiency**		
	(a) Report the overall water usage intensity for irrigated *active* open space (a few pavilions may be associated with this, but no car parks should be included)	Can report annual water intensity figures for active open space. Seasonal figures could be reported on an optional basis	5.8 ML/ha/year. No seasonal data
	(b) Report the overall water usage intensity for irrigated *passive* open space (a few pavilions may be associated with this, but no car parks should be included)	Issues with accurate reporting of passive open space area. Needs further work, or to be held over until this data is available	5 ML/ha/year No seasonal data
	(c) Annual list of water efficiency actions applied during the year	Can report. Need to standardise qualitative supporting statements	Warm season grass conversion, upgrade irrigation, soil aeration on all sites, wetting agents (at some sites)

(continued)

Table 4.2 (continued)

	Open space and water security indicators		
		Capacity to report?	Example reporting
2	**Institutional capacity**		
3	**Resourcing**		
3.1	**Changes in the long term trend in the cost and frequency of extreme weather event clean-ups**		
	(a) Report anecdotal notes about impacts on operational expenditure from climate change events observed during the year. Speak to open space or parks staff and ask them to answer the following questions	Can report	7 claims for trees. 0 claims for storms
	(b) Report the total annual $ amount associated with insurance claims	Can report	$0. No claims were paid due to being classified as 'act of nature'
3.2	**Understanding the impact of climate change on council's operational budgets**		
	(a) Report anecdotal notes about impacts on operational expenditure from climate change events observed during the year. Speak to open space or parks staff and ask them to answer the following questions	Can report qualitative data	Reduced amenity due to low rainfall and increasing temperature. Parks staff did not use their temporary staff overtime budget for growth season (spring) due to low rainfall reducing need for mowing
	(b) Long term trending of impact of water supply costs on operational budgets	At a minimum, councils should report annual main water expenditure and $/kL charge. Other data is optional	Recycled: $2/kL/year ($543,704) Mains: $2.66/kL/year ($567,704)
3.4	**What climate adaptation outcomes have been implemented in open space capital expenditure projects?**		
	(a) Report the proportion of open space capital works that have an adaptation action implemented	Can report. Need to standardise qualitative statements	Tree planting to increase canopy cover. Stormwater recovery project with CWW. Park retarding basin to reduce flash flooding

(continued)

Table 4.2 (continued)

	Open space and water security indicators		
		Capacity to report?	Example reporting
4	**Participation and awareness**		
4.1	**Understand community satisfaction with open space over time**		
	(b) Report the community satisfaction with sports grounds over the long term	Limited reporting can occur, depending on individual council relevance for this indicator and ability to collect and report it	7.72/17—already publicly reported
	(c) Community satisfaction with passive open space	Limited reporting can occur, depending on individual council relevance for this indicator and ability to collect and report it	7.25/14—already publicly reported

Source WAGA

implementation of the framework. Two key issues emerged, the first concerned resourcing constraints arising from conflict with pre-existing work commitments and insufficient work-planning. This was amplified through a lack of managerial support with other priorities seen to be more important. The second concerned the longer than expected time involved in undertaking effective internal engagement to get participation from other teams which was difficult to achieve in some areas. The engagement process, which was largely driven by the project officer took between six weeks to three months to gain internal support and negotiate with their existing work commitments. An organisation’s capacity to invest in climate adaptation response, committing in this case to a process of data collection, monitoring, evaluation, learning and review to inform decision making, requires political and senior management support and resourcing to support it (Productivity Commission 2012: 156). Without this support some council officers struggled to commit the necessary time towards the process.

Despite these challenges around implementation, the piloting process was important for a number of reasons. Firstly, the pilot process allowed for an assessment of the revised indicators to ensure they were valuable to operational teams’ decision making around adaptation response. This included confirming that indicators were considered achievable, either because of their alignment with existing reporting, or because it would not be very difficult to collect the necessary data. Secondly, the pilots also identified a need to determine whether there were different ‘levels of reporting’ required to accommodate a progression pathway from entry level reporting through to advanced reporting, to align with councils’ varying levels of adaptation capacity. Lastly, the pilots also initiated discussion around the disclosure levels for reporting against the framework including which indicators would be reported against internally only, and which would be reported publicly through the community-reporting tool.

Table 4.3 Community wellbeing and emergency management (15 draft indicators)

	Community wellbeing and emergency management indicators		
		Capacity to report?	Example reporting
		Denotes capacity for optional or limited reporting	
		Denotes capacity of full reporting	Denotes reporting that may be considered high risk
1	**Service vulnerability and resilience**		
1.1B	**Continuity of critical home and community care services**		
	(a) Report % of critical food, personal care and welfare check services rescheduled or cancelled during extreme weather events compared to average/standard service cancellation rates for critical services	Optional reporting, depending on each councils' interest in this indicator and ability to collect and report it. Qualitative statements can be provided for context	1% of services were disrupted during heat wave events. All cancellations were client-side cancellations due to hospitalisation
1.1C	**Continuity of critical maternal and child health services and family care services**		
	(b) Optional indicator: Report % of play group services cancelled during extreme weather events compared to average/ standard service cancellation rates for critical services	Optional reporting depending on individual council relevance for this indicator and ability to collect and report it	No playgroups were cancelled due to heatwave events
1.2A	**Residents seeking refuge in official, council-run emergency relief centres during severe weather events**		
	(a) Report the number of people using official and temporary refuge centres during extreme weather event emergencies	Report quantitative results with supporting qualitative context	0—No relevant EM activations occurred (heatwaves do not activate opening of relief centres)
	(b) Report any capacity breaches at refuge centres		
	(c) Report the type of service accessed at the centre		
1.2B	**Residents seeking relief at council managed centres during extreme weather**		
	(a) Report use of unofficial refuges such as libraries, leisure centres and community centres during extreme weather	Optional: Councils with data available can report data	20% increase in library attendance on heat wave days. 25% increase in leisure centre attendance on heatwave days. During extreme heat weather events Council responds with extended library hours, extended community centre

(continued)

Table 4.3 (continued)

	Community wellbeing and emergency management indicators		
		Capacity to report?	Example reporting
			hours and providing water at these places. Supervision ratios at leisure centres with pools are adjusted to ensure water safety
	(b) Report if capacity was breached at any Council managed centres during an extreme weather event	Optional reporting: Councils with data	Capacity was not breached. Capacity exceeded occupancy permit 5 times
	(c) Report whether any changes or responses have been made to better manage residents seeking relief	Standardised qualitative statement as a minimum for all councils	Council's leisure centre staff on hot days were asking people camped out to move on. They are now more aware of community need for cool spaces
2	**Institutional capacity**		
2.1A	**Staff capacity to address climate change in decision making**		
	(a) Report results of self-assessment or guided interview assessment of whether climate change impacts and responses were considered in decision making by coordinator and manager level staff within relevant work areas	All councils to report. Can report on number of staff surveyed, and give a standardised summary statement or assessment for each council for public reporting	Number of staff interviewed: 5. Average organisational scores demonstrated: Excellent level of awareness amongst staff. (Average 4/5). Good level of knowledge of supporting strategies, procedures and policies that addressed these impacts (Average 3/5). Marginal level of consideration of how to respond through day-to-day operations (2/5). Marginal degree of cooperation with internal departments and partner agencies (2/5)
2.2	**Emergency management framework recognises and responds to changing risk levels with climate change**		
	(a) Record how Council's emergency management framework recognises and responds to risk	All councils to report. Public reporting statement could be a high level statement of current process for considering climate impacts in CERA	CERA considers climate hazards, but not increases in climate hazards. Risk Action Plan was recently updated following a mini tornado. Review recommended improvement in info sharing process to facilitate decision making around need for post impact assessment

(continued)

Table 4.3 (continued)

	Community wellbeing and emergency management indicators		
		Capacity to report?	Example reporting
2.3	**Strategic consideration in emergency management**		
	(a) Record whether climate change considerations have been included in Council's Municipal Emergency Management Plan to increase prevention or preparedness for increased climate change impacts	All councils to report. Y/N and qualitative statement of how	Y: Climate Change Adaptation Plan has been added to part 3 of the MEMP which is the section that links to Council plans. N: Prevention and preparedness for climate change emergencies has not been considered in the MEMP, though the MEMP references Council's climate adaptation strategy which includes preventative actions
	(b) Record whether climate change considerations have been included in Council's Municipal Emergency Flood Plan	All councils to report	Y/N
	(c) Record whether climate change considerations have been included in Council's Municipal Fire Management Plan	All councils to report	Y/N
2.4	**Meeting legislative requirements**		
	(a) Record whether climate change considerations have been included in Council's Municipal Public Health and Wellbeing Plan (MPHWP)	All councils to report Y/N and scale (0–5)	Y (1) Requires improved consideration
3	**Resourcing and budgeting**		
3.1B	**Tracking long term trends in resourcing required to respond to extreme weather events**		
	(b) Provide report at the end of the heat wave season of any limiting or prioritisation of the critical Home And Community Care or Maternal Child Health services during prolonged extreme weather	Optional indicator: HBCC and BCC	Services restored within 2–3 days. In extreme cases, overtime and people redeployed to cover emergency Community gardens—need to make consideration about how these run during heat wave. All other Community Planning and Development activities are indoors (a/c)
4	**Community participation**		

These outcomes and challenges identified through the pilot process informed the broader roll out of the finalised framework with the five councils that participated. The project team expanded efforts to create buy-in through engagement with senior management, a lengthier embedding phase and dedicated project support to establish an initial baseline of data associated with the framework. Engagement with upper management was also important to facilitate stronger engagement and perceived value around the framework throughout implementation. Despite these efforts, buy-in was still difficult when the value of such a framework only becomes clearer overtime once data has been collected and long term trending is available to inform decision making.

The other key challenge that remained through the initial implementation was uncertainty around the number of indicators to include in the framework. With varying approaches to adaptation across the region, and similar, though not identical processes within the various local governments, along with differing capacities to resource data collection, there was never an agreed position on which indicators to keep or remove. Therefore, the framework kept many of the indicators, but allowed councils flexibility in choosing which ones they would use, depending on how narratives and indicator sets aligned with their organisations particular adaptation approach and data collection capacity.

4.4 Conclusion: Lessons for Decision Makers

In this chapter we have provided an analysis of how a group of local councils in Australia developed a framework to monitor, evaluate and report on climate change adaptation that was ‘fit-for-purpose’. While there are a range of frameworks and approaches to M&E for climate change adaptation available to local decision makers very few have been implemented and as such little is known about the process of actually ‘doing M&E’ in practice at the local scale. The Councils examined in this case study adopted a ‘learning by doing’ approach involving a range of key stakeholders to help inform the development of a framework that addressed a range of issues and challenges around M&E for CCA (identified through a literature review see Turner et al. 2014) and also addressed the specific needs of local councils who would be implementing the framework. In adopting a participatory approach, the project team was able to ensure that key stakeholders across each council understood the relevance and value of developing a framework and clarified the purpose of doing M&E for their service delivery areas. An important phase in the ‘How Well Are We Adapting?’ project was the piloting phase and subsequent evaluation of this phase as this revealed a range of practical challenges and issues around implementing an M&E framework, the lessons from which can inform future efforts in other municipalities. Here we highlight some of the key findings and lessons from this implementation phase that at the time of writing are informing the continued work on this project with WAGA councils.

While there were a number of challenges around the initial implementation which finished in 2016, many practitioners involved in the project have seen value in the framework and the indicators to inform their decision making and improve and align internal processes around climate change adaptation response. Some of the key benefits around the framework are that it allows councils to thoroughly embed adaptation into council activities and that the data effectively engages officers and senior managers across local government sectors by taking climate change adaptation from an abstract issue with ill-defined effects on service delivery to a tangible 'day-to-day' issue which they can identify directly impacting their work. The framework can also be used to monitor and facilitate governance and compliance for adaptation for local government against their internal adaptation strategies and assist with state government legislative requirements. The framework will also be used to share knowledge around the varying approaches and facilitate learning around adaptation across the region, providing a useful platform to compare differences and identify what is working and what needs to be improved.

The co-design of the indicators and narratives under the framework ensured that the framework was grounded in practical application, and that data collection and the indicators themselves would be broadly useful, readily collectible, and relevant to the defined scope and decision making processes embedded within local government. It also provides council staff with a sense of ownership over the framework, as something that has been designed by them and for their decision making, not just a framework that requires their input and would be informing someone else's decision making and analysis. The feedback from staff following the workshops also showed that the co-production process itself had increased recognition for the need to adapt to climate change, and contributed to general capacity building around adaptation amongst council staff, particularly a clear and tangible recognition of how climate change impacts affected their roles and responsibilities in local government. The workshops also allowed staff to shift their perspective toward longer term timeframes for their decision making and a realisation that there may be conflicting adaptation goals or trade offs around potential solutions at local and regional scales. Staff also recognised the importance of progress rather than perfection when learning to respond and adapt to climate change impacts and that the ME&R framework could be a useful tool to inform the learning process. These key benefits recognised by staff were crucial to the success of the framework, and helped ensure buy-in throughout the preliminary testing and roll out of the framework across the region.

In conclusion, the process and findings from this case study provide valuable insights into the issues and challenges around "the actual experience" (Ford and King 2015) of climate change adaptation work at the municipal scale. Given the common issues that local councils around the world face in responding to climate change, including lack of resources, limited capacities, variable leadership and political support in prioritising climate change and resilience, the need to develop effective and embedded M&E processes is critical to ensure that the decisions being made and actions taken are effective and efficient and importantly that lessons are learned to inform future decision making. It is hoped that the lessons from this case study can provide decision making support and guidance to others embarking on similar processes. As we see more examples of M&E processes emerging in local contexts, future research is needed to explore further how the process of embedding M&E is and can inform effective planning and decision making.

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Part II
Case Studies

Chapter 5
European Municipalities Engaging in Climate Change Mitigation and Adaptation Networks: Examining the Case of the Covenant of Mayors

Wolfgang Haupt

5.1 Introduction

In the last two decades climate protection alliances designed for towns and cities, such as the Local Agenda 21, Local Governments for Sustainability (ICLEI), the C40 Cities Climate Leadership Group or Energy Cities emerged in considerable numbers. Particularly in the current decade transnational climate initiatives, which include city networks, came to the centre of attention (Fuhr and Hickmann 2016, p. 89 ff.). One main reason for that arose out of the outcomes of the 2009 United Nations (UN) Climate Change Conference in Copenhagen. On that occasion, the assembled nation states spectacularly failed to agree on a follow-up document for the expiring Kyoto Protocol. City networks started to receive much more attention from academia and politics and some even considered them as good alternatives to the international climate negotiations (ibid.).

Six years later during the climate summit in Paris, representatives of cities and city networks found themselves in a much more influential position, even pushing the national leaders to come to notable agreements (Worland 2015). Rather new on the list of these city networks is the Covenant of Mayors (CoM), an initiative emerged in 2008. It was launched by the European Commission (EC), a supranational organ that over the years considerably paid more attention to cities and urban areas than most national governments in the European Union (EU) did. Egenhofer et al. (2010) referred to the CoM as the 'EU's flagship initiative' (2010, p. 9). Through the CoM the mayors of the signing municipalities pledge themselves to develop an action plan that leads to a distinct reduction of greenhouse gases. For most of the time the CoM was focussing on the mitigation agenda only, however, since very recently climate change adaptation is increasingly gaining importance. In this way, the initiative is consistent with the general debate: The summit in Paris

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brought a shift from mitigation to adaptation by promoting to consider them both as equal components of climate change action (Smith n.d.). The American Union of Concerned Scientists (UCSUSA) pointed out that the potential to close the resilience gap—"the degree to which a community or nation is unprepared for damaging climate effect"—is highest when combining adaptation and mitigation measures (UCSUSA 2016, p. 2).

This book chapter illustrates the different framework conditions on the European and global level that accompanied and facilitated the development of a network like the CoM. At first, the changing role and importance of the city mayor as a relevant stakeholder on the international scale is illustrated. Thereupon, the functioning of the CoM and its role and evolution in the European system is outlined. The following part is dedicated to the core document of every successful CoM-signatory: The Sustainable Energy and Climate Action Plan (SECAP). In the subsequent section it is discussed how the local policies corresponding to the CoM-membership are put into practice and how the decision making process is supported by the EU. The chapter is completed with an overview of the previous and present performance of the initiative.

Some of the conclusions drawn in this chapter derive—among other sources—from the results of an online-based questionnaire that produced some preliminary results. The survey addressed towns, cities and metropolitan areas that joined the initiative. It was carried out in March and April 2016 and was completed by 214 signatories from 27 countries. Since the response to the questionnaire was far away from representing a sufficient sample and since the participation rate was very different from country to country the results do not allow to formulating strong statements. The purpose of the survey was not and cannot be to fully reveal and explain the motives of local governments taking action on climate change. These preliminary results should rather be seen as a collection of opinions.

5.2 The City Mayor as a Global Political Actor

A mayor that exerts strong influence on the national level is not a new phenomenon. The former New York Mayor Michael Bloomberg once pointed out that his police forces are bigger than the ones of some US-states and that he even has an own foreign policy (Barber 2014b). Boris Johnson, mayor of London between 2008 and 2016, has undoubtedly become one of Britain's most observed and well-known politicians and is time and again considered as possible upcoming British Prime Minister. However, he would not be the first ex-mayor of a major city to become a state leader. The list of former local politicians to hold the most powerful political position of their country is long: There is Grover Cleveland, the twenty-second and twenty-fourth President of the United States and former mayor of Buffalo/New York State. Also the British Prime Minister Neville Chamberlain (Birmingham) and the first Chancellor of the Federal Republic of Germany, Konrad Adenauer (Cologne), were running a major city before entering the national policy level.

Willy Brandt, the first social democrat to become chancellor of Germany, made himself a name as mayor of West Berlin before. To round this list up, there are also Jacques Chirac, former mayor of Paris and long-time President of the Fifth French Republic and Matteo Renzi, Italian Prime Minister from 2013 to 2016 and former mayor of Florence.

Relatively new at the same time are mayors, who actively try to bring forward city issues on the global scale. The negotiations for the UN Climate Change Conference in 2015 were attended by a considerable number of big city mayors from all around the world. This included representatives from London, Seoul, Johannesburg, Mexico City, Sydney, Los Angeles, Montreal, Toronto and Vancouver, just to mention a few (Stothard 2015; Bailey 2015). The environment editor of The Guardian, Vidal (2015), summarizes the role of the mayors at the Paris summit as follows:

> What it shows is that much of the power to reduce climate emissions lies now with cities, not national governments. In the last few weeks, dozens of cities have lined up to announce targets that far surpass anything that countries can hope to do.

Five month before the Paris summit Pope Francis invited around 60 city mayors to a gathering on climate change. Although it was not the first event of that kind hosted by the Vatican, it was the first time the church leader specifically addressed local politicians. The event was complemented by a mayor's pledge to exhort and pressure nation state leaders to pass a profound agreement in Paris (Pianigani 2015).

> It's telling that the Pope is reaching out to mayors as part of his direct-action agenda to tackle climate action and poverty because we're on the front lines of it and we're committed to dealing with these challenges, reports Vancouver mayor George Robertson (Omand 2015).

Mayors around the globe are pursuing their own green agenda, and don't necessarily see the impact of local policies and ideas limited to the level of their own communities. 'We know this is how we can save the world', says Stockholm's mayor Karin Wanngård when she describes the practical measures that made her city Europe's first Green Capital (Larsson 2015). This is also the vision of the CoM: Developing a variety of possible climate change mitigation and adaptation strategies at the local level and sharing knowledge and experience among a network of towns and cities.

Most observers would agree that cities are one main cause of but also the main solution for the challenges arising by global climate change. Thus, mitigating greenhouse gas emissions directly, where most of them are induced, sounds reasonable. However, opportunists might invoke that mitigating or not mitigating in their own city will not have a serious impact on global warming. With regards to adaptation this argumentative pattern no longer works: The impacts of climate change are and will be noticeable everywhere and a city can only react to them with a tailor-made strategy that takes into account its specific vulnerabilities. Consequently, (urban) resilience should be in the interest of all municipal policy makers. Through providing a platform for exchanging ideas and expertise transnational networks can help to make cities more fit for the upcoming challenges and to a certain point assist them to take the lead in battling climate change. This has to be seen in the light of many nation states not appearing to be up to the job yet.

If Mayors Ruled the World—Dysfunctional Nations, Rising Cities: Already the title of Barber's book published in 2013 might sound quite provoking for some people. In his book Barber, a political scientist mostly known as passionate proponent of grassroots democracy, brings cities into play as new drivers for global leadership and as renovators of democracy (Barber 2013a, p. 3). Against a background of nation states struggling to deal with major global issues, be that the financial crisis, an immense inequality in economic and social development or climate change, he believes it is now the cities turn (Barber 2013a, pp. 3–24). People today are living in a world full of interdependences and cross-border issues. However, today's global issues are still mainly faced with institutions that were designed some four centuries ago: Autonomous, sovereign nation states with territory and jurisdictions apart from each other (Barber 2013b). Barbers perception is that the acceleration of globalization has led to a situation in which cites rather unrecognized are positioning themselves as autonomous global actors in order to find solutions to some of the most pressuring issues of humankind (ibid.). He sees the constantly rising number of international, intercity and cross-border institutions and networks of cities as a proof of his hypothesis (Barber 2013a, p. 5; Barber and Means 2016). For him, one explanation why cities seem to be more willing to act against climate change is because they are strongly exposed to its consequences. About 90% of cities are located near rivers or the seaside, places more exposed to the impacts of climate change (Barber 2014a). Also environmental issues are very urgent in many of the world's megacities. Consequently, it is not a surprise that more and more cities are joining together in networks such as the CoM (van Lindert 2016). Although, generally supporting the process of cities joining together in transnational networks (an initiative like the CoM) doesn't receive Barbers unlimited consent. In his view the EU is managing the network following a highly top-down principle:

> EU and national institutions are not in a position to explain to cities what they have to do. We have to go from cities to European level and not the opposite, because innovation comes from the ground. The most important thing is to empower cities and let them manage their own resources, so that they will not have to ask other levels for money. It is also a way to restore democracy (Energy Cities 2014, p. 3).

To put his vision of global urban governance into practice, Barber proposes the establishment of an informal global parliament of mayors. This assembly would include 300 representatives from 300 different cities[1] that meet three times a year, each time with a different set of cities (Barber 2013a, pp. 352–355).

[1]Cities between 50,000 and 500.000 and cities between 500.000 and 10 million inhabitants would send 125 representatives each, while 50 seats would be allotted to megacities bigger than 10 millions (Barber 2013a, pp. 352–355).

The reactions to Barber's book have varied considerably. Rogers (2013), New York Times urban affairs correspondent, called Barber's book 'the most audacious—even messianic—of a torrent of recently advanced urban manifestoes.' Besides, Barber finds a brother in spirits in Edward Glaeser, who makes the case for cities as mankind's best hope for the future (see Glaeser 2012). Furthermore, Barbers ideas about urban global governance are endorsed by Richard Florida and Don Tapscott, who jointly with him, published a report on a Global Parliament of Mayors governance network (see Barber et al. 2014).

Also Saskia Sassen came to similar conclusions as Barber. Indeed, Sassen (2012) admits that nation states are still important. Since they hold a broad range of duties, their political assertiveness is still enormous. Otherwise, she sees cities already as the forerunner of a complex global network, which will one day bear the main burden of solving global challenges. For Sassen there is no doubt that the future belongs to the cities and she posits that in 100 years city representatives will be more important than national governments (Sassen 2012). Like Barber, also Sassen is convinced that urban leaders are more likely to find solutions to issues of global importance, since they are reality in cities worldwide (Sassen 2013, pp. 2–4; Barber 2013a, p. 13). Especially with regards to environmental issues and climate change Sassen defends this position:

> Indeed, thousands of cities worldwide have initiated their own de facto environmental policies to the point of contravening national law, not because of idealism, but because they have been compelled to, as national governments are far more removed from the immediate catastrophic potentials of poisoned air and floods and have been slow to act (Sassen 2013, p. 4).

As mentioned, Barber's hypotheses did not remain unquestioned. De Graaf (2014), among others, is very sceptical about the (alleged) benefits of a world being governed by mayors:

> I would argue that the current generation of mayors, described in the book, is successful precisely because they do not rule the world. They are successful because they are allowed to focus on smaller, more immediate, more local responsibilities, which means that their efforts by definition generate quicker and more visible results (de Graaf 2014).

Another prominent critic of those who have little regard of nation states and describe them as archaic constructs that allegedly don't fit in the twenty-first century is Dani Rodrik. As economist he focuses stronger on economic effects of globalization and the role nation states play in it. Rodrik advocates a 'sane globalization' with sovereign nation states as individual key players that have the right 'to safeguard their domestic institutional choices' (Rodrik 2011, p. 240).

A range of different opinions on the proposed role of cities and nation states in the world has shown that this is rather an abstract and quite cardinal debate. This is also due to the often normative and all-embracing character of the ideas of thinkers like Saskia Sassen or Benjamin Barber. For some stakeholders, the strong visionary component in their ideas and convictions and the conclusions drawn by them might sometimes appear to be rather distant from the contemporary reality.

5.3 The Functioning of the Covenant of Mayors and Its Role in the European System

Being one of the most urbanized world regions, the EU has always recognized the importance of its urban structure (Cremaschi 2002). As areas with the largest share of growth and innovation urban areas were regarded as the places being mainly responsible for the well being in the EU (Cremaschi 2004). A look at spatial policies of the past two decades shows that the EU, mainly in the shape of the EC, has made significant attempts to identify and valorise cities as relevant policy actors on the European scale. The start was made with programs such as the Urban Pilot Projects (1989) and the Urban Program (1994) that were focussing on urban anti-poverty policies (ibid.). In the meantime, the urban dimension of the European spatial policy has grown further. For the 2014–2020 funding period of the European Regional Development Fund (ERDF), at least half of the subsidies placed at disposal are dedicated to urban areas. The EC plans to distribute around ten billion Euros to around 750 cities in order to support their efforts of implementing integrated strategies for sustainable urban development (EC 2016). So from the rather modest beginnings as a receiver of some poverty mitigation funds, now the urban level finds itself in the heart of the EU cohesion policy. Setting up an initiative like the CoM, that supports decision making in urban climate change mitigation and adaptation and helps connecting (small) towns, cities and urban areas to share knowledge and experience, is another example for the EC's concrete efforts to strengthen the role of the local level.

The efforts demonstrated by the EC seemed to be more profound than those ones being implemented on the national levels of most of the EU-states. Alongside this rescaling of the European spatial architecture towards cities and urban areas, these are consistently using the new opportunities offered by the processes of European integration and globalization. The change of direction towards the urban dimension was generally stronger on the European scale than on the national level. However, also the nation states made efforts to take account of the growing importance of the urban scale. Le Galès (2002) and Bäck et al. (2006) also reasoned the increased importance of the urban in Europe by major institutional changes in many countries of the union. One change would be that in some countries (e.g. United Kingdom, Germany, Italy) the election system was reformed in order to establish a direct election of the mayor by universal suffrage. Moreover, in some countries, where the mayor's role was already rather important (Scandinavia, France), their political influence on the national system was further strengthened (Le Galès 2002, p. 240). Mainly because of these institutional reforms Le Galès observed a general revaluation of European mayors and city councils and emphasized that many mayors and city councils are 'keen to see their cities becoming political actors in Europe' (p. 236). Other than most of the EC's implementations to strengthen cities in the European spatial architecture, the described institutional reforms in the mentioned countries were targeting the local level in general and not only cities or urban areas.

However, one example to show that also the EC showed efforts to recognize the local level as a whole is the CoM initiative, which welcomes municipalities of all sizes to engage in local action on climate change.

In 2008, the European Parliament adopted the 2020 climate and energy package including the so-called EU 20/20/20[2] targets (EC 2010, p. 2). The parliament making a decision aiming at national states is not an extraordinary act, but what followed shortly after certainly was: The EC launched the Covenant of Mayors initiative and thus directly involved the local level to achieve a major EU-wide objective.

Markku Markkula, president of the European Committee of the Regions (CoR), summarized it as follows:

> The Covenant of Mayors is a perfect example of successful multi-level governance in climate policy: it delivers results and surpasses national ambition (CoR 2015).

A local entity that signed the CoM commits itself to reduce the greenhouse gas (GHG)—emissions on its territory by at least twenty percent referring to the 2020 goals, or 40% referring to the 2030 goals (Kona et al. 2015, p. 5; CoM 2015, p. 2). By setting the minimum goal of a 20 and later 40% emission cut the EC explicitly encouraged the signatories to surpass the national level vision. The measures and policies to achieve this goal include, for instance, the development of renewable energies and increasing energy efficiency (CoM 2015, p. 2).

The CoM in its initial design tried to bring forward local climate change strategies for mitigation of greenhouse gases. In order to decide about the future thematic orientation of the initiative a large-scaled survey supported by the CoR was conducted in 2015. Here, a significant majority of CoM-signatories endorsed the idea of supplementing the mitigation vision with a climate change adaption dimension to increase a city's resilience to the impacts of climate change (CoM 2015, p. 2; CoM and Mayors Adapt 2015, p. 2). This was based on the conviction that mitigation and adaption represent strategies that complement each other. In addition, a merge of both can help 'to make the whole process more effective and cost-efficient, help harness political support and strengthen coordination among municipal departments' (CoM and Mayors Adapt 2015, p. 2). To put these desires in action, that same year the CoM was merged with Mayors Adapt, a climate change adaptation initiative launched by the EC in 2014 (ibid.). Mayors Adapt was set in motion in the context of the EU Adaption Strategy (CoM and Mayors Adapt 2015, p. 2). It enables towns and cities to optionally adopt local adaptation strategies as well as awareness-rising activities (CoM and Mayors Adapt 2015, p. 1). CoM and Mayors Adapt signatories that aimed to renew their commitments

[2]**EU 20/20/20** includes the following three targets: A 20% cut in greenhouse gases (base year 1990), 20% of renewable energy generation in the EU and a 20% improvement in energy efficiency (EC 2010, p. 2). In 2014 the EU member states agreed to add a new climate and energy framework for the years 2020 until 2030. The new targets for 2030 are a 40% cut in greenhouse gas emissions (base year 1990) and at least 27% renewable energy production and energy efficiency (European Council 2014, pp. 1–5).

were asked to also develop an adaptation strategy (CoM and Mayors Adapt 2015, p. 5). Since November 2015 it is no longer possible to join either the CoM or the Mayors Adapt but only the updated CoM with its 2030 mitigation and adaptation vision (CoM and Mayors Adapt 2015, p. 4). Mid-2016 the CoM merged with the Compact of Mayors, a global city network, to form the new Global Covenant of Mayors (Andrews 2017). This new initiative that aims to represent cities all around the world recently appointed nine city leaders to join a mayoral leadership board (ibid.). The group includes personalities like Park Won Soon, mayor of Seoul and President of ICLEI, Anne Hidalgo, Paris mayor and chair of the C40 group or Gregor Robertson, mayor of Vancouver (ibid.).

5.4 The Sustainable Energy and Climate Action Plan—The Heart of a Covenant-Membership

Within two years after joining the initiative the signing municipality is supposed to submit an action plan, in which the adaptation and mitigation strategies and goals are specified (CoM 2015, p. 5). Table 5.1 illustrates the intended process following signing the CoM. After the plan submission SEACP experts of the JRC-IE[3] evaluate it and decide if it will be validated. If this step was passed successfully, the local entity has the opportunity to gain access to funding programs relating to the SEACP implementation that are not available to municipalities without an approved action plan (Lombardi et al. 2016, p. 34). So far the submitted action plans proved to be more ambitious than the issued goal of a 20% emission decrease: Mid-May 2014 the action plans brought on the way had an average overall reduction goal of 28% (Kona et al. 2015, p. 6).[4] In 2015 the signatories that were already in the monitoring and reporting phase reached an average greenhouse gas reduction of 23% (Kona et al. 2015, p. 28). At the same time, there is also a fair number of signatories that missed the deadline (1643) to submit the SECAP and that are thus listed 'on-hold' in the CoM statistics (CoM 2017a). Some countries show a strikingly high number of signatory communities that didn't manage to submit their SECAP in time (France: 47%, Romania: 50.7%).

For a CoM-membership the SECAP can be regarded as the core document since it outlines and specifies the respective target and the strategy how to get it. By this means, the local action plan is a crucial document to define municipal energy policies (Schenone et al. 2015, p. 21). It turned out that many signatories don't use the action plan just as an energy planning tool but even as the fundament for an integrated urban planning approach (Kona et al. 2015, p. 40). The process towards the successful development of the plan should be structured in such a way as to guarantee a combined implementation of the plan actions and their monitoring

[3]JRC-IE stands for 'Joint Research Center, Institute of Energy' of the EC.

[4]The 28% overall average goal was referring to the 2020 framework (20% reduction goal).

Table 5.1 A common CoM roadmap

Steps/pillars	Mitigation	Adaptation
(1) Initiation and baseline review	Preparing a baseline emission inventory	Preparing a climate change risk and vulnerability assessment
(2) Strategic target setting and planning	Submitting a SECAP and mainstreaming mitigation and adaptation considerations into relevant policies, strategies and plans within two years following the municipal council decision	
(3) Implementation, monitoring and reporting	Report progress every second year following the SECAP submission in the initiative's platform	

Source CoM (2015, p. 5)

(Delponte et al. 2017, p. 17). Therefore, an organic transformation which involves different stakeholders, such as public administrations, business, academia and citizens needs, to be enabled (ibid.). One excellent example for this approach is the Danish city of Sønderborg, where more than 100 stakeholders from different sectors were involved in the developing process of the local strategy (Kona et al. 2015, p. 40). Despite the support signatories can receive from the CoM, the EC and regional or national authorities, implementing an SEACP is often a great challenge for a municipality. Reasons for that are often the lack of knowledge and economic resources (Ortego et al. 2015, p. 13). Especially because of that, the importance of best practice sharing among signatories, e.g. on the feasibility of certain measures and the expected results, cannot be overemphasized (ibid.).

To add, the questionnaire sent out to CoM-signatories suggests that, for some of the local representatives, the on-going economic crisis in many European countries severely hindered a successfully gathering of the human and financial resources to develop and implement a SEACP. Almost half of the survey respondents stated that the current crisis negatively affected the work on their action plans. Slightly less respondents quoted that the crisis had no effects on their work. In another step the interviewees were asked to specify concrete obstacles caused by the crisis that hinders them from implementing the SEACP. For many this was the cut of existing funding programs and/or the non-willingness of their governments to newly establish urgently needed programs. Besides, it was often stated that the crisis caused budgetary constraints in their municipality that complicated the implementation of the action plan. Furthermore a decreased willingness to invest from business and other interested stakeholders was named as another main obstacle. Since the impacts of the crisis differ from country to country it is not astonishing that the country-specific results also show some significant differences. Overall, the results reflect the current economic situations in the respective countries. The share of signatories that strongly feel that the crisis negatively impacts their work was particularly high in Spain, Greece, Portugal and Italy. In contrast, many signatories from Sweden, Austria, Germany, Denmark, Belgium and Malta stated they do not feel its negative effects. It seems that in order to meet the global challenges of climate change and the threat it poses to local communities a network that provides its members with effective assistance and access to (European) funding programs is needed, particularly in times of economic decline or stagnation and scarce public funds.

5.5 The Participation in the Initiative and Its Previous and Current Performance

In June 2017 there were a total of 6550 Covenant signatories from 53 different countries (see Table 5.2). In total, 5869 action plans were submitted and 1,419 of them were already implemented and are currently in the monitoring phase (ibid.). 793 municipalities and urban areas have signed up for the adaptation and mitigation goals (ibid.) These numbers illustrate that the (new) CoM is far away from having achieved an equilibrium of mitigation and adaptation. Thus, at this point it is difficult to estimate if and how the merge of the old CoM with Mayors Adapt and the even larger network of the Global Covenant of Mayors, that also demands an adaptation and a mitigation strategy (Compact of Mayors n.d., p. 10), will lead to a more effective response to climate change in the future.

To specify, both the highest total number of signatories and the highest share of signatories are to be found in Italy (CoM 2017a). Further countries with a significant number of signatories are, in this order, Spain, Belgium, Greece and Portugal and Ukraine (ibid.) The participating signatories represent around 7.8% of total local entities within the EU (CEMR[5] n.d.; CoM 2017a). However, the number of citizens being represented by the signatories is much higher: Roughly 225 million people live in local entities that signed up for the initiative (CoM 2017a). This can be explained with the relatively stronger participation of more populous cities and the participation of some metropolitan areas (Eurostat 2015). The vast majority of the EU's most populous cities has signed the CoM: 44 of the 50 biggest cities are members. The biggest cities that didn't sign are Marseille, Krakow, Łódź, Sheffield, Leipzig and Poznań. The only EU-capital not to sign is Valletta while Athens, Bucharest and Luxembourg signed, but are listed on-hold since they missed the deadline to submit their action plan (CoM 2017a; Eurostat 2015). The number of signatories and the participation rate differs greatly from country to country. In the following, some particularities of a few selected countries are briefly described.

A stronger participation than in Italy, both in percentage and in total numbers, cannot be observed in any other country. With 3241 signatories the Italians represent around 50% of all members. All of the 10 most populous cities of the country signed; the biggest city not to sign is Taranto. However, the participation is strong among cities of all sizes: 123 cities with more than 50,000 inhabitants, 665 with a population between 50,000 and 10,000 and 2454 smaller than 10,000 signed up for the imitative (CoM 2017a; Eurostat 2015). With its 1786 signatories Spain is another country with a very high total number: 27.3% of all CoM-members are from Spain. Like in Italy, the participation is strong in towns and cities of all sizes. Except for Las Palmas all of Spain's 10 most populous cities joined the initiative. 91 Spanish CoM-municipalities have a population higher than 50,000, 316 are between 10,000 and 50,000 and 1379 are smaller than 10,000 (CoM 2017a; Eurostat 2015).

[5]CEMR: European Committee of the Regions

Table 5.2 Number of signatories per country (June 2016)

3241	Italy	1786	Spain	288	Belgium
149	Greece	117	Portugal	110	Ukraine
87	France	73	Croatia	72	Romania
59	Germany	56	Sweden	40	Poland
36	Denmark	35	United Kingdom	34	Hungary
29	Slovenia	25	Bulgaria	24	Cyprus, Malta
22	Belarus	21	Latvia	19	Bosnia and Herzegovina
18	Netherlands	15	Armenia, Lithuania	14	Moldova
13	Austria, Slovakia	12	Finland, Georgia, Ireland,	11	Turkey
9	Switzerland	8	Czech Republic, Lebanon, Norway	4	Estonia, Morocco, Palestinian Territories
3	Albania, Algeria, Israel, Montenegro,	1	Azerbaijan, Iceland, Jordan, Kazakhstan, Macedonia, New Zealand, Serbia, Tajikistan, Tunisia		

Source Own diagram based on CoM (2017a)

On the one hand, the strikingly high number of signatories from Italy and Spain—around three quarters of the whole initiative's members are from one of the two countries—consequently leads to a high number of action plans (CoM 2017a). On the other hand, there are justifiable doubts about the significance of the commitments of many Italian and Spanish municipalities. Olazabal et al. (2014, p. 9) pointed out that around 96% of the signatories from both countries committed themselves to a reduction target close to the minimum agreement of 20%. Furthermore many municipalities, around 40% in Italy, have not even committed to any target in 2014 (ibid.). Also the vast majority of the action plans must be regarded as sole mitigation plans (De Gregorio Hurtado et al. 2015, p. 42). At the same time, over the last years a number of cities, such as Barcelona, Madrid, Valencia or Bologna have developed plans with a stronger adaptation component (ibid.). In these cases, this development was mainly pushed by the Mayors Adapt initiative (ibid.).

Although having the 17th highest number of total members (87), France finds itself on the third last position in the percental share of signatories. This can be explained by the circumstance that France is by far the country with the highest number of municipalities in the EU. With its 36,682 municipalities the country is home to more than one third of all EU-communities. The average French signatory is significantly more populous than the average French municipality: Only 21 signatory communities are smaller than 10,000 inhabitants. In France there is the strong participation of urban areas consisting of one or more big cities and their surrounding areas and associations of local authorities (32) that joined the CoM as one signatory (CEMR n.d.; CoM 2017a; Eurostat 2015).

The German mayors apparently perceive the Covenant as an affair for big cities only. Just 59 of the 11,213 German municipalities have signed it (CoM 2017a; CEMR n.d.). However, these municipalities represent a population of around seventeen million. 13 signatories have a population higher than 500.000 and a

Table 5.3 Different forms of participation by country

Strong overall participation	Low overall participation	Dominance of big communities	Dominance of smaller communities	Strong participation of big and small communities
Belgium, Denmark, Georgia, Greece, Italy, Lithuania, Latvia, Malta, Spain, Sweden	Austria, Czech Republic, France, Germany, Hungary, Luxembourg, Slovakia	Denmark, Finland, Georgia, Germany, Netherlands, Norway, Sweden, UK, Ukraine	Austria, Croatia, Hungary, Malta, Portugal, Slovenia	Belgium, Cyprus, Greece, Italy, Latvia, Spain, Sweden

Source Own diagram based on CoM (2017a) and Eurostat (2015)

further 18 have more than 100,000 inhabitants, while only two signing municipalities were smaller than 10,000 (CoM 2017a; Eurostat 2015). The situation in the United Kingdom (UK) is quite similar to Germany. Also in the UK there is a high number of fairly populous participating local entities: 35 British signatories represent more than twenty million citizens (CoM 2017a; Eurostat 2015).

Table 5.3 summarizes and classifies the varying forms and rates of participation across countries. Synoptically reviewed, the CoM is an initiative addressing a large number of countries with partially different political systems and national policies. It must be assumed that there are a couple of general and country-specific reasons to explain the very different role the CoM plays in each country. However, a detailed examination to identify and to interpret these differences is beyond the research question and the framework of this chapter.

5.6 How Are the Policies Put It into Practice and How Is the Decision Making Process Supported?

On their way to implement their action plans,[6] the signatories are assisted by CoM-supporters and coordinators. The coordinators can be subdivided in national (regional and provincial authorities) and territorial coordinators (national energy agencies and ministries). Their main duties are to provide the signatories with the administrative, technical and financial assistance they need for the implementation of their SECAP. The CoM-supporters consist of networks of local and regional authorities and help to promote the initiatives' vision through their communication and networking activities (CoM n.d.). In a technical report by the EC's science service it was pointed out that an effective combination of urban energy policies and

[6]For the 2020 goals: Sustainable Energy Action Plan (SEAP). For the new 2030 goals: Sustainable Energy and Climate Action Plans (SEACP) (CoM n.d.).

a better coordination between the local and the national government are of major importance for tapping the potential for urban climate change mitigation (Kona et al. 2015, p. 40). It could be observed that, in some cases, these coordinators were successful in connecting small and medium-sized communities with stakeholders from the regional level and thus enabled the participation of municipalities that otherwise would have struggled to develop an SEACP on their own (Kona et al. 2015, p. 40).

Via its webpage the CoM regularly informs its signatories and the interested public about conferences, seminars or workshops. This can help to get new ideas and stimuli for the concrete projects to work on and to connect the municipality representatives with each other. In the questionnaire the signatories were also asked if they attend these events and a solid majority of around two thirds indicated to do this. However, only a bit more than 10% stated to attend these events on a regular basis, whereas the majority attends them once in a while. Another tool provided for municipalities to be informed or to learn more about possible strategies and measures to reach their goals is the 'Benchmark of Excellence'. It lists local initiatives of CoM-signatories that can serve as examples worthy of imitation (CoM 2017b). Participating municipalities have the opportunity to present their projects and share relevant information such as the achieved GHG-reduction or the implementation costs. So far 4933 of these benchmarks are shared on the CoM-website (ibid.).

Many municipalities engaging in city networks are highly dependent on external funding in order to implement large-scale local climate protection measures (Fuhr and Hickmann 2016, p. 91). For an effective planning of climate change response local governments need funding (De Gregorio Hurtado et al. 2015, p. 43). This need is particularly strong for medium-sized cities with fewer resources (Reckien et al. 2015, p. 2). Also the survey results suggest that access to funding sources is important for implementing local climate change action. More than one third of the interviewees stated that they successfully applied for funding programs in connection with their CoM-commitments. About one half was generally satisfied with the funds available on the national and European level, whereas the other half indicated they don't receive any funding. The national programs seem to be of certain importance in this context, since the results differ significantly from country to country. There are Sweden, Denmark, Georgia, Belgium and Germany where a solid majority of the interviewees was fully or generally satisfied with the funding and there is Italy where the majority indicated they don't get any subsidies. Less clear were the results in Spain and Ukraine, where about one half stated to be generally satisfied with the available funding sources, whereas about the same number responded that they don't receive funding at all. However, while these questions provide an insight into the signatory's overall assessment of the existing funding opportunities and its current state, they only cover if the municipalities from the respective countries were satisfied or dissatisfied with their existing national funding framework.

As shown, the availability of national funding sources can differ from country to country. However, there are also Europe-wide funding programs that are equally accessible for local and regional authorities from all EU-member countries. For European municipalities working on the implementation of renewable energy or energy efficiency projects there is the European Local Energy Assistance (ELENA) program (Lombardi et al. 2016, p. 39). The funding target of the program is helping to achieve the EU 2020 goals (European Investment Bank n.d.). The funding provided by ELENA is closely linked to the needs of the local level and is thus considered the most suitable program for CoM-signatories (Lombardi et al. 2016, p. 35; European Investment Bank 2012, p. 1). The biggest obstacle for local entities is not always just the lack of financial resources, but often even more the lack of know-how or the capacity to implement a project (European Investment Bank 2012, p. 1). A lack of technical knowledge and experience in handling renewable energy or energy efficiency projects was also pointed out as one main limiting factor by some of the survey respondents. Through the program, local and regional authorities have the opportunity to receive the financial means needed for the technical support of (large-scale) projects (Lombardi et al. 2016, p. 35; European Investment Bank n.d.). Here, ELENA can cover up to 90% of the eligible costs of a project (European Investment Bank 2012, p. 2). Until 2016, there were twelve completed and thirty-nine on-going ELENA-funded projects (European Investment Bank 2016). The highest number of (successful) project applications came from local and regional authorities from Italy, the UK, Spain, Denmark and the Netherlands (ibid.).

ELENA is by far not the only funding instrument that can help local entities to put their commitments into practice. The CoM provides its members with a long list of different funding sources that can be eligible, depending on the specific project, which is constantly being updated. Also the EC now adapts, upgrades and creates new specific financial mechanisms that can be helpful for the financing and implementation of a SEACP (Lombardi et al. 2016, p. 35). However, despite these opportunities available on the European level, in most cases municipalities still rely on incentives from the regional or national level (Kona et al. 2015, p. 41). This finding is in compliance with the results of the survey, where almost half of the respondents stated to not receive any funding: An answer that must lead to the assumption that these local representatives only took into consideration the funding opportunities of their region or country.

The CoM represents only one of the many transnational networks. The literature dealing with the added values of network governance suggests that policy learning from other cities and professionals seems to be, despite being a rather soft and difficult to measure outcome, one of the main assets of city networks (Pattberg and Widerberg 2015, p. 693). Giest and Howlett (2013, p. 12) described that "the analysis of various networks shows that environmental challenges are being addressed through network management efforts, because individual local governments lack the capacity or resources to address some issues without the cooperation of neighbouring municipalities while national governments deliver incentives". In the framework of its Making Cities Resilient Campaign the UN Office for Disaster Risk Reduction outlined that accelerated learning among cities is a key component of urban responses required to cope with the challenges caused by climate change and by rapidly changing urban environments (van Herk et al. 2016). All this suggests that that a main value of city networks has to be seen in serving as a platform for and facilitator of knowledge sharing and collaboration between cities, which eventually bears the potential to enhance urban resilience.

To sum it up, there are a variety of tools provided by the CoM and the EU to support the development of local climate change mitigation and adaption. Engaging in the CoM-network can trigger the sharing of knowledge and experience, facilitates the access to national and European funding programs and allows the signatories to benefit from institutional support provided by local and national bodies. Through the CoM the work on implementing mitigation and adaptation measures can be organized in a more simple and effective way, an asset that can be crucial in times of economic crisis and diminishing public resources.

5.7 Conclusion

Transnational city networks play an increasingly more important role for solving global issues such as limiting the extent and dealing with the impacts of climate change. Not least through launching an initiative like the Covenant of Mayors the European Commission has identified towns, cities and urban areas as relevant actors on the political scene. In some member countries these efforts were complemented by major institutional changes that helped strengthening the position of the local level.

The CoM is an initiative that encourages municipalities to engage in topics and tackle issues that were some years before an exclusive domain of the spatial levels above the local. Many towns and cities showed the willingness to make use of these new opportunities. In order to develop climate change mitigation and adaptation strategies in order to increase climate resilience municipalities often do not want to work on their own but seek the cooperation with their colleagues. However, when it becomes more tangible the optimism of many signatories is giving way to realism: A successful implementation of a climate change action plan, in the majority of the cases, appears to be not possible without (monetary) assistance from the national level. This is especially so for municipalities from Southern Europe, which represent the clear majority of the initiative's signatories.

On their way to implement the action plan the signatories' are supported by a number of tools provided by the initiative. The CoM informs its members regularly about events and workshops. Regional and provincial authorities, as well as national energy agencies and ministries support and help coordinating the work of the signatories. Cites get connected to each other and encourage to share ideas and experiences. Moreover, the 'Benchmark of Excellence' as the best practice-sharing instrument was set in motion. Ideally, these tools will contribute to having better informed and better coordinated municipal policy makers.

In general and also within in the CoM, climate change adaptation did not receive the same attention as mitigation, although things are slowly changing. The initiative is heading towards a thematically more balanced response to climate change.

The reasons for this are the merge with the adaptation initiative Mayors Adapt and the setting of new guidelines binding new signatories to work on both mitigation and adaptation.

Ultimately, the final success and the long-term significance of this initiative remain unclear. However, it should be recognized that with setting a new framework for the year 2030 and with including the adaptation dimension, the initiative and its members have done a lot to prevent the Covenant of Mayors from being just a passing phase.

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Chapter 6
Barcelona Experience in Resilience: An Integrated Governance Model for Operationalizing Urban Resilience

Lorenzo Chelleri

6.1 Introduction

In the last two decades the concept of resilience conquered global policy reports dealing with sustainability and urbanization processes (GSP 2012). Many cities have started to label with this concept any climate, environmental or disaster risk reduction plan. This has resulted in a growing literature criticizing resilience for its conceptual emptiness (Albers and Deppisch 2012; Pizzo 2015). While having a long tradition in engineering and social sciences, resilience applied to cities only recently has been explored, recognizing the complexity of its operationalization (Chelleri and Olazabal 2012). Indeed, while different projects could easily integrate resilience through safety, redundancy or flexibility measures, the application of this concept to cities rises different issues. Among others, knowing that cities are characterized from "slow and incremental processes of growth and accumulation" from one side and "rapid and sudden processes of destruction and reorganization shaped under a disturbance" on the other (Eraydin and Taşan-Kok 2013:6) these questions come to mind: how to integrate the resilience with respect to short- and long- term threats? and How to prioritize between investments in short term treats-responses, or building long term resilience through adaptive capacities building? Consequently, some scholars suggested the importance of conceptually distinguishing between embedded 'inherent resilience' of a system and 'adaptive resilience' process (Cutter et al. 2008), or between 'cumulative' and 'disaster' resilience (Johnson and Blackburn 2014). A related issue is therefore how to put into urban planning and management practices the emerging and metaphorical "urban resilience thinking" (Elmqvist 2014), enabling the shift from a project or

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plan centred approach in building resilience to an integrated policy or governance process. This chapter offers a clear example about a tentative framework for framing such an integrated governance centred around the concept of city resilience. By reviewing the last five years of Barcelona policies and strategic moves in framing a Municipality Resilience Unit, and exploring the range of past and current resilience related projects within the city, this chapter contributes to better understand challenges and opportunities of framing a resilience related governance model.

6.2 Methods

This case study has been developed through a qualitative research addressing the analysis of official institutional documents and plans, and attending 2 international workshops organized in Barcelona by the city council in order to launch the Barcelona resilience model. Furthermore, preliminary learning and results have been discussed and implemented through a set of semi-structured interviews, with policy officials from the Barcelona City Council, members of the UN-Habitat City Resilience Profiling Programme (CRPP), and the research institutes, foundations and industry partners constituting the Barcelona Partnership for Urban Resilience (interviews performed from January to June 2015).

6.3 Case Study Introduction: The Background for Building the Barcelona City Resilience Strategy

Barcelona is one of the most known Mediterranean cities because of its vibrant night life and quality of public spaces, but also because of its governance based "Barcelona Model" (Marshall 2000), risen after the Olympics (1992). Indeed, the city leveraged through the Olympic Games a set of strategic investments in mobility and public space design operationalized through very efficient public-private partnerships, which has been defined as the Barcelona Model. Been the capital of Catalonia region (Spain), Barcelona is a dense and compact city as illustrated in the Fig. 6.1. The city municipal area is included between two river estuaries, the sea and the north-western Collserola hill.

As many other Mediterranean cities, Barcelona suffered periodical flooding, droughts and summer heat waves. However, and unexpectedly, among all those stresses, a tipping point shaking the city government decision making process has been a technical failure happening in 2007, when the city suffered during the same year three unexpected events threatening business continuity in the city. The first was a blackout leaving over 300,000 users (corresponding to 6 city districts) without electricity for almost three days and implying: three subways to be out of

Fig. 6.1 Barcelona location and city centre morphology. *Source* Author from Google Map

service for almost half an hour, six hospitals running only the most urgent surgeries thanks to their emergency generators, traffic jam out of control due to 23,100 traffic lights off (60% of the total), temporal breakdown of water supply and communication services due to the interdependency with the energy provision. There is no official estimated costs of those three days of blackout, but in 2013 ENDESA, the energy distribution utility company, and the *Red Electrica de España* (Spanish Electricity Net), have been fined with a 20 Ml Euro penalty for the blackout. Back to summer 2007, just after the blackout, an accident during the works for the high speed railway interrupted the train services, causing several human injuries. At the same time, a slow but worrying climatic variable threatened Barcelona, since the whole Catalonia region suffered the driest seasons in more than 60 years (AGBAR 2009). Barcelona metropolitan area population (counting with 3.2 Million inhabitants) is provided with the freshwater coming from the two river basins of Ter and Llobregat, while counting with 5 water reservoirs of 789 hm^3/year, supplying a total average water demand of 525 hm^3/year. In 2007 and until 2010, the freshwater reservoirs registered a deficit of 177 hm^3/year in water re-charge (Dalmau et al. 2008). While different technical and policy solutions were trying to respond to the water scarcity, in 2011 Barcelona suffered some unexpected and out-of-the-range floods with precipitations that reached 100 mm rainwater in less than 48 h and a maximum intensity of 47.7 mm in 1 h (Servei Meteorològic de Catalunya 2011).

6.4 Barcelona Responses Toward an Integrated Model of City Resilience Projects Management

The unexpected concentration of emergencies triggered a set of responses dealing both with climate change and technological potential failures issues. From the recently created *Oficina Catalana por el Canvi Climatic* (OCCC—Catalan Office for Climate Change) established in 2007 the *Convencion Catalana por el Canvi Climatic* (CCCC—Catalan Convention for Climate Change) putting the bases for the forthcoming *Plan por la Mitigació al Canvi Climátic en Cataluña 2008/2012* (Plan for Climate Change Mitigation in Catalonia; PNACC 2008). From the other side, Barcelona city council run in 2008 an assessment on the vulnerability of its infrastructures and services called 3Ss (Security of Services Supply). This vulnerability assessment identified the weakest points of the city infrastructures networks and highlighted their interdependencies suggesting 40 improvement projects. In Fig. 6.2c the 40 actions enhancing city resilience have been illustrated, and among these the most strategic are: emergency protocol in case of food chain problems (14), audit on the safety state of underground tunnels (21), optimization of the performance of electric buses (32), review of the Drought Plan (44), and assessment of the relationships between gas and water pipelines (51). All these actions have been framed within 8 management issues (represented using different colours in Fig. 6.2b, c) corresponding to different sub-department of the city council, which are: municipality services, urban tunnels, electricity, water cycle, energy, mobility and public transport, telecommunication and finally underground works. In order to manage all those projects and decision-making processes in an integrated way, a management board has been established in 2009, called *Taula de Infraestructuras i Serveis Urbans TISU* (Resilience Technical Bureau on Infrastructures and Services Supply, Barcelona City Council 2013). As represented in Fig. 6.2b, TISU wants to be a formal and institutional place where seventy-two professionals involved in thirty-seven entities are clustered within different Municipality departments, sharing information and coordinating their involvement in the 40 Improvement Projects enhancing city resilience.

In its first stage of existence, the TISU operated with the objective of improving the relationship with all the public and private actors involved in the Improvement Projects, establishing a coordination team (CT) re-defining the projects (if needed) in order to deepen a self-assessment process, and better detect and tackle the dynamic nature of urban vulnerability (Valdes et al. 2013). As reported by Filippi, five years after the creation of the TISU there were only four projects completed out of the forty established in 2009 (Filippi 2014). However, apart from the performance of the projects implementation, TISU evolved step by step toward an integrated governance-oriented model, including more urban challenges including sustainability and societal issues (Valdes and Ferrer 2015). Indeed, two more topics, or boards (related to social Services and Urban Planning), were introduced within the 8 sectors previously framed. Also, a Control Room where services incidences are reported was established, jointly with a Situation Room (an information

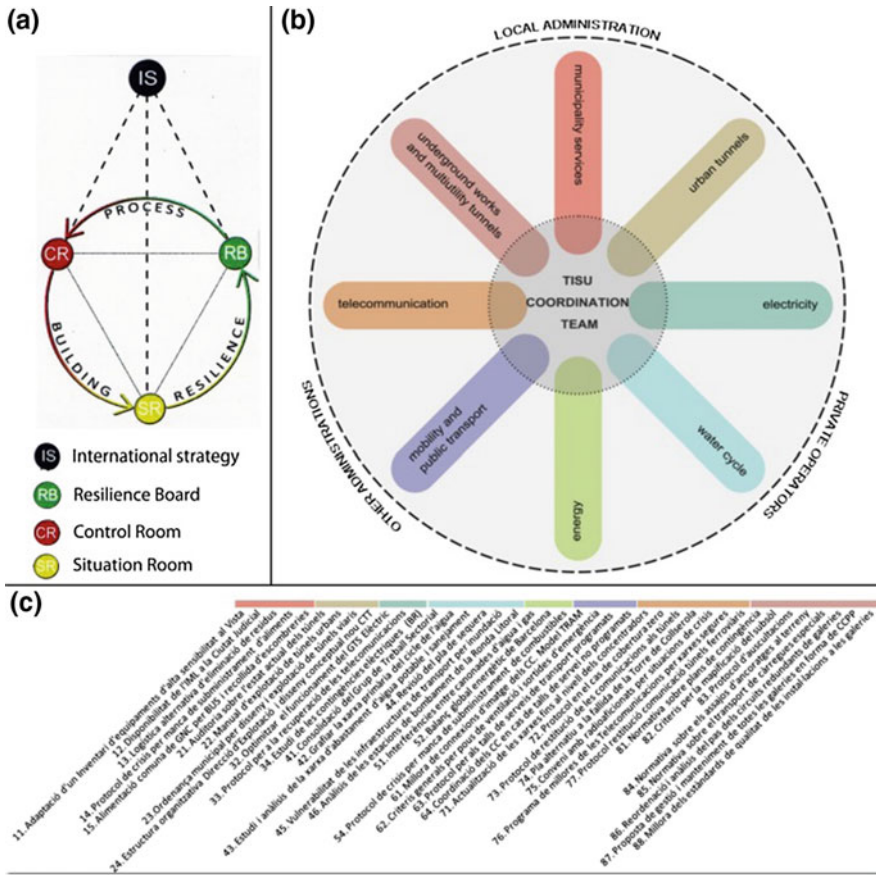

Fig. 6.2 Barcelona resilience strategy (**a**), TISU resilience boards (**b**) and the related actions proposed by the 3Ss report (**c**). *Source* Author from Barcelona Municipality 2013

platform supporting decision making processes, improving the emergency management), contributing to build a new, and as much as possible integrated, working method dealing with urban risks management (illustrated in Fig. 6.2a). Such a working method is a continuous process, in which any service failure-incidence is detected and reported by the Control Room, then managed in the emergency phase in the Situation Room and finally the Resilience Boards will take the necessary decision in order to manage the necessary actions/projects to enhance the resilience to the risks triggering the failure. What emerged from such a working methodology is not only the working tasks and responsibility re-framing within different Municipality departments, but the increased cross-sectors collaboration within a set of industrial and international partners, supporting the different projects and the dissemination of such a good governance practice.

6.5 Unpacking and Understanding the Barcelona City Resilience Model

From the creation of the TISU resilience board, Barcelona successfully promoted in different international events this integrated projects management model, until been awarded in 2013 as “role model city” for infrastructures and services risks reduction policies from the UNISDR Making Cities Resilient campaign. Also, being already part of the C40 Network for climate mitigation challenges, the city strategically offers to host and support financially the headquarter of the UN-Habitat City Resilience Profiling Program (CRPP) and one year later awarded to become one of the Rockefeller Foundation’s 100 Resilient Cities. Officially, the Barcelona Resilience Model (consisting within the TISU boards and integrated management described above) has been defined and presented during the first international workshop organized by the municipality and titled “Barcelona’s Experience in Resilience”, on February 2015.

Because of this rapid and successful international networking and support, framing public-private partnerships and defining a governance model, in the following sections this chapter uncovers all the strategic steps, and components of this emerging model. In particular, the two following sections will explain: (a) which influences and strategic political moves lead to the creation of the proper locals and international network of supporters for the Barcelona resilience model to be proposed, and (b) which previous specific experiences and expertise in resilience constituted the bases in Barcelona for a successful framing of the model.

6.5.1 Institutional Re-framing and Strategic Moves Toward a Resilience-Centred Governance Approach

The crises shaking the city from 2007 led to the creation of the TISU resilience board, but until the 2013, as briefly introduced above, there was not an international projection, nor the official announcement, or promotion, of any “governance model”. Indeed, the shift from an internal projects’ integrated coordination board to a governance model happened after a mayor policy change happening in Barcelona in 2011. A new department called *Hàbitat Urbà* (urban habitat) was created when the right-wing party won the election after almost 30 years of leftists. The mission of the new department was to integrate the existing variety of different units dealing with urban planning and management related issues (see Fig. 6.3). Leveraging on this new integrated configuration of the units the new deputy chief of the TISU board (previously managed by the infrastructure unit) succeeded to propose and create a new unit named Resilience Unit, expanding the previous mission of the TISU board and having influences on most of the other units and departments (Filippi 2014).

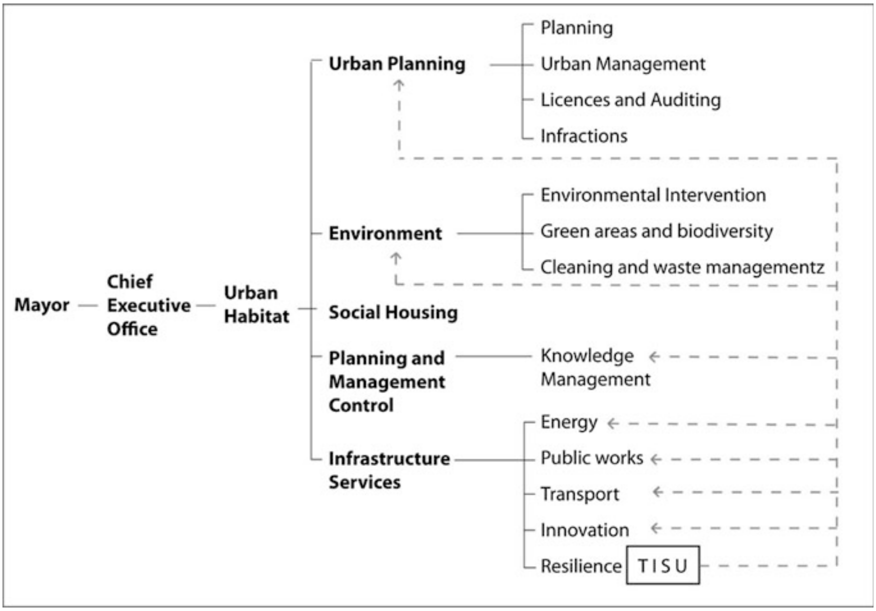

Fig. 6.3 The organizational chart of the Barcelona Municipality departments in 2014, with emphasis on the new Resilience Unit position within the hierarchy and its emerging influences on other units. *Source* Adapted from Filippi (2014)

Having the opportunity to influence others units' projects, and therefore be also connected with a vast number of private companies involved in public-private partnerships, in 2013 the team of the resilience unit succeeded in building a consortium of 13 industry partners and research institutes (which will be named Barcelona Partnership for Urban Resilience) financially supporting with 2 Ml euros in four years the Municipality in offering to host in Barcelona the Headquarters of the City Resilience Profiling Programme (CRPP), by the United Nations Human Settlements Programme (interviews and national press).[1] UN-Habitat CRPP is a program framing an innovative assessment tool for driving investments once urban resilience needs to be operationalized. Such a tool should be able to evaluate a range of urban risks in an integrated way in order to prioritize them, offering practical advises, based on solid evidences and measures, to practictioners and decision makers. Also, the CRPP works with global partners such as the UNISDR Secretariat, Red Cross, Habitat Partner Universities, big insurance groups, engineering and utility companies, and last but not at least relevant global networks such as ICLEI, Rockefeller 100 Resilient Cities, UCLG, Metropolis and the C40 Climate Leadership Group. Furthermore, Barcelona Municipality being among the

[1]http://www.elperiodico.com/es/noticias/barcelona/bcn-sera-sede-programa-onu-2355024.

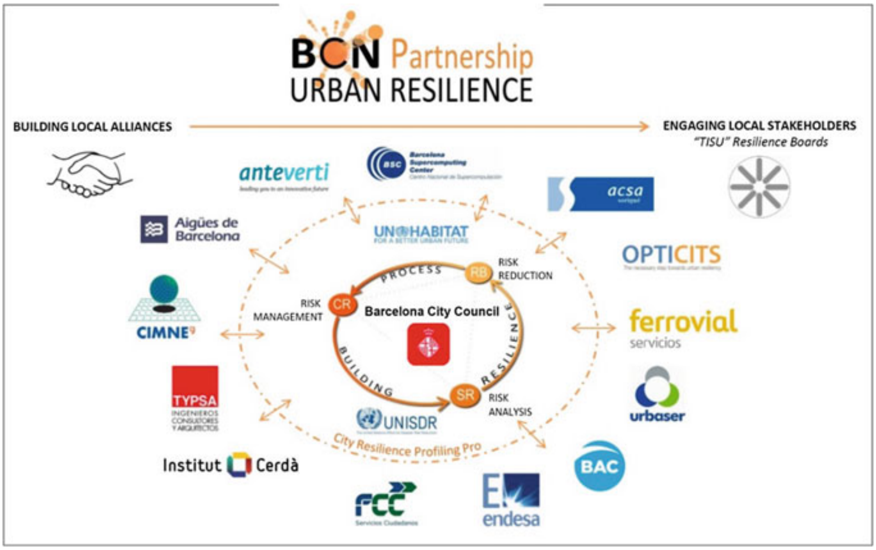

Fig. 6.4 Barcelona partnership for urban resilience. *Source* Author from Valdes and Ferrer 2015

10 selected cities of the CRPP,[2] the Resilience Unit would be directly involved in the framing and testing of the CRPP urban resilience framework, tools and indicators. In the light of all these networking opportunities and strategic partnerships the consortium built from the Resilience Unit was aiming at bridging, broadening and exporting commercially their accumulated local resilience expertise, also leveraging on the more than 2000 cities involved within UN-Habitat activities (interviews with different Barcelona Partnership for urban resilience members, 2015). Formally, the Barcelona Partnership for Urban Resilience[3] has been created as a public-private alliance built on the TISU framework (as illustrated in the Fig. 6.4) and contributing to shape the Barcelona Resilience Model, defined as "a multi-level public-private long term collaboration fostering local and international networking in order to shape resilience strategies and boost experiences and opportunities sharing" (Valdes and Ferrer 2015).

This governance model, framing public-private partnerships within a set of key strategic networking moves has been presented as an innovative and effective way to operationalize resilience to the Rockefeller 100 Resilient Cities program, which recognized and awarded it in 2014. Once hired officially a Chief Resilience Officer, Barcelona undergo another political turn in 2015, with the left-wing party again in

[2]The ten cities, selected on the bases of the successful proposals submitted to UN-Habitat in response its call in November 2012, are: Balangoda (Sri Lanka), Barcelona (Spain), Beirut (Lebanon), Dagupan (Philippines), Dar es Salaam (Tanzania), Lokoja (Nigeria), Portmore (Jamaica), Concepcion/Talcahuano (Chile), Tehran (Iran), and Wellington (New Zealand).

[3]See http://www.barcelonaresiliencegroup.org/.

power. Due to the economic crisis and recent cut in education, health, and different social programs, the new policy agenda was promoting social policies while neglecting the recent emphasis and budget on infrastructures and public works. Also because of this turnover, the very same Resilience Unit, leading the Barcelona Partnership for Resilience, suddenly introduced within their goals "social resilience" aspects (officially presented during the Barcelona Experience in Resilience Workshop, held in February 2015, see Valdes and Ferrer 2015). Indeed, the official resilience challenges for Barcelona, as reported in the website of Rockefeller 100 Resilient cities program, are: flooding, heat waves, high unemployment, lack of affordable housing and social inequity.[4] However, Barcelona experience in resilience (explored in the next section) from one side does address physical and climatic threats, but from the other, social inequity, unemployment and housing are very smoothly addressed in practice, notwithstanding the policy discourses.

6.5.2 Barcelona Experience in Resilience

After having explored the mechanisms and strategic moves contributing to the emergence and consolidation of an urban resilience unit within Barcelona Municipality offices, and the framing of a resilience-centred governance model, this section explains which of the experiences were already contributing to resilience building in Barcelona, before this concept was used in policy discourses. Indeed, while the boosting event for the first vulnerability assessment has been the chain of hazards suffered in 2007, a long list of previous resilience-related projects constituted Barcelona experience in resilience. Within the next subsections those experiences will be presented and critically analysed in order to better understand the contribution of the "accumulated resilience" (Satterthwaite 2013) to the emerging of the Barcelona urban resilience model.

6.5.2.1 The Evolution of Flooding Resilience and Water Management

Barcelona has been always exposed to flash floods and droughts, as any other part of the Mediterranean region. In a dense city like Barcelona, climate change coupled with the Spanish *laisse faire* of urbanization practices, increasing soil sealing, generation of barriers for subsurface waters or occupation of the natural basins and sewer networks deficiencies (lack of pipes capacities, poor maintenance) have always put flood resilience, challenges and solutions, at the forefront of urban vulnerability issues. Along the history of Barcelona's drainage and water management strategies (Favaro 2014) the *Plan Especial de Alcantarillado* already in 1988 (PECB) conceived the first underground rainwater retention deposits

[4]Rockefeller Foundation 100RC website, http://www.100resilientcities.org/cities/entry/barcelona#/-_/.

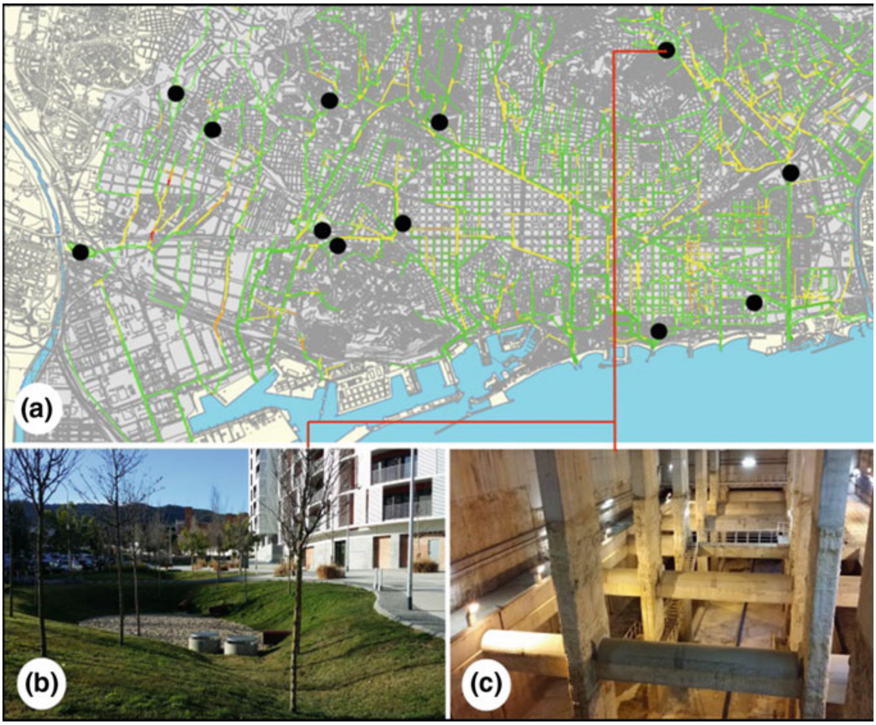

Fig. 6.5 Rainwater underground retention tanks map of Barcelona (**a**) and pictures of a retention tank placed under a big central city square (**b**) and an overflow basin for rainwater infiltration (**c**). *Source* Map adapted from Favaro (2014) and pictures from author

preparing the city for the 1992 Olympics' Games. Three main typologies of rainwater retention were planned as detailed in (Gago Lara 2010): (i) hurricane retention tanks (underground deposit designed for a flooding return period of 10 years) (ii) overflow basins (designed for rainwater retention and infiltration improvement, with multiple functions being open green spaces, although placed not in Barcelona city centre but at the edge of the sealing intensive areas) and (iii) Sustainable Drainage Systems (implying a consistent reduction in the pollution carried from the first flash flood waters since placed near a key pipe delivering the water to the sewages). Two decades after the Olympic Games, the city counted with 12 deposits already built with a total volume of potential rainwater retention of 722,200 m^3 (see Fig. 6.5). Within the last plan called PECLAB (*Plan Especial de Alcantarillado*), 24 more retention tanks have been planned within the Barcelona city area and other 6 in nearby municipalities (PECLAB 2003).

As one of the different outstanding performances of such measures, in 2011 about 154,000 m^3 of rainwater have been treated, avoiding flooding and the flowing of 1784 ton of pollutants into sea waters (CLABSA 2011). This hard-infrastructure based solution to flooding has been necessarily linked to improvements in the monitoring, modelling and forecasting of weather, and new sensors integrated within a real-time infrastructures control systems, which can be managed from a control room optimizing water management while avoiding risks (Russo et al. 2015).

6.5.2.2 Dealing with Drought

Barcelona accumulated flooding resilience provides the city with increasing capacities in facing climate and urbanization challenges related to drainage management, but has little to do with reducing the risks of droughts (Aqualogy Interview 2015), which have been threatening the capital city several times in the last decade. As mentioned in Sect. 6.1, the region of Catalonia suffered from 2007 to 2010 the worst droughts in 60 years. A special law for water saving (Decreto *de Sequía 108/2008*) helped in reducing the domestic water usage rates by 10% which reached the excellent performance of just 103 l/pers/day (AGBAR 2009; Dalmau et al. 2008). At the same time un-used water wells were recovered, and re-using treated waters from the sewage plant (*Estación Depuradora de Aguas Residuales*—EDAR—at El Prat de Llobregat) for agricultural purposes has been introduced a new good practice. At the same time, from 2007 to 2009, one of the biggest European Desalination plants has been constructed, having a capacity of sea water desalination of 60 hm^3/year (AGBAR 2009) although requiring the very high energy demand of 3 kWh/m^3.

Notwithstanding the numbers and synergy between policies and infrastructure works, the Catalan Water Agency prediction of an increase of 110 hm^3/year water consumption by 2025 (Agència_Catalana_de_l’Aigua 2008) makes these solutions insufficient to meet long-term goals.[5] At the same time, it is unlucky that due to the heavy pollution of the rainwater stored during the flash floods by the underground tanks, it’s not a technically and economically feasible to save, treat and reuse the rainwater as a potential buffer of fresh water provision (Aqualogy Interview 2015). However, because the 37.5% of fresh water in Barcelona is used for the maintenance of parks and public gardens, such an amount of water could be saved by using rainwater collected from the roof-tops of parks adjacent buildings, as proposed by Fernandez Pérez (Fernandez Pérez 2009). Indeed, emerging local regulations from different municipalities are introducing (rain)water recollection, storage and reuse within the Barcelona metropolitan area, opening new opportunities for increasing drought resilience.

[5]It is worth mentioning that the desalination plant energy used for freshwater production correspond to 3 kWh/m^3.

6.5.2.3 Coordination, Management Capacities and Mainstreaming City Resilience in Barcelona

Beyond the just mentioned big projects contributing to city resilience, it is also worth mentioning some local urban management capacities which already few decades ago constituted the bases for a successful longer-term city resilience strategy. Indeed, since the opportunity of hosting the Olympic Games in 1992, Barcelona demonstrated a wise planning strategy regarding the city-wide sprawling of Olympic sites and infrastructures benefitting different parts of the city. All the works have been executed through a governance based on efficient public-private partnerships without neglecting the quality of public spaces (Marshall 2000). In order to better manage all the necessary public works, a mixed private-public company called ACEFAT was created in 1990, with the mission of managing the work of utilities in an integrated way. Still nowadays, any public work should be executed through a previous application and communication to ACEFAT with respect to all of its details. ACEFAT will release the permit to each application only after having considered potential synergy with other works to be done in the same, or nearby area. Such a coordination and management practice has optimized public works execution during the last almost three decades, providing all the cartographic and potential synergies to any public work toward a method which nowadays has evolved into a web portal, called EWISE. This portal receives approximately 40,000 requests/year, from 6334 professional users registered, and connecting around 5656 organizations (interview ACEFAT 2015). Nowadays EWISE automates the management of administrative procedures, information on existing underground works and services, and resulting in a sensible reduction of administrative costs, prevention of damages to existing services, accelerated administrative procedures, and improved quality of service offered by the companies.

It could be also worth mentioning that among the hundreds of public works managed through this innovative service, Barcelona counted with dozens of projects which contributed to decrease the vulnerability of infrastructures and housing. These projects contributed to build Barcelona experience in resilience, as presented during the international workshop mentioned above, organized to celebrate the awarding of the Rockefeller 100 Resilient Cities program. Different enterprises introduced during this event their past and current experience in resilience, which could be synthetized mentioning that: (i) Agbar and Aqualogy, which are the water utility companies in Barcelona, offered an overview about the past and current flooding resilience initiatives, (ii) Endesa, the energy utility company, explained how the redundancy and monitoring of their nets have been enhanced in the last decade, (iii) Urbaser, responsible for streets cleaning and part of the waste management of the city, showed how they renewed and re-framed all their vehicles for being used 100% with renewable energy, produced within their own photovoltaic panels (and addressing both sustainability and resilience thanks to the redundant and flexible use of batteries and recharge options), (iv) TYPSA engineering consulting group explained how integrated measures in the (re)development of Barcelona city surrounding neighbourhoods have adopted resilience to flooding thanks to their project and monitoring, (v) Anteverti consultant company, responsible of the organization of the Barcelona Smart City Word Expo, addressed how from Barcelona the synergy between the smart city concept and solutions could enhance resilience, (vi) research institutes CIMNE and Barcelona Supercomputing Centre illustrated how their research capacities in earthquake simulation and evacuation modelling could contribute to emergency management and damages prevention, (vii) the foundation *Istitut Cerdá* was responsible, among other projects, for leading since 2010 (for more than 5 years than) a board for enhancing crisis prevention and management involving different big or utility companies across the region and utility, while (viii) Opticits, a small start-up created after the 2009 Barcelona vulnerability assessment, introduced how Hazur, the software they framed in order to assess the interdependencies among critical infrastructures, could help planning and management for a more resilient infrastructure and city services (attendance to the workshop and personal interviews with all the enterprises and research centres, 2015). Those specific tools, activities or public works contributed to the background experience related to resilience which lead to the emergence of the Barcelona partnership for urban resilience, and allowed the Municipality to leverage these expertise for framing a governance model centred on resilience. However, in the next section we explore the challenges of making this model a truly integrated governance process, with a long-term sustainability approach.

6.6 Discussion: Challenges of Enabling an Integrated Governance Model for Urban Resilience

The case of Barcelona illustrates how an integrated, multisector and long-term public-private partnership framed around the concept of urban resilience can be operationalized, resulting in a governance model. When asked during the interviews, policy makers and industry partners taking part in the Barcelona Partnership for urban resilience revealed their enthusiasm to collaborate for "doing things better in order to improve city infrastructures and services" (interviews, 2015). As an example, the technicians from water supply and management utility company reported that after been working during these previous years within the Resilience Unit through the resilience boards, now they are better informed about the underground conditions and specific requirements of other companies and better networked to other partners which could frame synergies in current and future projects. Those "invisible improvements" in the short term are part of the new governance model which could enable a more integrated perspective in building urban resilience for the long term, as suggested from different scholars addressing the integration of resilience to planning practices (Eraydin and Tasan-Kok 2012). The synergies have actually existed, but not always exploited, between a variety of plans, ambitions, networks and projects led by different city departments. Such synergies represent the opportunity for framing such integrated governance approaches. For instance, in Barcelona, the head of the Smart City World Expo, is part of the Barcelona Partnership for Urban Resilience, mentioning that resilience and the municipality workshops could be done in synergy with the global Expo, sharing the audience, networking and business opportunity rather that organizing events for promoting resilience autonomously (interview Antevertiq 2015). Quantitative information and recent policies justify these synergies, since Spain for example has recently framed in 2015 a National Plan for Intelligent Cities, having a budget of 152.9 Million euros. Barcelona already in 2012 signed an agreement with CISCO to wire Barcelona for becoming a "global model for urban sustainable development and an economic motor for Southern Europe" (Cisco 2012). Such an initiative, again aiming and promoting Barcelona as "a model for something" is in line with the entrepreneurial capacities of the city, which since 1992 make Barcelona to become a branded destination offering history, leisure, the post-modernities of star architects and cosmopolitan buzz (McDonogh 2011). Nowadays Barcelona has become a regular centre for global meetings in rotation with other cities like Paris, London and few other European capitals, but at the same time, emerging critics accompanied such a stride toward the global success, since the city was leaving back locals' social needs, as reported from different scholars in the last decades (Casellas 2006; Casellas and Pallares-Barbera 2009; Delgado 2007; Morató 2005). Following this tradition, the Barcelona Resilience model has indeed the very same characteristics of previous governance models. The deputy mayor of Barcelona reminded in 2014 that the city resilience strategy "more than on infrastructures it is centred on peoples' needs, and hinges upon three core ideas: its social dimension, the long-term thinking and the importance of establishing solid partnerships" (Deputy Mayor Interview 2014). Wishing to emphasize its social approach, one year later (maybe also because of the policy turnover from right to again left wings parties chairing city government), during the International Workshop Barcelona Experience in Resilience the head of the Resilience Unit highlight that a new resilience board was created, named *Xarxa Barcelona Resilient* (Barcelona Resilience Network). This initiative, gathering a group of local entities, mutual support groups, public and private institutions, has the mission to provide support to the victims of critical incidents, and rescue vagabond people during frozen nights in winter providing them emergency shelters. Such a "façade", respect to the meanings and possible strategies related to enhancing social and community resilience (Mulligan et al. 2016), uncovers the business as usual and very mission of the Resilience Unit, standing on the public-private partnerships enhancing the investments in infrastructures and public works, while internationally promoting the Barcelona city resilience branding, better than serving local or social needs. Indeed, it's interesting to notice that Barcelona Municipality itself boasts a very innovative social program called PLA BUITS, consisting in two competitive calls for public spaces co-management opportunities, through which more than 25 spaces (public un-used, vacant plots in the city centre) have been left for 3 years to a consortium of citizens in order to self-manage the spaces with the purpose of organizing public activities (Urbá 2014; Brody and Chelleri forthcoming). Organized from the Public Participation Unit of the Municipality, this very successful experience of public management of city spaces truly contributed in building community and social resilience, thanks to the self-organization, learning about regulations and procedures and people networking activities. However, PLA BUITS program, running since 2012, has been never mentioned or included within the resilience boards, or mentioned from the Resilient Unit when presenting the Barcelona Resilience Model. Through the interviews conducted, this paradox has been revealed: the Resilience Unit has been always led by the infrastructure and public works department, having much of their relationships consolidated with construction and utilities companies, rather than with public participation activities and department. When asked why PLA BUITS was not part of the Barcelona Resilience Plan, the responsible of PLA BUITS said they have never been invited to be part of the meetings, while the resilience unit said it was already very complex to manage such a consortium of partners (referring to the Barcelona Partnership on Urban Resilience) and they could not include easily, in the short terms, other interesting initiatives (interviews with the responsible person from the Resilience Unit and Public Participation department, 2015). Beyond speculations and hypothesis about how and which social aspects of resilience have, or haven't, been included within the Barcelona resilience model, this case study illustrated an example of how critical infrastructure resilience projects could be managed in an integrated way, and how leveraging on these projects a new governance model could be framed.

6.7 Conclusion

This chapter explored Barcelona experience in resilience, by analysing the recent paths ranging from addressing some critical infrastructures failures to the international awards for the framing of an innovative model of urban resilience centred governance. Resilience has been mostly related to risk reduction measures and policy making in the last decades, but emerging integrated perspectives are including also economic, social and planning aspects within the need of framing urban resilience governance beyond risk reduction. The case of Barcelona is showing how such a framing is not only possible, but also positive because it indirectly creates business and internationalization opportunities for the city. In the discussion section this chapter provided some critical reflection about the mechanisms of inclusion or exclusion of aspects related to social (or community) resilience. However, the overall learning of this case study is that from one hand framing public-private partnerships and managing them through some kind of long-term integrated boards, in which institution departments, stakeholders, industry partners can interact and address common problem, is a success factor in operationalizing resilience in cities. From the other hand, the details about the management of those partnership revealed that framing such an integrated governance model has its limitations, which go beyond the context and inertia of Barcelona Municipality, but are embedded within the structure of any public administration. The scope of such public administrations is often extremely vast and complex, due to the need to run hundreds of activities a day, behind each of which there are public and private interests making any integration challenging. Notwithstanding the difficult and sometimes conflictive dichotomy between policy discourses and practices, this book chapter contributes to build through the Barcelona case an example for any other city, of how an urban resilience governance framework could be used to leverage more integrated city management and planning practices.

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Chapter 7
Resilience Concepts and Planning Realities: How Quy Nhon Is Becoming a Resilient City by Integrating Climate Change Adaptation into Master Plans?

Jiwnath Ghimire, Kim Chi Vu and Hang Nguyen Thi Thuy

7.1 Introduction

Resilience is a new concept in urban planning. The term was introduced by Hollings into the field of ecology. It originated from the Latin word "resilience" which means "to bounce back" (Hosseini et al. 2016). There are three popular views on resilience. They are ecological, engineering, and evolutionary (Davoudi et al. 2012). Some scholars also classify resilience into two broad categories as ecological and engineering (Holling 1996; Liao 2012). As discussed in detail in Chap. 1 of this volume, the engineering approach to resilience is less popular in planning because it emphasizes the rigidity of the system and its capacity to bounce back after facing shock. It assumes the absorption of external shock without losing core functions of the system (Nelson et al. 2007). Ecological resilience is the original concept of Hollings which conceptualizes resilience as the capacity of a system to absorb the disturbances before it changes to a different regime. According to evolutionary resilience, the system will enter a different normal state after experiencing the shock. It recognizes the importance of acknowledging unpredictability, chaos, and uncertainty (Davoudi et al. 2012). Davoudi and others argued the relevance of evolutionary resilience in planning. Another perspective on resilience recognizes the relationship between society and ecology. Here, a system changes while

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retaining structure and functions, has a capacity of reorganization and maintains capacity for learning (Nelson et al. 2007). This perspective considers the nexus between society and ecology to maintain the resilience of the system.

Contemporary planning problems are “wicked” which are untamable with rational processes and scientific efforts (Rittel and Webber 1973). It is realized that the contemporary planning theory is not being able to address the neoliberal challenges in cities in terms of adaptive capacity, self-organization, and transformability (Eraydin 2013). The dominant planning theories are mainly focusing on the processes, whereas newer problems in the substantive side are increasingly pushing the planning profession towards a new direction and demanding new responses (Eraydin 2013). The resilience thinking can inform city planning through three ways: providing new metaphor on nature of structural change in linked and complex systems, providing new frameworks and tools for analysis of complex social-ecological urban systems, and providing options for a more adaptive governance (Wilkinson et al. 2010). Resilience thinking can be that new direction in planning.

Urbanization and resilience are two major concepts that are relevant in the context of cities of developing countries. The urban growth in developing countries is rapid and relatively unplanned. Multiple initiatives are emerging to make cities resilient to different internal and external shocks. Of the frequently discussed shocks are natural disasters and climate change impacts. Cities in developing countries, especially in Asia, are continuously facing disasters such as flooding, typhoons, and droughts. They have been proof of human societies to adapt to changing conditions including climatic events (Hamnett and Forbes 2011). But disasters are more complex in the 21st century. They are interacting with climate change and urbanization, and became more aggressive, prolong, and frequent. The climate change adds extra stress to cities in developing countries which are already facing different sources of risks (Hamnett and Forbes 2011). Making these cities resilient is a daunting task requiring serious efforts from multiple stakeholders including governments and NGOs (Malalgoda et al. 2013).

Under the uncertainty of climate change and disaster risks, land use planning can be an effective measure for building resilient communities (Berke and Stevens 2016). Integrating natural hazard mitigation into land use planning can make communities more resilient through enhancing awareness, strengthening problem-solving skills, and advancing creative planning and management strategies (Burby et al. 2000). Resilient land use plans limit the development of risk-prone areas (Burby and Dalton 1994) while reducing the vulnerabilities (Burby 1998). But planning agencies around the world are facing challenges in order to make cities resilient to disasters. There are empirical studies on challenges in addressing climate change and disaster risks in the course of land use planning. In case of Batticaloa, Sri Lanka, the major challenges are inadequate financial and human resources, lack of knowledge about vulnerabilities, the absence of political commitment, lack of clear responsibilities and coordination, and lack of appropriate land use regulations (Malalgoda et al. 2013). These challenges are context specific. The change in governance and institutions can facilitate the effective use of land use planning as a tool to improve community resilience in an urban environment. Development of frameworks for urban resiliency assessment is an effective way to integrate resilience in the planning process (Sharifi 2016; Sharifi and Yamagata 2014). But the majority of those frameworks are context specific and many of them have limited replication value. Some of the empirical frameworks to operationalize resilience are Natural Disaster Density Indicator (NDDI) (Su 2015), resilience action planning (Shah and Ranghieri 2012), resilience framework (Nelson et al. 2007), city resilience framework (Ove Arup and Partners International Limited 2015), subjective well-being approach (Nguyen and James 2013), etc. These frameworks vary in terms of their focus and scope. Developing context-specific measures to assess resilience is the first step to improve the adaptive capacity of cities to deal with the impacts of climate change.

This research tries to explore and evaluate the role of land use planning to improve community resilience in the context of Quy Nhon city of Central Vietnam. Using awareness, assessment, and action framework, this research assesses the resilience of two master plans of the city. Integration of climate change adaptation into land use planning is a determinant of resilience in this research.

7.2 Study Area: Quy Nhon City

The study was conducted in Quy Nhon city of Central Vietnam. It is the largest city of Binh Dinh Province located on the coast with tremendous economic opportunities. Quy Nhon city is the capital of Binh Dinh province. The city has an area of 285.53 square kilometers in total, and a population of over 283,000 people (Challenge to Change et al. 2009; Chi et al. 2015; Quy Nhon Sub-office of Statistics 2013). The city contains 16 wards with 258,010 people, which belong to urban administrative body and 5 communes with 25,430 people, which belong to the rural administrative body. It has high development potentials having a connection with Central Highland of the country.

The town of Quy Nhon was established in 1898 as a small trading town. The development of Quy Nhon after Doi Moi in 1986 (the economic renovation or reform process) has been remarkable with three stages: population development, administrative changes, and spatial expansion. From a small city with eight wards, six communes and 160,000 inhabitants in 1986, Quy Nhon has added two more wards, Bui Thi Xuan and Tran Quang Dieu, to the old Phuoc Long Commune of Tuy Phuoc District. In 1998, several city wards were divided, and Nhon Binh and Nhon Phu communes became city wards. In 2006, the city's administrative boundaries expanded into Phuoc My Commune and it remains the same until present. However, the administrative area of Quy Nhon has slightly increased from 285.529 to 286.1 square kilometers due to the landfill activities along the coast in the Thi Nai lagoon (Binh Dinh Statistical Office 2016). According to statistical yearbook of Binh Dinh (2016), currently 13.5% of the area is agricultural production land, 42.3% is forestry land, 18.9% is specially used land and 3.7% is homestead land. Figure 7.1 presents the current administrative boundaries of the Quy Nhon city and Fig. 7.2 shows the city expansion which was derived from different sources such as Landsat satellite images and literature (Chi and Hang 2017).

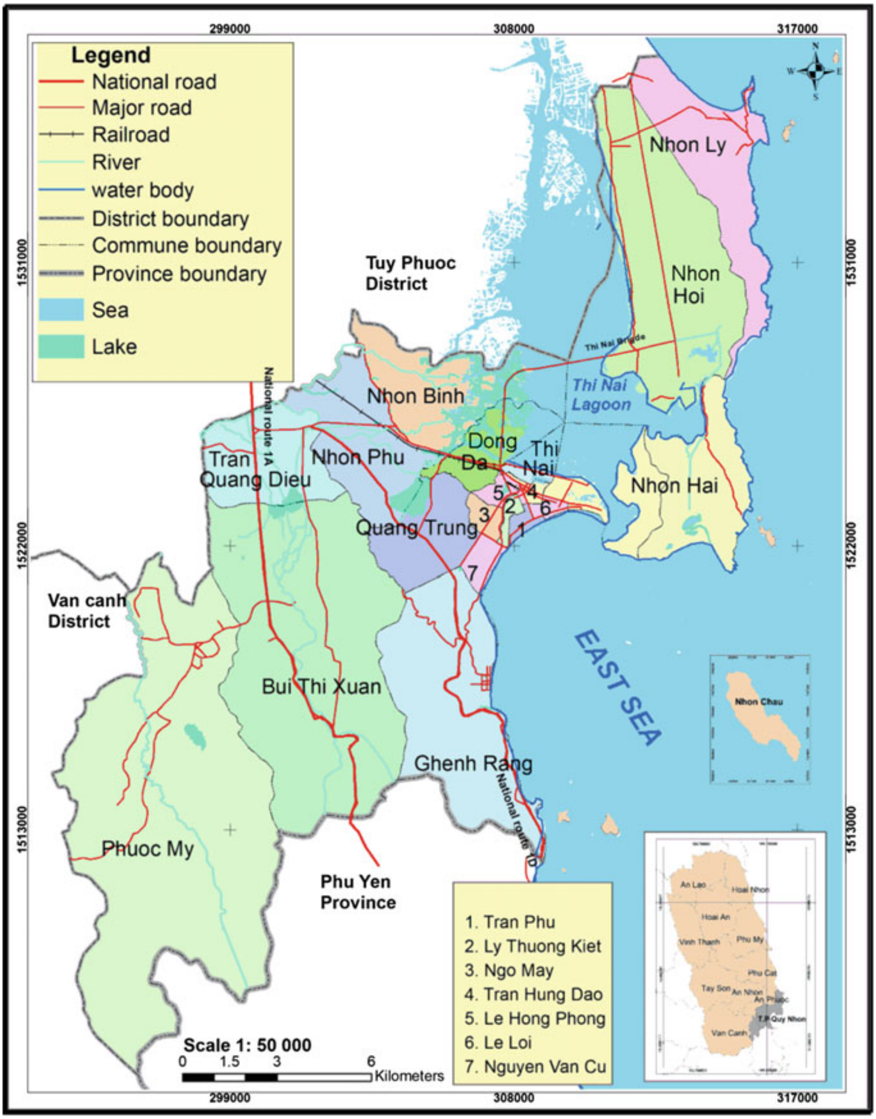

Fig. 7.1 Administrative map of Quy Nhon city

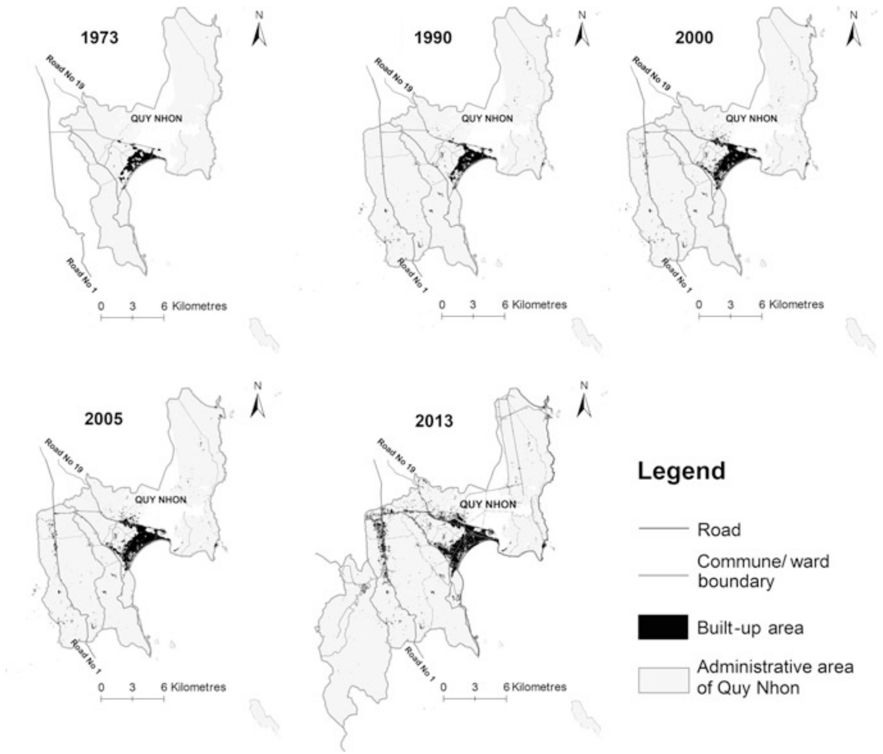

Fig. 7.2 Expansion of the administrative and built-up areas in Quy Nhon city (Chi et al. 2015)

7.3 Methodology

Despite strong interests in plan evaluation, systematic evaluation of land use plans, focusing on resilience and climate change adaptation is scarce. Different criteria are recommended to evaluate the plan quality (Baer 1997). Despite the presence of interest and knowledge in plan evaluation, there is still a gap on assessment of land use plans because they are highly contextual and future-oriented (Berke and Godschalk 2009). There are studies focusing on the evaluation of local plans from the perspective of hazard mitigation, and land use approaches (Lyles et al. 2014). There are also specific studies focusing on the evaluation of climate change adaptation plans (Anguelovski et al. 2016). The role of land use plans is strongly realized in the literature related to disaster risk reduction and climate change adaptation (Berke et al. 2015; Berke and Stevens 2016). In case of newer focus of plan evaluation, the underlying principles of a concept such as a climate change adaptation can be used to determine the criteria for evaluation. In case of sustainable development, Berke and Conroy used six principles of sustainable development to assess the extent of compliance of 30 comprehensive plans to the principles of sustainable development (Berke and Conroy 2000). A similar approach can be developed to assess the plan qualities in terms of climate change adaptation.

Plan evaluation studies have used quantitative analysis to conduct the evaluation. They included multiple plans in the course of analysis. But, in case of this study, there is a comparison of two plans to assess how the climate change knowledge is being used (if any) in the plan documents to determine the policies, strategies, and regulations of different socioeconomic sectors of the plan. The qualitative content analysis (Weber 1990) is used to assess climate change adaptation measures in Master Plans of Quy Nhon City. Plan evaluation was supplemented with interviews with decision-makers and planners at Provincial and City levels to understand the practices of climate change adaptation in the course of land management within the city. The interview method is used in previous research to collect opinion on resilience among local decision makers (Kuhlicke 2013).

Plan evaluation considers different factors. One way to assess climate change adaptation aspects in land use plan can be through awareness, assessment and action (AAA) (Baynham and Stevens 2014; Luers and Moser 2006; Moser and Luers 2008; Tang et al. 2009; UKCIP 2003). Others have used theory-based evaluation approaches. One study uses rationalism, pragmatism, sociological idealism, collaboration and communication, and, political economic mobilization as theories to determine different variables to assess the plan quality (Tang and Brody 2009). The AAA approach has been used to evaluate climate change adaptation in land use plans (Baynham and Stevens 2014; Tang et al. 2009), climate action plans (Tang et al. 2010), and preparedness of local governments to address impacts of climate change (Tang et al. 2012; UKCIP 2003). This framework is used to assess the Master Plans (2004 and 2015) of the Quy Nhon city from the perspectives of climate change adaptation and disaster risk management. The measurement criteria for each component of the framework are shown in Fig. 7.3.

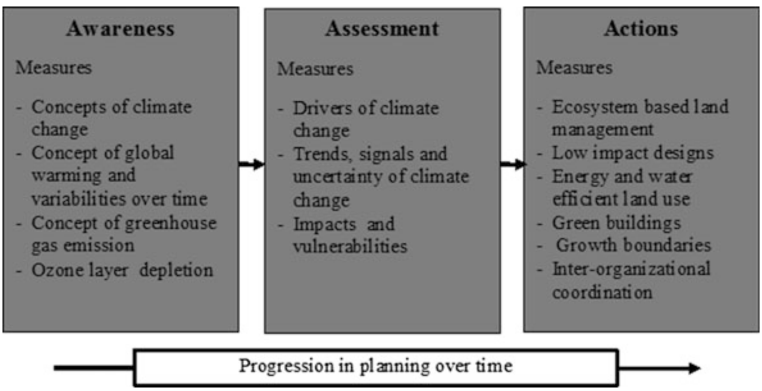

Fig. 7.3 Awareness-Assessment-Action Framework of climate change adaptation in land use planning (adapted from Tang et al. 2009)

– Awareness: From the perspective of planners, decision-makers, and politicians, the first step will be having awareness about the potential impacts of climate change. It can be applied to public and private sectors. The awareness can be improved through improvement of climate science. One of the examples is that a higher level of awareness among the state agencies in California is facilitated by the role of climate science (Moser and Luers 2008). Evaluation of awareness of climate change can be contextual and subjective, and also depends on the scope of the research. Evaluation of the level of awareness about climate change can cover issues such as:

  - knowledge of climate change, variabilities, and global warming
  - Concept of greenhouse gas emission
  - Concepts of ozone layer depletion
    (Tang et al. 2009).

– Assessment: "Analysis" is another terminology to cover this step. It is the step in which decision makers and planners assess the potential impacts of climate change in their sectors. The study conducted by Moser and Luers (2008) among resource managers in California shows good knowledge and assessment capacity of climate change but the challenge is the lack of compatibility of scientific information with the existing decision-making procedures (Moser and Luers 2008). It includes following variables. But the list is not exhaustive. The assessment is basically having a good grasp of the climate change impacts in the selected sectors or geographic area. For example, in case of land use planning, it may include the risk and vulnerability assessment, historical pattern of climatic disasters in a certain geographic area, and modeling future impacts. Specific issues to be considered are:

  - major drivers, contributors to climate change
  - the trend, signals, and uncertainty of climate change (temperature change, precipitation change, sea level rise, extreme events)
  - Impacts and vulnerability (ecosystem, food security, settlements, society, water resources, human health)
    (Tang et al. 2009)

– Actions: This the most crucial step of addressing climate change in the course of land use planning. Actions are dependent on the interest of users. They also depend on the context. Some variables that are included for land use planning are:

  - Green building and green infrastructures (i.e. urban forests, park and open spaces, natural drainage systems)
  - Watershed-based and ecosystem-based land management
  - Low impact design for impervious surface
  - Energy-efficient land use
  - Risk/vulnerability assessment
  - Multi-modal transportation corridor improvements

- Water sensitive land use (agriculture or industry)
- Waste and stormwater management
- Public awareness and participation
- Control of urban service/growth boundaries
- Zero waste/high recycling strategy
- Mixed use or compact development
- Pedestrian/resident friendly, bicycle-friendly, transit-oriented community design
- Inter-organizational coordination procedures
- Infill development and reuse of brownfield sites
- Disaster-resistant land use and building codes
- Vegetation (forest/woodlands) protection
- Creation of conservation zones or protection areas
- Vehicle emission reduction
  (Tang et al. 2009)

Above mentioned variables for each component may not be relevant in the context of Quy Nhon city. Overall, the awareness is about concepts and basic information of climate change, assessment is evaluating the impacts in the context of Quy Nhon city and action is related to designing interventions to deal with the impacts.

7.4 Quy Nhon Master Plans—Resilience Through Climate Change Adaptation in Land Use Planning

Two master plans are included in this study. The rationale behind evaluating Master Plans in this research is to identify and assess the land use planning activities/ policies in plan documents that are relevant for climate change adaptation. Two Plans are Quy Nhon Master Plan Update of 2004 and Quy Nhon Master Plan of 2015. Master Plan Update of 2004 has 5 chapters and one appendix that added new provisions and updates on the Master Plan of 1998. It is a 54-page document. Master Plan of 1998 was not included in this analysis because of lack of accessibility to the document. Further, serious integration of environmental issues into planning and policy-making in Vietnam occurred from the beginning of 21st century, making an investigation of previous plans less relevant. Master Plan of 2004 has detailed provisions on economic and social development.

Unlike Master Plan Update of 2004, the Master Plan 2015 details layout of the goals, objectives, strategies, and actions of urbanization of Quy Nhon because it is the new and complete Master Plan for the city. It is a 296-page document with 10 chapters and 3 appendices. As in the 2004 Master Plan, this also starts with the rationale behind the establishment of the Master Plan in Chap. 1. Chapter 2 details layout of the context including climatic conditions, geology, and hydrology. It lays out a detailed description of the industrial zones, water supply, tourism development, transportation, cultural preservation, urbanization, power distribution, air and water pollution, wastewater and solid waste management systems, and potential impacts of climate. This chapter also provides the achievements and challenges of implementation of Master Plan 2004. Chapter 3 covers an international case study of small city planning from Marseille, France which is relevant to Quy Nhon. Chapters 4 and 5 are focusing on the socioeconomic development and spatial strategies of urbanization. The land use planning is covered in Chap. 6. This chapter is about the architectural and historic preservation of the city. Chapter 8 covers the physical infrastructure development and Chap. 9 forecasts the future of urban expansion, land use change and industrialization in the city. Chapter 10 presents the regional importance of Quy Nhon city for Central Vietnam.

7.4.1 The 2004 Master Plan Update

The consideration of climate change in Master Plan Update of 2004 is minimal. This is the update of 1998 city Master Plan of Quy Nhon. There is no mentioning of the word "climate change" in the whole document. This plan focuses on the socioeconomic development and the land management in the city. It has a projection of population growth. It is projected that the population growth rate of the city was 1.62% in 2004. The total population in 16 wards of the city were 223,305 people in 2000, out of which about 57% is active labor force. The total area of the city is mentioned as 21,644 ha including 14,531 ha in the inner city and 7113 ha in the outskirts. Most of the contents of the plan are related to economic performance, especially the industrial development of the city, and its contribution to the overall economy of the province and status of the city at the national level. For example, the city is designated as one of the three tourist centers in Central Vietnam; the Phu Tai Economic Zone of the city provides employment to 8846 people and its area has been enlarged to 140 ha from 101.7 ha. The trade sector has contributed 47.8% of total GDP of the city in 2000 which was equivalent to 716.9 million VND. As background information for the land use planning, urban service management, and industrial expansion, the plan mentions environmental aspects. Considerations are not specific to the impacts of climate change or potential risks from the disasters such as flooding, typhoon, sea level rise, drought, etc. Rather, they are taken into account in the course of urbanization such as residential area expansion, management of drinking water, waste management, industrial park planning, powerline expansions, etc.

7.4.2 The 2015 Master Plan

The potential impacts of climate change are widely mentioned in the Master Plan. According to this plan, one of the challenges of Master Plan Update of 2004 is the restriction of urban expansion caused by the terrain. Also, there is a limitation on urban development in old areas in the bank of Ha Thanh River because the old areas are heavily affected by flooding and uncertainties created by the climate change (Chap. 1). As in Plan Update of 2004, it contains the population projections for the city. It mentioned population projection under six scenarios (for 2025, 2035 and 2050). The first three scenarios are with petroleum processing center (named as "Victory Project") in the Plan and second three projections are without petroleum processing center in Nhon Hoi Peninsula. Without Victory Project in the city, the population growth is estimated to be 545,000; 640,000; and 740,000 by 2025, 2035 and 2050, respectively. With Victory project, the population size will be estimated to be larger because it attracts more workers of different skills to the city. With Victory Project, the population of the city is estimated to be 620,000; 680,000 and 740,000 by 2025, 2035, and 2050, respectively. It has mentioned the population growth in the city and outskirt territories.

This Plan points the lack of consideration of climate change in the course of urban growth as another limitation of Master Plan Update of 2004. It states:

> According to the Quy Nhon city's construction master plan up to 2020 approved by the Prime Minister in 2004, minimum construction height is $H \geq 2.5$ m and the maximum ground slope is 0.4%. Up to now, detailed plans have been approved and some have been implemented, most of which are basically built to comply with approved QHC standards. However, the 2004 blueprint does not address the issue of global climate change due to sea level rise as the QHC plan of Quy Nhon City and its vicinity is until 2030 and vision to 2050.
>
> (The 2015 Master Plan)

Especially, impacts of flooding are mentioned in almost all chapters of the Plan of 2015. The discussion on standards of Type I city to adapt to erratic rainfall, sea level rise and the flood is also mentioned. Cities in Vietnam are classified into five classes (I–V) based on socioeconomic development, population size, population density, non-agricultural labor proportion, and infrastructure development (The Socialists Republic of Vietnam 2009). Comparing these two master plans of the city there are significant shifts in the narrative on climate change in Master Plan of 2015 compare the 2004 updates.

The Table 7.1 shows that climate change and its impacts are mentioned and addressed in Master Plan of 2015. The flooding has been most widely mentioned in the Plan. In five chapters, there are more than 30 citations of flooding and its adaptation and mitigation measures. There is a discussion of the building standards to deal with impacts of climate change including flood, high waves, sea level rise, etc. For example, it has mentioned the exact height of foundation of houses near shore where the waves can cause damage. Measures are different for different areas. These measures are connected to the ground level of the city. Unlike the Master Plan of 2015, the 2004 updates did not have any discussion on any of the impacts of climate change.

Table 7.1 Awareness, assessment, and actions on climate change in Master Plans (2004 and 2015)

Climate change and its effects	Master Plan update 2004			Master Plan 2015		
	Awareness	Assessment	Action	Awareness	Assessment	Action
Mentioning "Climate Change"	X			√		
Sea level rise	X	X	X	√	√	√
Tidal impacts	√	X	X	√	√	√
Temperature change	X	X	X	√	√	√
Rainfall change	X	X	X	√	√	√
Flooding impacts	X	X	√	√	√	√
Typhoon impacts	√	X	X	√	√	√
Drought impacts	X	X	X	√	√	√

X Component not covered in the plan
√ Component covered in the plan

7.5 Findings and Discussions

Quy Nhon is progressively becoming resilient through climate change adaptation in land use planning. But the achievements are mainly in terms of awareness. There are no significant efforts to develop coordinated actions to address climate change impacts in land use planning even though there is a discussion of actions in the Master Plan of 2015. There is no citation in the Master Plan that the recommended actions in the Plan are aimed at addressing the excessive flooding in certain parts of the city caused by anomalies of rainfall as a result of a change in climate. Both Plans have detail priorities and actions for urban expansion and economic development. The Master Plan of 2015 has high priority of oil refinery project in the city. There are clear measures of pollution control by enforcing national standards. The climate change is a multisectoral and complex issue. Promoting collaborative efforts among sectors is an effective measure to deal with it. In the Master Plan of 2015, there are not enough details on how prescribed actions will be coordinated among different sectors. The flooding has been the most widely discussed impact in the city but the proposed concrete actions are mainly focused on the sea level rise and tidal variations. The uncertainties of impacts and lack of clear standards to address them are some of the challenges that need to be addressed in order to take account of climate change in the course of land use planning. It has been attested by government officials during the interview. One interviewee mentioned:

> …..Until now, from the Ministry of Construction, they have the problem of only talking about the climate change, the climate change is only in discussions, we discuss how it can be integrated but there is no standard or a strong guideline to say that in the Binh Dinh province, the sea level rise will increase this much and this area will be impacted, and we need to raise the height of the bridge and construction to adapt with that…..
>
> (Personal communication 2014)

Higher attention to climate change and disaster risk management is in the Master Plan of 2015. The Quy Nhon Master Plan Update of 2004 does not have any description of potential climate change impacts. It has a partial recognition of risks from flooding, typhoon, and tidal impacts. Master Plan of 2015 has mentioned impacts of flooding, typhoon and sea level rise in the city. It has ameliorated the mainstreaming of climate change impacts in land use planning. It details potential impacts of climate change and flooding in different segments of the plan. It has covered climate change scenarios in Chap. 8. It also discusses potential flood impacts in the new development in the city and elevation requirements for structures to adapt to those impacts. The elevation height is determined based on the flooding level in the area. It is different for different parts of the city. This raises the major question on why Master Plan of 2015 is ubiquitous regarding climate change risk assessment and adaptation. If the duration of 2004 to 2015 is observed, the major intervention between 2004 and 2015 is the introduction of Asian Cities Climate Change Resilience Network (ACCCRN) in the city. The ACCCRN project has the role to improve the awareness, assessment, and actions of climate change of climate change in the city.

ACCCRN has brought tremendous changes in thinking among communities, policymakers, and cities in Asia. The Rockefeller Foundation has launched a new initiative among 10 example cities in order to improve their resilience to tackle present and future challenges of climate change. Cities are shown in Fig. 7.4. The

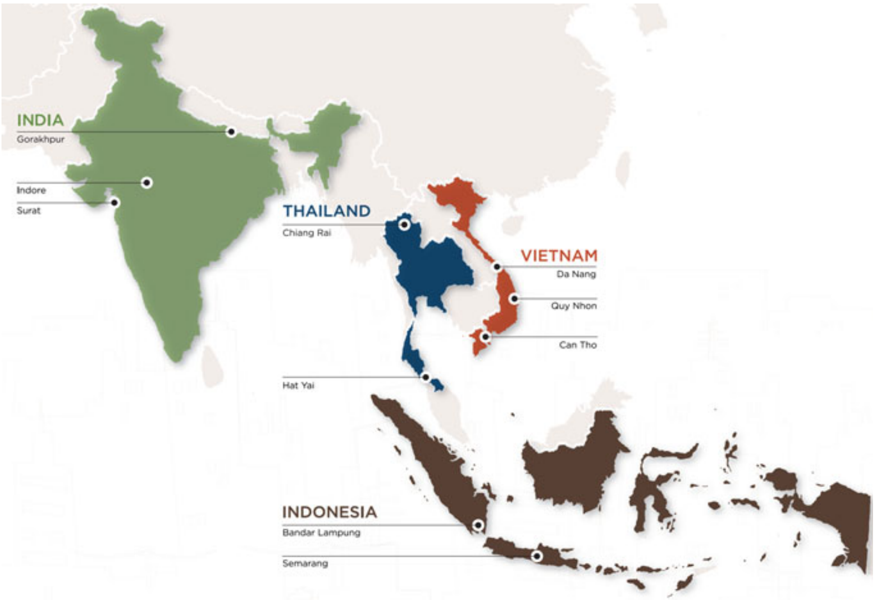

Fig. 7.4 10 Asian cities under ACCCRN (The Asian Cities Climate Change Resilience Network 2014)

Initiative was launched in 2008 with about USD 59 million for 9 years. The major driving force behind the launch of this Initiative is the importance of urban resilience to address the impacts of climate change. It is believed that the impact of climate change in cities was less discussed even though more than 50% of the global population was living in cities and Asian cities were becoming economic powerhouses (The Asian Cities Climate Change Resilience Network 2014). In this context, The Rockefeller Foundation has launched this Initiative in 10 small and medium-sized cities to fill the vacuum of intervention. The major goal of this initiative is "…to measurably enhance the resilience of ACCCRN cities' institutions, systems and structures to current and future climate risks, and through this, measurably [to] improve lives of poor and vulnerable people." (Bahadur and Tanner 2014). All 10 cities did not follow the same model of implementation of this initiative. There are six different models of resilience building among these cities. They are:

1. Community empowerment neighborhood/ward focused approach
2. Technocratic project approach
3. Multi-stakeholder engagement approach
4. City climate cell—CCCO
5. Choice of entry point—climate specific or problem identification/governance
6. Light touch city facilitation
   (The Rockefeller Foundation and Verulam Associates Ltd 2014)

By 2014, this model is extended in more than 30 cities in Bangladesh, India, Vietnam, Indonesia, and Thailand (The Asian Cities Climate Change Resilience Network 2014). This has created big movement on climate change adaptation in Asia; especially in urban areas. The City Climate Cell or Climate Change Coordination Office (CCCO) approach is the Vietnamese approach to implementation of ACCCRN. Two cities (Can Tho and Da Nang) of Vietnam established CCCO under the jurisdiction of the city, and Quy Nhon city has CCCO under provincial people's committee. CCCOs are intended to play the role of coordination, interpretation, and collection of climate change related data for risk assessment, developing strategies of city resilience, building technical capacities on resilience planning, and coordinating external funding and climate change projects at the local level (Taylor 2017). During the interview with planners, scientists and international experts on climate change, they mentioned ACCCRN and its activities in the city as their effort to adapt to climate change. The implementation of the program is coordinated among many Provincial Departments and offices. That led to broader ownership of the program activities. Similarly, the establishment of Climate Change Coordination Office (CCCO) under Provincial People's Committee has established a new culture of duties and responsibilities to deal with climate change. The CCCO was established to implement ACCCRN project in the city. In the course of the interview, many representatives have mentioned the same project as their own project.

The climate change is a relatively new topic in Vietnam. Although there is the difference in opinions between scientists and policymakers on how and when the projects, programs, and national prioritization was started on climate change, the evaluation of Master Plans (2004 and 2015) illustrates that the initiatives on climate change were started after 2004. Regarding the initiatives on climate change, one interviewee mentioned:

> Because climate change is a very new topic in Vietnam you said that it is 20 years but I say that it is not actually 20 years. It was started from 2005 [until now], they have to conduct a lot of training [for] activities in this area in this field; [even] they do not have enough basic information about the climate change, they misunderstand about the disaster and climate change.
>
> (Personal communication 2014)

The Master Plan of 2015 shows higher awareness of climate change impacts in Quy Nhon City (and includes assessments and actions) compared to Master Plan Updates of 2004. It has clearly realized that the major impacts of climate change for Quy Nhon city will be sea level rise, flooding, drought, and typhoons. Therefore, in every section, when it talks about disaster risks in the city, it has some discussions on the potential role of climate change. It has pointed that the flooding will increase in the future due to climate change. It further mentions:

> …Flooding tends to increase in terms of the frequency of occurrence, combined with sea level rise will create deeper floods with longer durations. Potential impacts are:
>
> – Threats to life (especially children).
> – Impacts on livelihoods: fishpond shattering; change of crops season; reduces tourism activities.
> – Economic damage: loss of crops, interruption in agricultural production, costly recovery; funding for the upgrading of roads, raising the house basement; increased operating costs for irrigation systems for agricultural production.
> – Environmental issues and public health: environmental pollution caused by rotting plants and dead animals; wastewater from drainage system; disease outbreak.
> – The sectors that are most vulnerable to flooding are agricultural production, infrastructure, irrigation, and aquaculture.
>
> (The 2015 Master Plan)

There is a separate section on trends of climate change and natural disasters in the second chapter of the plan. It has been realized that the flooding has been serious in terms of frequency, duration and impacts of events. It has also realized that one of the major causes of increasing impacts of flooding in the city is increasing unplanned development in flood-prone areas such as wetlands and riverbanks (Chi and Hang 2017). The Plan has realized this nexus between climatological disasters and rapid urbanization.

Based on the case of Quy Nhon, continuous support (technical, financial and institutional) is required to integrate adaptation and mitigation into the city planning process to improve urban resilience. Figure 7.5 shows that the land use plans adapt and mitigate to the climate change impacts through awareness, assessments and actions over time if there is a continuous incentive and capacity building for planners and decision makers.

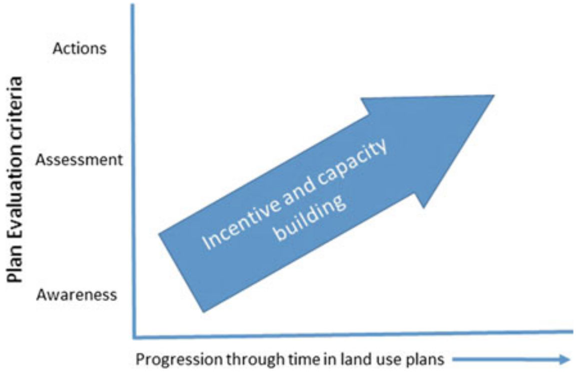

Fig. 7.5 Continuum of awareness, assessment, and action in the land use planning

With the effort of ACCCRN, tremendous awareness has been achieved. During an interview with 29 government officials, leaders, and project managers at the provincial level, they mentioned that they are aware of climate change impacts in the city and province. They provided examples of those impacts. In the same manner, the Master Plan of 2015 enshrines detailed information about the climate change. Even though there is no complete assessment and actions to address all the potential impacts of climate change, there are examples of assessment and actions for flooding and sea level rise. The City Resilience Strategy of has identified the spatial distribution of potential impacts of climate change (Dinh et al. 2010). It has also proposed potential interventions in different sectors to deal with those impacts. But the implementation is not in practice yet. Government offices are participating in the dialogue of climate change through the institutional setup of CCCO. But there is a gap on how they can operationalize recommendations of Master Plans and the City Resilience Strategy in their decision making. Therefore, it is required to have continuous support to city focusing on mainstreaming climate change in land use planning and decision making. This includes providing different decision support tools, establishing intergovernmental coordination and improving governance and institutions to address climate change impacts in the planning process. That way, the strength of city towards assessment and action will be improved in land use planning and implementation. One of the major limitations mentioned by a government official during the interviews was not having enough resources (especially financial, human and technical) to carry on climate change related projects and programs in the office.

7.6 Conclusion

The 2015 Master Plan is more aware of climate change compared to the 2004 Master Plan Update of the city. Although the land use planning has been proven an effective approach to reduce climate change impacts, it can be challenging to manage it in the context of rapidly transforming cities of developing countries. It is because of competing priorities of economic growth and rapid urbanization in cities, and limitation of resources to address emerging and uncertain issues like climate change.

With the introduction of ACCCRN project in Quy Nhon, the overall awareness among leaders, government officers, and residents has enhanced. As a result, the Master Plan of 2015 has covered detailed climate change information. It has projections on sea level rise, flooding, and typhoon which will be accelerated by climate change. The Master Plan of 2015 also has assessments of future impacts of climate change. For individual disasters, it covers adaptation actions. But those actions are not for every sector. For example, there is a height requirement for residential areas that are developed in the flood-prone areas. But there are no adaptation recommendations on how other infrastructures such as power lines, drinking water distribution system, drainage system, waste management systems, and road network will adapt to flooding. There is also confusion and gap in skills and tools among government offices in the city regarding operationalization of some of the adaptation recommendation in Master Plan and Climate Action Plan of the city. They mentioned that they needed some type of clear standards on the adaptation to climate change. In order to establish coordinated actions among different sectors to deal with climate change impacts, continuous support and incentives on capacity building (government offices, planning consultants and, provincial and local leaders) on climate change adaption are necessary.

The use of AAA framework for the evaluation of climate change adaptation should be extended to other cities. Further understanding of climate change adaptation and mitigation initiatives through empirical studies will help to conclude how cities get motivated to address challenges of climate change in the course of land use planning in the context of rapidly transforming cities of Asia and beyond.

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Chapter 8
When a Disaster Risk Reduction Policy Fails in the Implementation Stage: Eroding Community Resilience and Traditional Architecture in Iranian Villages

Boshra Khoshnevis and Lorenzo Chelleri

8.1 Introduction

Iran is a disaster-prone country. It is mentioned by United Nations Development Programme (UNDP) that out of the 40 different types of known natural disasters in the world, 31 types have been identified in Iran. Major hazards include frequent, serious earthquakes, floods, droughts, landslides, and storms. Earthquakes take an especially heavy toll (2005). As part of the Alp-Himalayan orogenic belt, Iran is one of the most seismic-prone areas in the world and suffers severe economic and social damage as a result. During the last 40 years, almost 200,000 people have lost their lives in earthquakes in Iran (Zare 2012).

Experiences from past earthquakes in different regions of Iran showed the high vulnerability of houses in rural areas (Bahrami 2008), hosting 20,730,625 inhabitants according to the last census of 2016, and accounting for nearly 26% of the country's population (Statistical Center of Iran 2017). The last analysis of rural housing units, made in 2003 at the country scale, reported the state of houses been highly vulnerable in 15 provinces (51%), in 9 provinces having minor vulnerability issues (33%), and only in 4 provinces the houses were in a good condition (14%) (Sartipipour 2009). These results describe the emerging priority of the government in supporting and subsidizing disaster risk reduction programmes to retrofit rural housing.

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However, decision-making processes in a vast and geographically diverse country such as Iran (with diversity of climate, ethnicities, and local architecture cultures) could be challenging because of the need for policy-making capable of addressing variety of context-specific needs (Sartipipour 2005). Indeed, not all the vernacular buildings are vulnerable to earthquakes since "seismic culture" and social processes of disaster response could be embedded in the construction methods and processes, as already pointed out in some very recent studies (Ortega et al. 2017; Aldrich and Meyer 2014). Also, from the Bam (2003) and Manjil (1990) earthquakes, the resistance of the vernacular buildings (if properly built and maintained) has been tested and demonstrated (Sartipipour 2012). Moreover, rural houses are self-sufficient units, able to provide all the functional spaces for the village production activities. They are well-fitted solutions to fulfill the requirements imposed by the environment and society. Since the physical features of rural houses is rooted into economy, social, cultural, and environmental aspect of rural life (Zargar 2011), unconventional changes in the patterns and design of the houses might affect traditional lifestyles dynamics. To this regards, the Sendai Framework for Disaster Risk Reduction 2015–2030 suggests complementing scientific knowledge in disaster risk assessment by ensuring the use of appropriate traditional and local knowledge and practices, framing disaster risk reduction strategies, plans, and programs tailored to localities and cultural contexts (UNISDR 2015).

Furthermore, construction of vernacular buildings is a group practice. In rural communities, houses are being built by the community. The process of involvement and participation in group activities is considered to generate positive consequences for the individuals and the community resulting in leveraging and strengthening social capital and networks. Social capital has a critical role in disaster survival and recovery, contributing therefore to enhancement of community resilience (Aldrich and Meyer 2014).

This chapter addresses the gap between the disaster risk reduction policy and its implementation in rural Iran and compares it to the traditional practices enhancing community resilience. Indeed, notwithstanding the overall vulnerability of rural settlements (see Sartipipour 2009), properly built and maintained traditional buildings can resist earthquakes because of the embedded seismic culture and community resilience, strengthened during construction processes (as demonstrated by Sartipipour 2012; Aldrich and Meyer 2014; and Ortega et al. 2017). However, the current policy for disaster risk reduction in rural Iran, implemented far from its very own objectives, is promoting a philosophy of demolition of rural houses and rebuilding following building codes and typologies common in urban areas. In order to explore the pros and cons of this policy implementation, we selected a case study from a remote village where traditional buildings showed seismic resistance during the last earthquake, but the disaster risk reduction policy is increasingly demolishing traditional houses, replacing them with new and concrete-based houses rising concerns among the residents. A viral weblog post titled "*An elegy for the death of traditional house*" expressed residents' dissatisfaction in how this retrofitting policy has been applied on the ground (Shams Nateri 2013). In the light of such dissatisfaction and disaster risk reduction framework operationalization, this chapter evaluates the decision-making process and the policy implementation steps in order to explain the expenses paid for vulnerability reduction, confronting community resilience.

The structure of the chapter is framed within five sections. After explaining the policy and legal frameworks for disaster risk reduction in Sect. 8.3, as applied to rural villages of Iran, Sect. 8.4 introduces the case study (Nater village) and justifies the reasons for this choice. In Sects. 8.5 and 8.6, the results of reviewing the provincial policy documents, their implementation on the ground, and their substantial differences to the traditional architectures in providing the built environment with earthquake resilient characteristics is mentioned. Finally, the results are discussed in Sect. 8.7.

8.2 Method

This chapter is based on a qualitative research which analyses the Iranian policy called Rural Housing Retrofitting Special Plan (RHSP), by reviewing the legal framework and the corresponding implementation processes. The study also involves fieldwork in a selected case study, the village of Nater, in which both the traditional architecture buildings (24 units) and new houses (41 units) built under the RHSP strategy have been assessed in terms of their typology, construction methods, and building processes. The results of the fieldwork observations were complemented with interviews with houses owners, while responses about building methods were later triangulated through the employment of secondary data on Iranian traditional building methods as illustrated by Zomarshidi (2005).

8.3 The policy and legal frameworks for Disaster Risk Reduction in small towns and rural villages

Development of rural regions, so as to reduce vulnerability to disasters, is one of the important missions of the government of Iran. The authority responsible for risk reduction in rural settlements of Iran is the Housing Foundation of Islamic Revolution (HFIR from here) (Deputy of rural development and deprived areas of Iran 2014) which operates tenure security programs (issuing building permits) and two schemes: one for land use and infrastructure planning (called Rural Guide Plans) and another, mainly focusing on housing retrofitting and enhancement, namely the Rural Housing Retrofitting Special Plan (RHSP from here). In the framework of the sixth National Development Program of Iran (2017–2021), the current RHSP is looking for retrofitting and renewal of 200,000 rural housing units per year (Islamic Parliament of Iran 2017) by allocating conditional low-interest loans to rural people, who are expected to apply the program in return for obtaining the funding, and retrofit their houses in accordance with the Housing Foundation of Islamic Revolution building standards (HFIR 2016; Beyti 2012).

Within the 16 articles of the RHSP Charter, the purpose of building more disaster resistant and durable houses (Article No. 1) is linked to the mandate to preserve the identity of the vernacular architecture of rural housing by minimizing the shortcomings of translation of urban housing style and promoting the selected outstanding patterns of rural architecture in terms of forms and aesthetics (Articles No. 2, 13 and 15, HFIR 2016).

Such integrated risk-reduction and aesthetic strategy is operationalized through the RHSP guidelines, which are interpreted by different consultants, separately, for each province. These guidelines usually consist of different documents, including landscape and built environment typology studies, which serves as the basis for a "design patterns" document, integrating and adapting within the context of the Iranian building codes for seismic resistant structures (Standard 2800).

The Housing Foundation of Islamic Revolution provincial offices are in charge of coordinating the implementation of the guidelines. This responsibility is given to the HFIR local technical offices. However, it is the HFIR national headquarter who is in charge of deciding the number of allocated loans per province and employing consultants to provide the guidelines. Therefore, while the decisions determining dimensions and territorial distribution of retrofitting projects is centralized, the responsibility of putting adequate building codes into practice, integrating disaster risks reduction standards with the rural aesthetic and traditional architecture is delegated to the local level. Indeed, HFIR provincial offices support the manufacturing of building materials to be used in retrofitting and also organize technical courses for local engineers to make them familiar with HFIR design and supervision criteria (HFIR 2016; Beyti 2012).

8.4 Case Study Introduction

Nater is a small village located in a remote mountainous area in the province of Mazandaran, Northern Iran (see Fig. 8.1), with the area of approximately 220 ha (Deputy of rural development 2005). Nater has cold semi-arid climate, with winters

Fig. 8.1 Geographical location of Nater, Google with the authors' additions

that usually come early accompanied by heavy snowfalls. Nater's economy is dependent on traditional husbandry and incomes are low and insecure.

According to the census of 2011, Nater has 490 inhabitants distributed within 151 families (Statistical Center of Iran 2011). Nater was one of the villages effected by the earthquake of May 2004, which had a magnitude of 6.5 (Deputy of rural development 2005). Luckily, and notwithstanding the traditional nature of the houses in this small village, a considerable number of buildings withstood the earthquake, or suffered minor damage (as reported from the local authority of Nater). However, from 2004 to 2005, people in Nater were eligible to get the earthquake reconstruction loan from HFIR. This opportunity induced a dramatic change in the built environment. Around 110 loans (since the date of the earthquake) were given for both retrofitting and enhancing maintenance of traditional buildings. The issue is that under this program and its "retrofitting" nature, even the houses that withstood the earthquake were destroyed and rebuilt. This trend has been reinforced through the implementation of the RHSP program in 2006, and over ten years 41 new houses have been constructed (HFIR internal statistics accessed on April 2017). As stated in the introduction, people have been increasingly concerned about how the RHSP has been applied (Shams Nateri 2013), neglecting the provincial guidelines (aligned with the traditional building culture) during its local implementation (see Fig. 8.2). Therefore, in the next section, the chapter explores the resilience features of the traditional architecture building techniques.

Fig. 8.2 Contrast between the traditional and RHSP constructed houses, (A traditional house of Nater being cut in half for a RHSP house to be constructed), author, March 2017

8.5 Traditional building culture in Nater: The disregarded earthquake resilience characteristics

The traditional houses of Nater are maximum two-storeys. The family lives on the first floor while the basement is allocated to the livelihood activity of the family, mainly husbandry. Locating the living space on top of a barn has thermal function as well. An elderly villager explained during the interview, that the heat produced by the animals would make the barn warm and consequently the first floor would have a comfortable temperature (owners of traditional houses interview, Nater, March 2017).

It is a ritual to retrofit some part of the houses every year before winter. During such a reconstruction, the plinth, walls, and roof's shingles are checked and replaced if necessary. The local authority of Nater stated during the interview that, unfortunately, this ritual has been forgotten for some years, and lack of maintenance is becoming a major issue that can potentially increase vulnerability to earthquakes (local authority interview, Nater, March 2017). Lack of maintenance is either caused by the poverty, old age of those with construction knowledge, or the intention of local people to build new houses using alternative materials such as concrete, under the RHSP program in future. During the interviews with the local authorities, we realized that people aspire to have new houses, because it represents wealth, but at the same time they regret losing the comfort (thermal insulation) of their old house and the traditional appearance of Nater.

8.5.1 *Building Methods*

Traditionally, houses were made of stones, wood, and cob. The double wooden ceilings of these houses are based on a framework of timber pillars and beams. The walls are thick, plastered by daub and gypsum which leads to a high thermal mass of the building. Notwithstanding most of the traditional houses of Nater withstood the earthquake of May 2004, most of the damages happened to the roof's shingles and the plinth (local authority interview, Nater, April 2017). The elements having seismic resistance features are, among others: the vertical members and horizontal bands, which are placed in different levels in the plinth, especially in its corners, to ensure proper load transfers and to reinforce the wall- to-wall connections of the building (see Fig. 8.3). The villagers had inherited this technique from their ancestors while its purpose became evident to them after the earthquake of May 2004, which remarked during the interviews: "during *the last earthquake, some stones fell out of the plinth but there was no major damage to the plinth itself, thanks to its beams*" (owners of traditional houses interview, Nater, March 2017). Indeed, the openings in the plinths are relatively small and boxed by wooden frames to increase the strength of the plinth.

Another feature of earthquake resilience of the traditional houses is the Daarvarchin method of wall construction, which can be described as the use of

Fig. 8.3 The plinth, author

round logs with bottom-cut corner notches as mortise and tenon joints. Sometimes mortise and tenon were also secured by nails (see Fig. 8.4). The flexibility of the joints provides basic seismic esistance in this building type.

One more traditional method for walls construction is called Nefar, and it is similar to timber frame structures. In this method, the columns are attached together by diagonal planks nailed or tied to the columns from both sides and the area in-between is filled with cob. Finally, the wall would be covered all by daub (see Fig. 8.5). Knocking on the wall of his house, one of the village elders explained that "*this wall has a structure, and is not made purely by cob. We put the diagonal timbers inside the wall to make it more stable*" (owners of traditional houses interview, Nater, April 2017). Indeed, the Nefar method with its diagonal planks has similar function of cross-bracing which supports compression and tension forces.

The use of flexible joints is also evident in other structural elements: the second floor beams are put on top of Y-shaped columns, resulting in flexibility in the connection between beams and columns. The provided flexibility can accommodate, to some degree, the horizontal tectonic movements (see Fig. 8.6). However, the connection of the beam and the column can still be improved. The villagers have developed their method to increase the durability of the wooden columns:

Fig. 8.4 Daarvarchin method, author

"*The old columns used to decay after a while but we figured out that by saturating them in bitumen we can overcome this issue*" (owners of traditional houses interview, Nater, April 2017).

These local capacities are recognized from the head of the local technical office, which reported during an interview that all these building techniques are indeed well known, also within the region, due to their earthquake resistance performance (head of local technical office interview, Marzan Abad, April 2017).

8.5.2 Construction Process

Traditionally, houses were built by the owner with the help of the community. To construct a new house, the young generation of the family would build his house with the help of their father who had learned the construction methods from his parents. "*I still remember clearly how I built my house with my own hands. But now, my son cannot do it anymore and a contractor is building his house*" said a village elder. The construction of the roof truss was a group work with the help of the community and everyone was invited by the owner to have a meal together

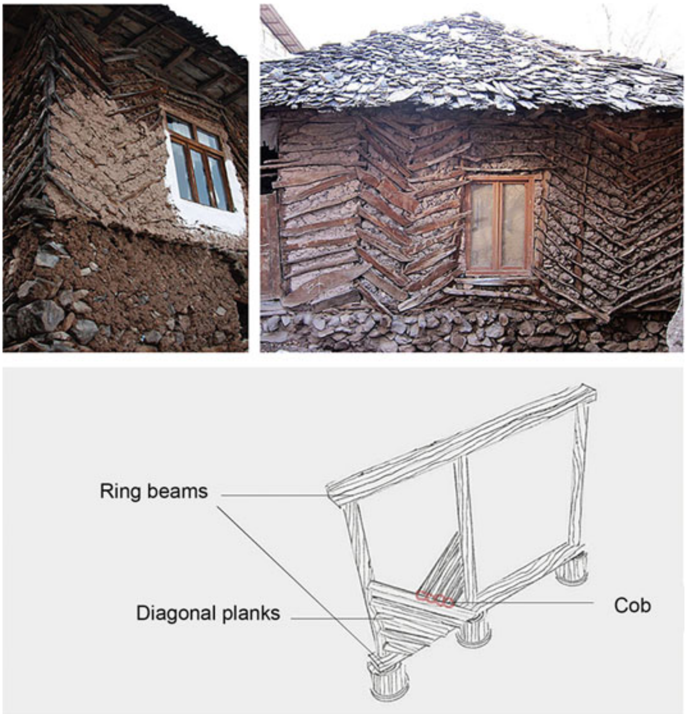

Fig. 8.5 Nefar method, author

afterwards. Anytime during the process when an obstacle was happening, the neighbours would gather and help solving the matter (owners of traditional houses interview, Nater, April 2017). The owner performed an active role in maintenance and fixing malfunctioning components as illustrated previously through the traditional yearly maintenance before each winter. Because of this accumulated building knowledge anybody was able to adapt or expand the houses for any further needs of the family. We can state that such activities and traditions will strengthening social capital in the community, contributing therefore to the enhancement of community resilience to earthquakes.

Construction materials were accessible and provided locally. However, things changed "*because of an environmental law that has prohibited the cutting down of trees, the afforestation office supplies the timber and logs*", mentioned by the local authority of Nater (local authority interview, Nater, April 2017). The next section illustrates how implementation of the RHSP program in Nater, aiming to enhance building seismic resiliency, is actually diminishing such a social capital that confers community resilience.

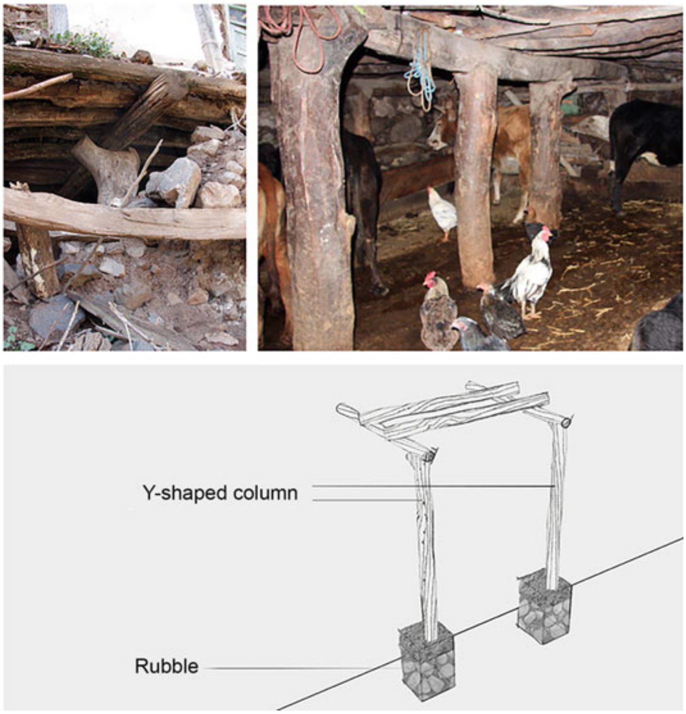

Fig. 8.6 Columns, author

8.6 RHSP on the Ground: From a Planned Policy Framework to a Subjective Application

8.6.1 Through the Provincial Guidelines

By the implementation of the RHSP in 2006, people in Nater who owned land were eligible to get RHSP low-interest loan (amounting at 200 million Iranian Rial, corresponding to 5800 Euro), which would be paid in 3 installments (The Cabinet of Iran 2015). The three trenches of the loan are to be paid by the approval of the technical supervisors from HFIR after the construction of the building's foundation, after the roof and walls have been built, and when the finishing is done (Beyti 2012). People can construct houses by their own but under the condition of accepting the HFIR building regulations, which for the province of Mazandaran, where Nater is located, suggested to use new methods and materials (specifically reinforced concrete). Although in the policy documents the strengths and weaknesses of the local techniques of construction were mentioned, no specific mention has been done supporting their use or adaptation within the new buildings under this program. Consequently, the HFIR guideline limits the use of local materials to the facade of buildings, or for special cases in remote areas that have difficulty accessing "new" materials, neglecting the relevance and built-in resilience features of the traditional houses walls structures.

Moreover, the results of the fieldwork suggest that the implementation of RHSP in Nater led to the destruction of most of the its traditional buildings, as far as the loans have been used and assigned to build new houses. The high expertise needed to insure the full structural safety of vernacular buildings, in general, is the reason for HFIR to focus on building of brand new units (HFIR headquarter officer interview, Tehran, April 2017). Due to limited available space on people's lands, many people destroyed their old homes to gain space and took advantage of the loan to build a new one.

Another important evidence from the fieldwork has been that the suggested "design patterns" provided by HFIR have not been used in practice, in Nater, nor in other villages of the province (interviews, Nater, 2017). Reviewing the enquiries at the local HFIR technical office and interviewing loans' applicants this research reveals that applicants were not informed at all about the existence of such design patterns, and actually the local technical office didn't promote them. Local engineers usually designed the houses from scratch without considering the HFIR guidelines, visiting the site, or studying the context; as the policy framework recommended. Their designs were based on the Iranian code of practice for seismic resistant design of buildings (Standard 2800) which, again, is not a context-specific document, but a generic guideline on technical design and building codes. Moreover, without referring to the HFIR guidelines, there was no other document for the local technical office to use as a checklist in order to approve the designed building plans for implementation. Paradoxically, the head of the local technical office was in charge of evaluating all the building designs based on his own knowledge and experience, rather than following the policy framework.

8.6.2 Implementation of RHSP

As of April 16th 2017, as previously mentioned, 41 houses were constructed by the RHSP in Nater. These buildings resulted in imitations of housing design style of major Iranian cities, introducing in so doing "new" materials and construction methods in Nater (see Fig. 8.7). An officer of HFIR in the province said during the interviews that the villagers like to imitate urban houses and explicitly requested local engineers of HFIR to design such houses for them (Officer of HFIR interview, Chaloos, April 2017). On the other hand, the head engineer of the local technical office admitted during the interview that, although architects were accredited from HFIR to build according to the traditional building styles and techniques, they do not have enough practical competence to do it, and because of this, their designs were imitations of urban buildings (head engineer of local technical office interview, Marzan Abad, April 2017).

Fig. 8.7 Design of the facades in Tehran (left), A house in Nater (Right). *Source* up.alamto.com, hira-static.com, Accessed May 2017 and the author, 2011

Unfortunately, the effects of these imitations are greater than the visual effect of placing concrete buildings among traditional houses, implying a mismatch between the construction provided, the actual local needs, and housing functions. An example resulting from this issue is that the new houses include a garage for each house, even though in Nater, due to the village topography and roads patterns, cars cannot enter the village. At the same time, locals' need for a space for their livestock has been neglected. An adaptation to this fallacy has been reported from the local authority of Nater, referring that locals converted those "compulsory spaces" (the parking) into barns or used them as warehouses, to answer their livelihood needs. A recognizable change in such conversion is blocking the garage windows or reducing their size in order to provide thermal comfort inside for the animals (local authority interview, Nater, April 2017).

8.6.3 Building Methods

Observation of the ongoing construction in Nater shows the use of reinforced concrete for foundations and structure. The walls are made of hollow blocks and the sloping roofs have an iron truss structure, covered by corrugated iron tinplate.

The construction details from the archive of the local technical office show that this method has been used in all 41 houses that have been constructed under RHSP.

The HFIR officers consider the structural resistance of buildings only being provided through the use of reinforced concrete structures. At the meeting in the local technical office of HFIR in April 2017, a case was mentioned: the use of wood was not approved for semi-structural elements although there was enough evidence that the resistance of this material and its method of construction was acceptable. The head of local technical office stated that, although he personally supported the use of vernacular material, he was not able to convince his superiors and so obtain approval for the procedure (personal communication, Marzan Abad technical office, April 2017).

8.6.4 Construction Process

With regard to the construction material, they need to be brought to Nater from the neighboring cities of Chaloos and Marzan Abad. The price of transportation would be added to the material costs, which would make it more expensive than the normal cost of materials available locally. Therefore, the villagers prefer to use lowest quality, second hand materials, or in some cases reduce the percentage of cement in concrete and mortar to save money.

Construction of buildings according to RHSP stipulations would be done by contractors hired by the villagers, since the villagers have no knowledge of the building methods that are being used. The workforce mainly comes from the nearby cities. According to the head officer of local technical office, contractors are mainly "self-thought architects" who do not usually pay enough attention to building regulations. At the same time, due to the distant location of the village, the supervisory engineers would normally only be able to make just the three required visits for approval of the next loan-payment. The head of the local technical office reported during the interview that the current visits by supervisors at the end of each construction stage are not sufficient to guarantee that the guidelines are being followed (head of the local technical office interview, Marzan Abad, April 2017).

Most of the RHSP built houses observed in Nater still have exposed structure and no plaster on their exterior walls. The reason for this is the insufficient amount of the RHSP loan to cover the construction costs of a building with a sloping roof, as mentioned by the head of the local office. Thus, after construction of the roof, people cannot afford to spend more money from their own savings on the facade of their houses (head of the local technical office interview, Marzan Abad, April 2017). This not only affect the appearance of the village, but also reduces the durability of the walls and their insulation properties.

8.7 Discussion

In order to respond to the different needs coming from the diverse climatic conditions and geographical contexts of Iran, disaster risk reduction programs should be framed in a way that respects local-specific conditions (as mentioned by Sartipipour 2005). Indeed, the charter of the policy called Rural Housing Retrofitting Spatial Plan (RHSP) considers preservation of the local characteristics (the landscape, built environment and its traditions). Moreover, its operational framework shows that its implementation stages should be carried out at the local level. However, notwithstanding the effectiveness of RHSP program in reducing the physical vulnerability of the built environment, as already mentioned in the recent literature (Einali et al. 2014; Abdollahi et al. 2015), the RHSP program so far, has just reached its quantitative goals (renewal of 200,000 rural housing units per year). The qualitative goals of the RHSP about preserving the identity of the vernacular architecture of rural housing and providing required spaces based on rural needs are not reached yet (Mahdian and Sartipipour 2012; Beyti 2012). Other scholars remarked that the implementation of the RHSP is having adverse effects on sociocultural relations and the economy of the settlements by neglecting peoples culture, need, production activities, and way of living (Ghasemi Ardehaee and Rostamali Zadeh 2012; Saidi et al. 2013). Therefore, Zargar consider the RHSP program "not realistic, but an emotional hasty approach in providing resistant structures" (Zargar 2010, p. 254). This chapter highlights the fallacies of the RHSP policy implementation when it comes to retrofitting rural villages houses in line with the spatial and cultural local contexts.

Notwithstanding the well-designed policy framework of RHSP program, integrating risk reduction measures while recognizing the local building architecture (stated under article No. 1, 2, 13, and 15 of its charter), this research results highlight the neglecting of local social and built environment embedded resilience characteristics. First of all, HFIR policy regards that buildings' structural resistance is to be provided only through the use of "new" materials and techniques, and indeed, interviews showed that local HFIR architects did not have enough knowledge about local architectural methods and designs to employ them (see Sects. 8.6.1 and 8.6.2). Moreover, although the term "retrofitting" is employed in the title of HFIR policy, this actually does not convey "Reinforcement, upgrading" (United Nations International Strategy for Disaster Reduction [UNISDR] 2009, p. 25) and "modification of existing structures to make them more resistant to seismic activity" (Management Association, Information Resources 2016, p. 1378). Rather, it focuses on increasing resistance of the buildings through construction of brand new units; due to expertise needed to keep the traditional houses and insure its full structural safety (as mentioned by HFIR headquarter officer through interview). Moreover, the implementation of RHSP in Nater including its strategy to assign the loan in the criteria of land ownership without considering the limited available space on people's lands, led to the destruction of most of the its traditional buildings (see Sect. 8.6.1). Also, the imitation of urban typologies in RHSP buildings (far from being in line with the local building culture, lifestyles and landscape) fosters the process of devaluating the vernacular houses, which are not maintained anymore, resulting on their decay.

Through its results, this chapter explained how the implementation of RHSP policy leaves no space for vernacular architecture to demonstrate and maintain its seismic resistance features. Furthermore, this chapter indicates that implementation of the RHSP vanishes the social processes related to traditional methods of construction (knowledge transfer, traditions of maintenance, community participation in construction, etc.); related to community resilience attributes (Aldrich and Meyer 2014). As illustrated in Sect. 8.4 and as others have recently highlighted, there are mechanisms of adaptation to the risk of earthquake developed by locals which are embedded in the vernacular buildings (Ortega et al. 2017). Indeed, not only the new RHSP buildings, but also the existing local vernacular architecture was providing the built environment with safety and earthquake resistant performances, while enhancing social capital and community resilience as well. Interestingly enough, the guideline of RHSP for Mazandaran province does mention and recognize one of such mechanisms, the Daarvarchin walls building method (see Sect. 8.6.1 explaining how this method contribute to enhance seismic proof performances). However, the operationalization of the policy completely neglects those guidelines. Also, the building processes in Nater have been done mainly by external workforce (see Sect. 8.6.4), disrupting the knowledge-transfer cycle to the next generation about traditional housing building methods. Therefore, for any the future expansion or repair of the new houses, locals will be depending on external specialized workforce.

8.8 Conclusion

As this chapter explored, the poor outcome sometimes is not due to having the policy being not properly framed or articulated. The chain of decision-making along the implementation process of a good policy can fail to deliver the proper outcomes of the policy guidelines to locals. It can disturb the existence local capacities to adapt or cope with stresses and threats by introducing distant practices and methods. Such deficiencies along the decision making and implementation process of the policy called Rural Housing Retrofitting Spatial Plan (RHSP), in the case of Nater, have been: (i) not believing in the use of traditional building methods and materials, nor supporting the conservation of traditional architecture, (ii) hiring architects and engineers who are not appropriately trained about the policy framework guidelines and local building culture, resulting in the production of inadequate housing units, (iii) neglecting the provincial RHSP policy guidelines and not having a checklist for evaluating the designed buildings, (iv) ignoring the relation of the physical features of rural houses with the economy, social, cultural, and environmental aspect of rural life (v) increasing the resistance of houses by construction of brand new units with different construction methods and demolishing the vernacular buildings,

(vi) neither investing on the maintenance of the vernacular architecture, nor enhancing local methods of construction. Indeed, it should be taken into account that 'poor maintenance' of the vernacular houses was a key indicator for overall seismic vulnerability of rural settlements (Ortega et al. 2017).

To minimize the gap between the RHSP objectives and its outcomes, the chain of decision-makers along its implementation process should change their negative mindset towards the traditional buildings. Indeed, a context-specific need assessment can reveal if the local seismic culture exists in building, as not all the vernacular buildings are vulnerable. Therefore, this chapter suggests to complement appropriate traditional and local knowledge and practices and ensure the development and implementation of policies to be tailored to localities and context, in the light of the Sendai Framework for Disaster Risk Reduction 2015–2030 and existing literature on vernacular seismic cultures and methods of enhancing the resistance of vernacular buildings (such as Yousefnia Pasha 2006; Sartipipour 2012; Minke 2005). To this end, a chapter on vernacular seismic building methods, its related regulations, building codes, and checklists should be provided within the RHSP guidelines. These methods should be taught to the architects and engineers responsible for RHSP implementation. Moreover, local communities need to be informed about the value of their cultural construction practices and its capabilities to withstand seismic shocks. In cases that a retrofitting method is suggested or a new construction technique is to be implemented in the village, local people need to be trained and educated on such method to be able to participate and get involved in construction, maintenance and reconstruction (if any damage happened). Since risk reduction policies should be framed in the light of both building and social capital features, contributing to the built environment as well as the community resilience.

This chapter demonstrated, only for the specific case study of Nater, that the vulnerability of settlements in remote areas of Iran is not due to the lack of coping mechanism, social capital and buildings weakness with respect to seismic treats. On the contrary, if well maintained, the vernacular architecture offers a variety of seismic resilience features, while contributing to enhancement of social capital. Paradoxically, those elements are neglected in the implementation of the disaster risks reduction policy of RHSP. However, for a sounding and consistent critic to the RHSP, we call for more case studies to be developed in order to test this chapter hypothesis and results.

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Part III
Urban Form and Resilience

Chapter 9
Resilient Urban Form: A Conceptual Framework

Ayyoob Sharifi and Yoshiki Yamagata

9.1 Introduction

Cities are home to more than 54% of world population (UNDESA 2014) and account for over 80% of global Gross Domestic Product (GDP) (UNHABITAT 2016). Since about 67% of world population is projected to live in cities by 2050 (UNDESA 2014), cities are expected to gain an even more outstanding role at the center of global socio-economic growth. Given the high concentration of resources and activities in urban areas, it is obvious that enhancing urban resilience is critical for maintaining global economic growth and for contributing to global social prosperity. Growth of world urban population is also expected to increase world energy demand which is considered as a major driving force of climate change. In turn, climate change is likely to increase frequency and intensity of extreme events that are likely to trigger disasters in cities. Therefore, cities need to build on their resilience capacities to survive and thrive in the face of global environmental change.

While the physical form of cities may be considered non-deformable and rigid, its properties influence urban socio-economic and environmental dynamics and feedbacks. Among other influences, urban form has implications for socio-economic performance of cities, disaster mitigation and response capacity, and building and transport energy demand. Desirable urban forms can play an important role in strengthening the economy of cities and enhancing health and well-being of their residents. It can, therefore, be argued that intervening in physical form of cities should be considered as a strategy through which advances can be made in terms of enhancing urban resilience.

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While a large body of literature has been published on urban resilience, research on resilience of urban form is still scarce. This chapter seeks to take a step towards filling this gap by discussing the concept of urban form in the context of resilience thinking, pinning down the meaning of ‘resilient urban form’, and developing a conceptual framework for analyzing resilience of urban form.

This chapter proceeds as follows: the next section provides a brief description of the resilience concept. In Sect. 9.3 urban form and its constituent elements are explored. In Sect. 9.4 the points and concepts discussed in the first two sections are connected to develop a conceptual framework for analyzing and assessing resilience of urban form. The chapter concludes with suggestions for future work.

9.2 Resilience and Its Conceptual Underpinnings

To discuss urban form in the context of resilience thinking, it is first essential to explain what is meant by the term ‘resilience’ and what issues/dimensions should be considered when developing a conceptual framework for urban (form) resilience assessment.

As discussed in chapter one of this volume, the resilience concept has multidisciplinary roots in fields such as physics, ecology, and psychology. Over the past few years, it has also been increasingly used in research related to urban areas. Due to being overused, there is a fear that resilience may turn into a somewhat hackneyed term. The term is frequently used to label any initiatives and actions (particularly related to disaster management and climate change mitigation and adaptation in cities) (Sharifi et al. 2017). Clarifying the concept and its underlying principles helps use the term in a more academic and scientific manner. It is particularly necessary to adjust the definition of resilience depending on the specific research question(s).

Generally, resilience can be defined as a property of urban system that enables it to survive and thrive in the face of uncertainty, adversity, and change (both incremental and rapid). Enhancing urban resilience requires continuous efforts during all phases of the disaster management cycle (i.e. mitigation, preparedness, absorption, recovery, response, and adaptation).

It is argued that considering questions such as ‘resilience of what?’, ‘resilience to what’, and ‘resilience for whom’ can help assign an adjusted meaning to the term resilience (Sharifi et al. 2017). Resilience of various urban form components to both natural and human-induced disasters needs to be considered. Since the focus of this chapter is on the physical form of cities, we assume that no specific group of people is excluded from the benefits of enhancing resilience of urban form and, therefore, do not address the question of ‘resilience for whom?’. However, this should not be taken to mean that ‘resilience for whom?’ is completely irrelevant in the context of urban form analysis. It is possible that different community groups have different visions and priorities concerning building resilient urban forms. Exploring this issue is, however, beyond the scope of this chapter.

Here we argue that spatial and temporal scales and the purpose of analysis/assessment should also be considered when studying resilience of urban form. Accordingly, the following questions should also be considered: 'resilience in what context and at what geographic scale?', 'resilience during what stage of the disaster management cycle?', and 'resilience for what?'.

Context is important because prioritization of efforts aimed at increasing resilience of urban form may be context sensitive. Take for example the issue of resilience to climate change impacts. Building and transport sectors account for the majority of carbon emissions in cities. However, the share of these sectors may differ depending on the region. In some countries such as the UK buildings are the dominant energy consumers, while in others a large share of energy is also used for transport (Steemers 2003). Therefore, resilience planning measures should be developed depending to the specific needs and priorities of the target area. Geographic scale should also be considered as different measures may need to be taken depending on the scale of the analysis (i.e. local, regional, etc.). Cities are complex and dynamic systems nested within an interconnected network of socio-ecological systems and it is essential to take account of interactions between different scales.

Resilience building priorities may also differ depending on the phase of disaster management cycle and the stage of the adaptive cycle. For instance, during the growth phase the competition for limited resources and domination of economic and institutional entities may reduce the need for redundancy. However, redundancy is likely to be indispensable during other phases of the adaptive cycle (Marcus and Colding 2014).

Last, but not the least, desirability of measures to enhance resilience of urban form is likely to depend on determining what resilience characteristic is sought to be improved. For instance, provision of redundant mobility networks is critical for facilitating evacuation when a disaster occurs. However, this will reduce the overall efficiency of the urban system.

To summarize, resilient urban form is defined by the degree to which it can support maintaining integrity and functionality of urban systems, as systems nested within an interconnected network of spatial and socio-ecological systems that are characterized by evolutionary spatio-temporal dynamics, under constantly changing socio-economic and environmental conditions. Resilience is a context-sensitive property of urban form, the defining characteristics of which may vary depending on various factors such as the spatio-temporal level of intervention, the risk in question, and the purpose of intervention.

9.3 Urban Form and Its Constituent Elements

In the previous section it was mentioned that 'resilience of what' is an essential question that should be answered prior to embarking on research in the field of resilience. Broadly speaking, here, the answer to the above question is 'urban form'.

However, better understanding of what urban form entails is needed to develop a conceptual framework for its analysis/assessment.

Different approaches to categorizing constituent elements of urban from can be found in the literature. The elements can be divided into two major categories: the built environment and urban (transport) networks (Silva et al. 2017). While covering most urban form elements, this broad categorization does not lend itself to addressing issues related to scale hierarchy and cross-scale relationships that were explained to be critical for building urban resilience. Taking a different approach, Dempsey et al. (2010) relate elements of urban form to some major features that can be categorized into five broad groups namely, density, housing/building type, transport infrastructure, layout, and land use. These are arguably the most common urban form elements. However, the list is not exhaustive. Furthermore, the above-mentioned issues related to scale hierarchy and cross-scale dynamics remain unresolved.

In an effort to introduce a more comprehensive categorization that takes cross-scale dynamics into account, we divide urban form elements into three major scale-based categories, namely macro-, meso-, and micro-scales. This approach recognizes that cities are part of a hierarchic system and helps gain a better understanding of the spatial distribution of elements, their location related to each other, and how they influence one another. In other words, this categorization builds a nested network of scales, characterized by strong inter- and intra-scale relationships.

9.3.1 Macro-Scale Elements

As can be seen from Table 9.1, at the macro scale, urban form concerns the whole structure of the city, its existing position, and its future development in relation to other cities and settlements in the broader network of cities and city regions. Understanding urban form from a macro-scale point of view is a pre-requisite for taking a 'systems thinking approach' that acknowledges dynamics and complexities of urban systems. Six major attributes of the macro-scale category are scale hierarchy, city size, development type, distribution pattern of people and jobs, degree of clustering, and landscape connectivity. Scale hierarchy concerns the integration of different small-scale components into higher-scale systems in an incremental and evolutionary process. Systems characterized by scale hierarchy are argued to exhibit a better adaptive capacity (Salat 2017). City area and density are two important indicators of city size. Different indicators can be used for measuring density. It can be measured in either gross or net terms. Gross density is the ratio of people, households, or dwelling units to a given area (block, neighborhood, city, etc.), irrespective of land use (Dempsey et al. 2010). Net density (e.g. net residential density), however, is the ratio of people, households, or dwelling units to the area allocated to a specific land use (e.g. residential) (Dempsey et al. 2010).

Table 9.1 Constituent elements of urban form

Scale	Attributes	Sub-attributes
Macro-scale	Scale hierarchy	Regional connectivity, etc.
	City size	Population density
		City area
	Development type	Planned/unplanned; formal/informal
		Infill, sprawl, etc.
	Distribution pattern of population and employment	Degree of equal distribution
	Degree of clustering	Degree of compactness
		Centrality/uniformity/monocentricity/polycentricity
	Landscape/habitat connectivity	
Meso-scale	Structure and shape of neighborhoods/districts	Neighborhood size and shape, Sanctuary area, etc.
	Diversity/Heterogeneity	Land use mix; ratio of open and green space
	Typology of transportation network (both active and non-active transportation)	Route type (grid pattern, curvilinear, cul-de-sac, radial, organic, hybrid, etc.)
		Street width
		Street orientation (direction)
		Design and layout of streets, cycling, and pedestrian networks
		Centrality and spinally of street network segments
		Permeability/connectivity
	Access to amenities	
	Open and green space	Size, shape (design), and distribution pattern of Vacant and open spaces
		Size, shape (design), and distribution pattern of green space

(continued)

Table 9.1 (continued)

Scale	Attributes	Sub-attributes
Micro-scale (building and block)	Block type	Block size, Perimeter urban block and its permutations,
	Site layout	Layout configuration (uniform/random)
		Lot size and geometry
		Site coverage
	Building configuration/layout	Dwelling size
		Dimensions and compactness (surface to volume ratio, depth)
		Orientation
		Spacing between buildings
	Roof type	
	Glazing	Size and position of windows; window to wall ratio
	Building typology	courtyard, townhouse, detached, …
	Density	Floor area ratio, etc.
	Street canyon geometry	aspect ratio,
	Design (street front/street edge)	Space between building façade and streets
		Front usage
	Design of emergency routes	

Development type indicators relate to characteristics such as formality/ informality, and location of the development (e.g. infill, greenfield, etc.). The extent of equal distribution of jobs and employment is often measured at the macro-scale. It can, for instance be used to see how urban form can facilitate/ constrain travel choices. Indicators related to the degree of clustering are used to measure the extent of compactness and understand whether a given city follows a uniform, monocentric, polycentric, or hybrid pattern. The degree of clustering has direct linkages to commonly known urban form characteristics such as centrality and accessibility. Finally, landscape connectivity relates to the nature and extent of two types of connections: connections between the city and other settlements in the hierarchic system of settlements, and connections between ecosystem components within and beyond the city boundaries.

9.3.2 Meso-Scale Elements

At the mesoscale, urban form concerns the general structure of neighborhoods and districts. Major attributes to be considered are structure and shape of neighborhoods, diversity, typology of transportation network, access to amenities, and size and shape of open and green spaces.

Factors such as size and shape of the neighborhood and distribution pattern of blocks and open spaces determine the overall neighborhood structure. Neighborhood structure can play a significant role in facilitating/constraining travel choices. It can also have numerous other socio-economic and environmental implications for achieving urban resilience. The diversity attribute is mainly related to the extent of land use mix in the neighborhood. Traditionally, urban planning was in favor of separating land uses in cities in order to avoid conflicts (e.g. disturbing and undesirable uses in the residential environment) (Dempsey et al. 2010). However, due to socio-economic and environmental benefits, mixed use development at building (vertical) and urban scales is increasingly encouraged by planners (Dempsey et al. 2010). Desired number and configuration of uses (mixture of them) may differ depending on the context (Dempsey et al. 2010).

Transportation networks are the backbones of cities and transport-related factors play a critical role in shaping urban morphology. It can even be argued that spatial configuration of cities and the way it evolves is highly influenced by the configuration of transportation networks. Different route types (e.g. orthogonal and non-orthogonal grid, curvilinear, cul-de-sac, radial, organic, and hybrid) can be found in cities. Resilience capacity of each type should be explored and considered in planning and assessment processes. Design, layout, and width of streets and pathways affect resident's travel choices and can have implications in terms of energy performance of abutting buildings. The latter is also influenced by the street network orientation. Street layout and orientation influence potential of buildings to capture solar energy. Centrality is an indicator of the importance of a given route in the transportation network. The degree of centrality should be considered when allocating land to commercial and office uses. Furthermore, planners need to pay attention to the adverse effects of potential disruptions in a street segment with high centrality value. Connectivity and permeability have interlinkages with other urban form attributes such as block size. These features have implications for movement of pedestrians and vehicles and can be measured using indicators such as intersection density, route directness, and route continuity. Closely linked to 'connectivity' and 'centrality', 'accessibility' is a measure of proximity and shows the level of easiness to reach urban facilities. It is influenced by various factors such as the extent of equal distribution of facilities. Open and green space is the last attribute listed under the meso-scale category. These particular land uses have been mentioned separately due to their importance in terms of enhancing coping capacity of cities and providing multiple 'regulating', 'supporting', 'cultural', and 'provisioning' ecosystem services. Optimal achievement of such services depends on the size, shape, and distribution pattern of open and green spaces.

9.3.3 Micro-Scale Elements

At the micro-scale, urban form concerns the structure of buildings, how they are located in relation to each other (on the site), and their relative position with respect to the pedestrian and traffic networks in a finer level of granularity. These granular elements of urban form have direct implications for energy performance of buildings and for regulating urban micro-climate. Furthermore, micro-scale elements have direct and indirect connections to elements and features such as the degree of clustering, connectivity, and accessibility that were mentioned above. For instance, the degree of connectivity and accessibility can, to a large extent, be determined by the size of urban blocks. Super blocks put constraints on the capacity to sub-divide or aggregate urban plots. Such blocks are often occupied by single uses and this has adverse impacts in terms of diversity and redundancy. Furthermore, large blocks result in long and impermeable street edges that reduce accessibility in the built environment. Urban blocks should ideally be designed in a way that allows future subdivisions and reconfigurations (Feliciotti et al. 2017).

Site layout is concerned with lot size and how buildings are situated with respect to one another and to the street. Lot size and geometry, site coverage, and uniformity and/or randomness of layout configuration are some related urban form measures that can be used to measure urban form resilience in terms of the site layout. The building configuration/layout elements include, but are not limited to, building size, compactness, orientation, and the spacing between buildings. These all affect adequacy of solar access and natural ventilation in buildings and have implications in terms of building energy consumption. Proper spacing between buildings should also be considered for reducing earthquake disaster risk. It also has implications for building energy demand. Roof type has significant impacts on the amount of heat gain in buildings. In addition, roof type influences photovoltaic solar potential and determines whether green infrastructure such as green roofs can be incorporated. Glazing is a granular feature that can contribute to climate resilience by facilitating daylight accessibility and natural ventilation. Design of emergency routes relates to resilience as it may affect the effectiveness of emergency evacuation process. Building typology is worth investigating because different building types (e.g. detached, semi-detached, multi-story, terraced, courtyard, etc.) exhibit different energy consumption behaviors and have clear linkages with other urban form measures such as density. Indicators such as Floor Area Ratio (FAR) and Coverage Ratio are commonly used for measuring density at the micro-scale. FAR is the ratio of total floor area of a building to the lot area (of the site) on which it stands (Dempsey et al. 2010). Coverage Ratio indicates the portion of the lot area that is covered by a building (Dempsey et al. 2010). Street canyon geometry influences air circulation in the urban canopy layer and can intensify the urban heat island effect. It also influences solar accessibility potential of abutting buildings. Sky view factor and aspect ratio are two commonly used indicators of street canyon geometry.

Finally, design at the street level affects walkability and has socio-economic and environmental implications. Take, for example, street edges which are the interface between plots and abutting streets (Feliciotti et al. 2017). These components of urban form play an essential role in strengthening/constraining characteristics such as diversity, efficiency, and modularity. Street edges need to be permeable so that they can facilitate connectivity between different urban modules. Permeability can be achieved through physical qualities such as smaller lots (narrow front) that provide multiple access points, shorter distances between street-facing building façades and property lines, fewer blank walls facing the streets and non-physical qualities such as presence of shopping and other businesses that create active frontages. It should be noted that the desirable degree of permeability of street edges depends on the context. More permeability is desirable in mixed use areas facing main thoroughfares for the purpose of enhancing accessibility and connectivity between different components. However, less permeability would be needed in sub-divisions that are dominated by a single land use (e.g. residential) (Feliciotti et al. 2017).

9.4 A Conceptual Framework for Assessing Resilience of Urban Form

The proposed conceptual framework for assessing the resilience of urban form is presented in Fig. 9.1. It can be seen that responding to the following questions is critical for developing the conceptual framework: ‘resilience of what?’, ‘resilience in what context and at what geographic scale?’, ‘resilience to what?’, ‘resilience during what stage of the resilience cycle?’, and ‘resilience for what purpose?’.

In response to the first two questions, the framework is developed to assess resilience of urban form elements that relate to different scales of the urban system,

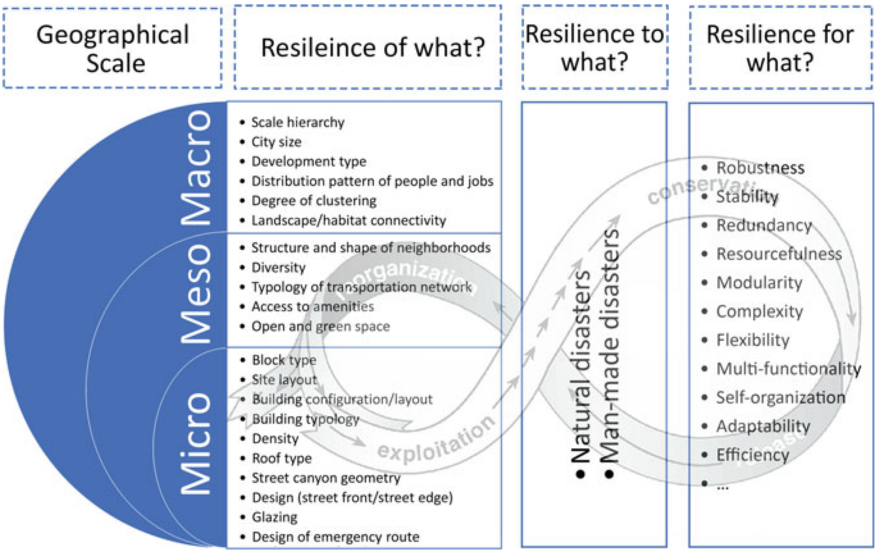

Fig. 9.1 Conceptual framework for assessing resilience of urban form

ranging from marco to meso and micro. More detailed explanation about the scope of each scale is provided in the previous section. It should be noted that this ‘scale-based categorization’ is not meant to imply that resilience of urban form elements belonging to each category can be assessed without considering the inherent cross-scale interactions. In reality, there are no clear boundaries between these three scales and certain levels of overlap always exist. This overlaps and dynamic interactions require understanding status of different scales relative to each other and relative to the whole urban system. In other words, in addition to understanding the status of parts lower in the hierarchy relative to the parts upper in the hierarchy (and vice versa), status of each part related to the whole urban system should also be studied. In addition, intra-scale relationships (interplay between different components belonging to each scale) should also be acknowledged.

Responding to the question ‘resilience to what?’ is essential to specify resilience of which components of the urban system against which disturbance is evaluated. Broadly speaking, hazards are divided into two major categories: ‘natural disasters and ‘man-made disasters. The former are natural phenomena such as earthquakes, landslides, droughts, heat waves, hurricanes, and tornadoes. The latter are caused by human interventions or failure of human-made systems (e.g. terrorist attacks, wars, fires, industrial disasters, etc.). Natural hazards influence and are influenced by man-made hazards. For instance, impacts of natural hazards can trigger the failure of man-made systems and cause serious man-made disasters (e.g. the Fukushima Daiichi nuclear disaster). Human actions and interventions can also change the frequency and intensity of natural disasters. Human-induced climate change, for example, is argued to change frequency and intensity of some extreme natural hazard events such as hurricanes. Certain urban form measures may enhance resilience to some hazards, but render the city vulnerable to others. For instance, while high-density areas can provide multiple socio-economic and environmental resilience benefits, they are more likely to be selected as potential targets for terrorist attacks. Connectivity is another frequently mentioned desirable urban form measure (Sharifi and Yamagata 2016a, b) which may prove detrimental when the aim is to enhance resilience to hazards such as health epidemics (higher connectivity may result in faster spread of epidemics). Therefore, type of hazards and their relative importance (in terms of both likelihood and impact) should be considered when making decisions about desirability of urban form, and cities be configured in a way that potential trade-offs be minimized.

Desirability of certain urban form measures (and threshold values related to urban form indicators) may vary depending on the phases of disaster management and adaptive cycle. An example of such temporal sensitivities (related to desirability of redundancy measure during the growth phase) was mentioned in Sect. 9.2. Other noteworthy urban form elements that may have different implications during different phases are ‘city size’ and ‘degree of clustering’.

Finally, addressing the question ‘resilience for what purpose’ is critical as different urban form configurations may be needed to pursue different resilience enhancement purposes. It is suggested that resilient systems aim at enhancing characteristics such as robustness, stability, redundancy, resourcefulness, modularity, complexity, flexibility, multi-functionality, self-organization, and efficiency (Sharifi and Yamagata 2016a, b). Trade-offs involved in efforts taken to pursue each of these characteristics should be adequately explored. For instance, increasing redundancy may undermine the efficiency enhancement purpose. When developing plans for minimizing trade-offs, the other sub-components of the conceptual framework should also be considered. For instance, efficiency may need to be prioritized during the growth phase.

Overall, a holistic approach is needed when applying the proposed conceptual framework for assessing resilience of urban form. For this purpose, thorough understanding of the inter-relationships between different components of the framework is required.

9.5 Conclusions

We are now living in an urban planet. The growing concentration of people and resources in urban areas indicates the significance of maintaining and enhancing urban resilience for achieving global sustainability. Given the frequency and intensity of risks that threaten urban areas, failure to build urban resilience can have serious ramifications. To achieve urban resilience, paying attention to multiple resilience dimensions is essential.

While a vast body of literature exists on different social, economic, institutional and environmental dimensions of urban resilience, relatively little attention has been paid to the role that physical form of cities can play in facilitating/impeding urban resilience. This study could be considered as an initial step towards filling this gap. While ‘resilient urban form’ may seem to be an oxymoron given the seemingly rigid and inflexible physical structure of cities, it is argued that urban form can affect resilience of cities both directly and indirectly and steering urban form towards more resilient pathways is critical for enhancing the overall resilience of cities.

The main purpose of this chapter was to introduce a conceptual framework that can be used for assessing and analyzing resilience of urban form. It is emphasized that addressing these questions is essential for developing the conceptual framework: ‘resilience of what?’, resilience to what’, ‘resilience in what context and at what geographic scale?’, ‘resilience for what?’ and, ‘resilience during what stage of the resilience cycle?’. The proposed conceptual framework has four major sub-components that are related to the first four questions. It is suggested that the stage of resilience cycle (corresponding to the last question) is an overarching component of the conceptual framework with linkages to the other four. City is a dynamic entity and its structure is constantly evolving. This constant evolution increases complexities of studying urban form and is indicative of the significance of paying attention to the resilience cycle (adaptive cycle and disaster risk management cycle).

The proposed framework underscores paying attention to urban dynamics over time and across space. Urban form elements are divided into three major categories that are related to macro-, meso-, and micro-scales of urban systems. It is emphasized that a urban system is greater and more complex than the sum of its constituent elements. How different elements of the urban system are linked to each other and to the whole urban system should be appropriately addressed when assessing resilience of urban form.

It is warned against taking a ‘one size fits all’ approach to developing resilient urban forms. Desirable urban form configurations, in terms of resilience, may vary greatly from one place to another and depending on factors such as type of disturbance, the phase of resilience cycle, and the purpose of assessment. Therefore, making improvements under certain conditions may cause detrimental effects under other circumstances.

It was mentioned above that urban form can affect resilience of cities both directly and indirectly. The proposed conceptual framework can be utilized to provide more details on such direct and indirect effects. A large, but fragmented, body of literature exists on urban form and disaster management. The proposed framework can be used to review this literature and extract potential direct and indirect linkages between urban form and resilience. Only few examples of potential synergies and tradeoffs between different urban form elements (under different conditions) have been mentioned in this chapter. Based on what discussed, we highlight one glaring challenge that need to be addressed in the future. More work is needed to better understand how different elements of urban form can be assessed/analyzed in an integrated manner so that we can, respectively, maximize and minimize potential synergies and tradeoffs between them.

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Chapter 10
Prospects for Urban Morphology in Resilience Assessment

Paul Stangl

10.1 Introduction

Literature on urban resilience has been shaped by scholars from an array of disciplines, thus it should be no surprise that it has become "a tapestry of definitions and meanings with little orthodoxy in its conceptualization and application" (Cutter 2016, 742). Chelleri (2012) agrees that, "it is unclear exactly what the catchword 'resilient city' means" (p. 288). He reviews how the concept has been understood and evolved in various disciplines from a static concept centering on "maintenance," "recovery," and "equilibrium" to "adaptation" and "renewal." Acknowledging the complexity of the concept, as well as the necessity of a working definition of resilience, this chapter broadly defines the term as the ability of an urban environment to mitigate the impact of shocks on its physical infrastructure and health of its residents, to continue functioning or quickly restore essential functions, and to adapt in ways that will lessen disruptions from future events.

Scholars have moved beyond definitions of resiliency to develop indicators for use in assessing communities and assisting planning and decision-making. These have taken a wide range of forms—albeit with a great deal overlap as much is derivative from early publications. Cutter (2016) has reviewed fourteen case studies in which specific concepts and variables were applied at the community level. In order, from most common to least, these fall under the categories of economic, social, physical/infrastructural, environmental and institutional. This chapter focuses on physical factors, but includes some discussion of the others as relevant. The variables used in these indices were designed to be easily quantified across entire metropolitan areas, while variations within metropolitan areas remain something of a black box. As a result, many of the factors considered are of questionable value,

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i.e. percent of housing stock that are not mobile homes, number of hotels/motels per square mile, principle arterial miles per square mile, and number of public schools per square mile (Cutter 2010). The distinction between mobile homes and other housing may be useful for hurricanes, but less so for earthquakes. Types of housing other than mobile homes vary widely in their vulnerability to any hazard. In a major catastrophe, the number of hotels and motels per square mile in a metropolitan area is of little benefit, while those in nearby areas or states may be crucial. Miles of arterial road tells little, but the capacity of all modes of transport exiting the city, and variations in the vulnerability to different hazards are essential. Trains can far more rapidly remove people from a city than roadways. Bridges may collapse where ferry service is available. Schools may be useful shelters if built in a place and manner to be more resistant than housing, and so are other types of building. The durability, capacity and distribution of all shelter-buildings is key.

In response to the tendency to aggregate data for entire areas, a number of researchers have directly asserted the importance of addressing urban resilience at multiple scales. Yet, here too, there is no agreement as to what form this should take. Alberti and Marzluff (2004) focus on ecological resilience in urban ecosystems, suggesting that studies should move beyond simple aggregated measures of urbanization such as population density and percent impervious surface to examine land cover patterns. Pickett et al. (2004) offer lessons from the study of ecological systems for application to resilient cities, pointing to a need to examine variation within metropolis, to examine the components of this "integrated ecological-social-infrastructural system" (p. 378). They offer a "summary of tactical insights promoting dialogue between ecology, planning, and design," notably more interdisciplinary dialogue. Vogel and O'Brien (2004) note that vulnerability is scale dependent and consider the levels of the individual, household, region and system. Novotny et al. (2010) proposes five urban planning and design strategies for building urban resilience, one being "multiscale networks." Their "strategies for building urban resilience capacity" include green streets, stormwater wetlands, gray water recycling, and urban bioreserves to name a few. Chelleri (2012) suggests adopting the Panarchy concept to address the "complex cross-scale effects between neighborhoods, suburbs, and the metropolitan region" (p. 295).

In fact, there are ready-made methods for breaking the metropolitan continuum into discrete units of analysis. The field of urban morphology has already done so. Like resiliency, this field has drawn researchers from diverse academic disciplines, who have generated an array of methods and purposes. Nonetheless, it is dominated by a few schools of thought and many attributes are widespread within the literature. Urban morphology offers a ready-made hierarchy of elements for examining the middle-scales that have received little attention in the study of resiliency. Though morphology examines the physical attributes of a city, data on social or economic variables can be keyed to these. The next section will review some fundamental aspects of urban morphology. The section after this will examine how some work in resiliency has already worked with these scales, and suggests how this could be fit into a standardized framework.

10.2 Urban Morphology

Gauthier and Gillard (2006) provide an overview of the extremely diverse field of urban morphology, including "scientific studies concerned with the city as an artifact and spatial form" to "urban design normative contributions [that] aim at devising an urban form that has yet to be built" (pp. 46–47). Urban morphology has been found applicable to such diverse fields as architecture, urban design, historic preservation, archaeology, urban history, and economics. The range of methodologies is extreme, from very general concepts for global application (Lynch) to the development of a system of notation for a specific topic (Satoh 1997). Despite a variety of techniques, and some completely unique approaches, two schools of thought have dominated the field. The English school heavily shaped by its most prominent theoretician, Conzen, and the Italian school, heavily shaped by the work of Muratori and Caniggia. Both work with a hierarchy of scales, and there is considerable overlap, but also some significant differences. In Conzen's approach:

> The town plan consists of the street system, plot pattern and building arrangement. The plot pattern corresponds to an arrangement of contiguous plots, divided into street-blocks bounded partly or wholly by street lines. Conzen's system also includes the plot series, a row of plots each with its own frontage placed contiguously along the same street line. … Combinations of streets, plots and block plans form plan-units characterized by morphological homogeneity, but also taking account of land use and era of origin. Plan divisions are groups of plan units with similar characteristics, again including land use and age. (Osmond 2010, 7)

In contrast, Caniggia emphasizes the emergence of building types, examining several scales comprising buildings (elements, elementary structures, and structure systems), and how building types constitute urban tissue (lot, street and pertinent strip) which in turn constitutes districts. The importance of working through multiple-scales and their relations is emphasized. A city cannot be comprehended as an agglomeration of beams and bricks. Effective interpretation for a given purpose depends on choosing the correct scale(s) to work with for the given purpose (Caniggia and Maffei 2001).

A recent application of morphological technique that illustrates this point is the development of form-based codes as an alternative to zoning for land use in the Europe and the United States (Parolek et al. 2008). While several approaches are evident, they all focus on smaller scales, from the neighborhood down to building volumes, some including architectural details, such as fenestration patterns. Some center on building types and work to larger and smaller scales. Others center on the interface between the public and private realm, with street types that guide development from building facade to building facade, leaving the design of the spaces behind the facade with great flexibility. Neither is inherently superior, but either could be advantageous depending on the context and the goal of the code.

Thus, the potential application of morphological techniques to the study of resilience must consider purpose and scale. Caniggia's statement on scale is of particular interest regarding resilience assessment tools as they typically define variables at the metropolitan level only (i.e. miles of arterial road and number of public schools per square mile for a metropolitan area) and lack any middle-scales. A review of the field of urban morphology reveals that the approach—including the scales incorporated and the definition of formal elements—is shaped by the purpose of the study. Thus, the ideal solution would not be to copy an existing format, but to use these as a base. McGlynn and Samuels (2000) touch on this issue regarding the potential use of morphology to inform planners and builders who seek to regulate development to retain local character. They suggest "sieving" information about the local environment through frameworks of morphology to identify what is important and how it is inter-related. Factors affecting resilience are complex and their definition remains a work in progress. Thus, the approach taken here is to examine some of the literature addressing substantive issues in resilience and urban form and perform a simple "sieving" process to suggest directions for the potential application of scale and hierarchy to both the study of resilience and planning for resilience. It is not possible to examine all threats to urban resiliency, so three have been chosen for demonstrative purposes.

10.3 Morphology and Resiliency

Researchers have examined various dimensions of threats to urban life and property, such as earthquakes, fires, severe wind events, tsunamis, river flooding, and heat waves. A subset of this work focuses on changes to the physical city that could help reduce impacts, enable evacuation or provide safe havens, or facilitate recovery. This section reviews literature on resiliency and three natural phenomena: heat waves, flooding, and wind events. There is considerable evidence for the significance of interventions at multiple scales, their inter-relatedness and the potential of morphological frameworks for organizing data.

10.3.1 Heat Waves

The potential for improved urban form to reduce heat-wave related deaths was already speculated upon in the 1970s. Schuman (1972) concluded his examination of heat wave deaths in New York and St. Louis with the suggestion that loss of life could be reduced through well-spaced parks and ponds, building design that enabled cross-ventilation in case air conditioning failed or power was rationed. More recently, the topic has attracted considerable interest due to the impending threat of increased events due to global warming. Wilhelmi and Hayes (2010) have noted:

> Spatial assessments, common in vulnerability research, often result in vulnerability index maps, where indices are constructed as cumulative composites of multiple factors. They highlight relative vulnerability within an urban boundary, but do not often provide sufficient information for communities and policy makers on specific intervention and vulnerability reduction actions. (p. 5)

They recommend examining physical, social and organizational factors in more detail than the current "broad homogenous units," instead examining the "patchwork mosaics of neighborhoods and households within their regional context" (p. 5).

Other research delves into the details of the impact of urban form on temperature at various scales. At the largest scale, urban patterns of expansion directly contribute to the metropolitan heat island effect, with temperatures in the United States most sprawling metropolitan areas increasing at twice the rate of its most compact metropolitan areas (Stone et al. 2010). Additionally, micro-urban heat islands are evident in the most densely built areas. Hence, the most environmentally beneficial form of development on a global scale suffers the highest temperatures (Brazel 2007; Gill et al. 2007; Smargasi et al. 2009). At the district or neighborhood level, proximity to large-scale green (vegetation) and blue (water) areas reduces temperatures and heat wave-related deaths (Burkardt et al. 2016). The benefits of strategically placed medium and large green areas with development are obvious, but less intuitive is the impact of urban form on this relationship. Tall buildings and surface roughness (abrupt changes in topography, building height and gaps between buildings) can divert or slow the winds that bring cooler air through the city. Hence, building volume along with street orientation and design can limit this effect, and even create "ventilation paths" into the city from green and blue areas (Alcoforado et al. 2009; Smith and Levermore 2008). Within districts, public streets and privately-owned plazas and parking lots (parcel level) can have significantly different impacts on local temperatures depending upon their material, color and shading. Even in high density town centers, extensive tree planting can significantly reduce peak temperatures (Gill et al. 2007). Sky view factor (essentially the percent of the sky visible from the ground) also impacts the amount of cooling that occurs at night, indicating the importance of street canyon design. Buildings also contribute to local heating, particularly their roofs. Reflective surfaces, or better yet, green roofs (where drought is not an issue) can reduce these effects and the internal temperature of the building (Gill et al. 2007; Takebayashi and Moriyama 2007). Though attention has been focused on roofs in this regard, there has been increasing interest in the potential of natural green facades across the exterior walls of buildings to serve the same purposes (Köhler 2008). Fenestration pattern and design is also significant for its potential contribution to the cooling of interior spaces (Smith and Levermore 2008) and when improperly designed, its potential contribution to overheated interiors (Kim and Ryu 2015).

It is clear from this review that a range of scales are essential to limiting the impact of heat waves on the city and its residents:

(1) Building: wall & roof materials, shading elements, planting; fenestration quantity and pattern.

(2) Parcel: paving amount, materials, shading; vegetation amount and type
(3) Street & small open space: street, plaza and parking lot size, proportion, materials and planting
(4) Neighborhood and district: pattern of building heights and sizes, location of large parks and water bodies, ventilation corridors

While the urban heat island accumulates from the sum effect of all development, great variations may be evident in small areas and these have immediate impacts on residents' health and energy demands.

10.3.2 Fire

Fittingly, research and government policy on the threat to property and human life from fire has centered on individual buildings (Hadjisophocleous et al. 1998; Yung 2008) and on achieving quick response times across a city through effective fire station placement (Murray 2013; Başar et al. 2012). A secondary concern with catastrophic fires has received increased interest, particularly as a dimension of urban resilience. One focal point of interest on this topic is fire fueled by dried vegetation near the wildland-urban interface, for which the parcel is the most crucial scale. Cohen (2010) observes that the "home ignition zone," the 100′ surrounding a home where flammable vegetation and debris can accumulate is usually private property in the United States. The City of Los Angeles, which has grown into canyons deemed "very high fire hazard severity zones" has implemented a brush clearance program requiring property owners to comply with standards for maintaining vegetation on their property (City of Los Angeles 2016). In Australia, Blanci et al. (2006) have determined that trees and shrubs near residences pose a significant threat. They also found that building envelope configuration can create crevices where embers can lodge and eventually ignite the structure. Complex roof shapes with multiple ridges and valleys, re-entrant corners, decks and balconies, and unprotected windows are all points of vulnerability. Also, outbuildings and fences made of flammable material can ignite readily and transfer embers to the main building.

Another major area of concern involves fires in densely settled districts, where earthquakes or terrorism can damage water supply systems essential for fighting fires (Scawthorn et al. 2006). Navitas (2013) suggests the potential for urban design to improve fire safety in dense urban areas in Indonesia, hindering the spread of fire with building spacing and providing emergency escape paths. In Japan, similar concerns have emerged for urban areas with extensive, densely packed wooden houses (Satoh 2013). In the 1960s and 70s, planning centered on six proposed large-scale "disaster prevention bases." Each would have a minimum of 10 ha of open space protected by fireproof high-rises, and provided with emergency infrastructure (Fluchter 2003). Broad streets serving as evacuation routes to the shelters would be protected by fireproof, highrise buildings. As that approach has proven impractical, planning shifted a series of smaller refuge bases, but the evacuation issue remained problematic. Recent planning has called for 816 small-scale "disaster-proof living zones" that would enable residents to remain in or near their homes. This eliminates the need to travel for safety, preserves desirable urban fabric, and reinforce community-level organization. Zones of traditional wooden houses with narrow streets and small blocks would be surrounded by slightly taller, more fire-resistant structures separated from adjoining blocks by fire-breaks, comprised of roads, railways, waterways and greenways, capitalizing on existing structures as much as possible. The program interconnects infrastructural improvements (roads, water/green areas, buildings, disaster prevention equipment) and human activities at five scales: the house (50–300 m^2), the neighborhood (0.5–1 ha), the district (10–30 ha), the radius of daily life (living zone size, 60–80 ha), and the city (10 km^2 plus). Parks and designated community buildings are retrofit to become emergency refuges. Key routes into the zones are identified and if necessary, adapted to allow access to fire trucks. Local water storage areas ensure access if city-wide lines are damaged in an earthquake.

While the building scale has justly received a great deal of attention for fire safety, other scales are important, too:

(1) Building: materials, configuration, fenestration,
(2) Parcel: amount and type of vegetation
(3) Neighborhood and district: fire breaks, escape paths, shelters, emergency crew access paths, on-site water storage
(4) City: fire station distribution, water lines

While fireproofing buildings is an essential focus, it is clear that the spread of fire, efforts to combat it, and to protect lives involve the interplay of factors at multiple scales.

10.3.3 Flooding

Urban flooding may result from storm surges or tsunamis in coastal cities, from overflowing banks in river cities, and excess storm runoff in any city. Recent thinking in this area has called for less reliance on large infrastructure projects to protect an entire city from water in favor of a multi-tiered approach (Carbonell and Meffert 2009; Watson and Adams 2010). Rather than eliminating city-scale efforts, redundancy is obtained through measures implemented at several scales. Liao (2012) suggests the key variable is percent of land that can be flooded without damage, which may include residential areas if structures are flood proof, but may exclude open space if the soils are contaminated. Thus, the provision of open space and flood-proofing buildings are essential to improving resilience. White (2008) suggests a multi-tiered approach including blue areas for water retention, green areas for recreation doubling as water retention sites when needed, intense development in urbanized areas, limited paving on private parcels in less dense areas, flood-proofing buildings, and constructing green roofs for water retention. Lennon et al. (2014) reiterate some of these ideas, and add others. New neighborhoods could be built on raised plinths, green streets and parking areas can be designed to double as water retention areas. A design charrette for the Greenpoint section of Brooklyn, New York included blue-green corridors at the water's edge, a new esplanade, and floodable streets, making water a feature rather than a barrier (Watson and Adams 2010, 241). In response to catastrophic flooding, Mumbai has implemented a range of measures, including the designation of 120 temporary shelters for stranded people in existing schools, which are by design distributed throughout the city (Guptha 2007). The Netherlands seems to have the most developed approach to managing flood waters, with detention in compartments (areas designated for water storage with different probabilities of flooding) and green rivers (flood plains and compartments with a high probability of flooding as a first line of defense) (Vis et al. 2003). Managing flooding removes the element of surprise for residents, because when left to nature, flooding could proceed in multiple directions at once with unpredictable consequences. Rotterdam has designed an underground car park to retain 10 million liters of water, and "water plazas," public squares in which modest storms result in "streams, brooklets, and small ponds" as play areas for children, the entire plaza fills as a retention area (Mackenzie 2010).

Like the other hazards considered, flooding is most effectively addressed at multiple scales:

(1) Building: height above grade, materials, water retention (i.e. green roof, cistern)
(2) Parcel: permeability of surface, on-site retention features (i.e. swales, ponds)
(3) Street & Open Space: green streets, floodable streets, water plazas, floodable parking
(4) Neighborhood & District: flood-proof shelters, green rivers, compartmentalized areas for water control & flood storage
(5) City: undeveloped buffer areas on urban periphery, seawalls, dikes, spillways for overflow

At first glance it may appear that one could solve the issue entirely at the city-scale or building scale. Yet in the first case, any breach of the city-defenses would leave the city flooded, hence the Dutch approach at multiple-scales, and it does not address the issue of runoff generated by rainfall in the city. Solely raising every building, apart from excess expense, would not prevent flooding of city streets, halting transportation. As flooding increases and decreases incrementally, actions to retain water at multiple-scales would reduce the necessary height of buildings. Most significantly, the patchwork patterns of severe flooding and damage resulting from Hurricanes (Harvey & Katrina) in Houston and New Orleans, demonstrate great variations in vulnerability that emerge from the interplay of factors at all scales.

This brief review of literature on three hazards reveals the significance of urban form at multiple scales, and their impact upon each other. The field of urban morphology provides a vocabulary to categorize and analyze these physical elements and their relations (Table 10.1). It offers a means of breaking the urban continuum into a nested hierarchy of discrete units. Floods and fires cut amorphous,

Table 10.1 Relationship between urban form elements and hazards

	Heat wave	Fire	Flood
Fenestration	Percent glazing, orientation, shading, relation to interior spaces	Recessed, frame material & size, screening (ignition, building entry)	x
Facade	Material, surface reflectivity, shading devices, vegetative cover—green facade (increase or decrease ext. & int. temperature)	Material, re-entrant corners, projected or recessed elements, i.e. balconies, arcades (ignition)	(see building scale)
Roof	Material, surface reflectivity, vegetative cover—green roof (increase or decrease ext.& int. temperature)	Material, number and length of valleys (ignition)	Vegetative covering—green roof (reduce/ slow runoff)
Building	See facade and roof scales	Fire-proofing (see facade and roof), sealable interior spaces & escape routes; Fireproof safe havens	Raised, flood-proofed, floatable
Parcel	Type and amount of vegetative cover, type and amount of paving	Type, amount & location of vegetation, debris, outbuildings (ignition)	Permeable and impermeable surface, vegetative cover
Street	Material, surface reflectivity, shading, sky view factor, ventilation path	Fire break, protected escape route	Floodable for water retention
Open spaces	Size, material, surface reflectivity, vegetative cover, water, sky view factor	Fire-proof safe havens	Permeable, impermeable, vegetative cover, floodable (runoff vs. retention)
Neighborhood/ District	Distribution of open space, distance & ventilation paths to large blue & green spaces	Station placement, backup water storage, safe haven placement	Placement in/out of flood plain, location & amount of smaller scale control measures
City	Emergency treatment facilities	Station placement, emergency treatment facilities	Large-scale infrastructure (levees, dams, spillways), emergency treatment facilities

variable paths across a city, and heat waves display irregular patterns that are suitable to depiction as an overlay on a city map. However, their interaction with the built environment, its susceptibility to damage, its potential contribution to worsening a disaster, and adaptations for improved resilience can be thought of in terms of morphological units. This seems essential to sound planning for resilience, and there are cases illustrating how a simple morphological framework can be applied in this regard. For instance, a study by the Greater London Authority determined that the urban heat island must be approached at the scale of the building & street, urban design, and city, and lists existing polity frameworks that apply to each, i.e. building regulations, area action plan, and regional spatial strategy (GLA 2006). The potential to improve resilience indices, which currently focus on entire metropolitan areas with some attention to the building scale, would seem immense, but difficult to attain.

One of the main factors limiting the application of a morphological approach for resilience indices is the ability to link data on key attributes of the built environment to hazard impacts. Yet, some researchers have started making inroads. Researchers in England have developed 29 "urban morphology types" compatible with the UK National Land Use Database and identifiable through aerial photographs. These were applied to a study of the urban heat island in Greater Manchester (population 2.5 million), along with 9 "surface cover types" as green cover does not always correspond with morphology (i.e. extensive street tree planting in a town center). Modelling the existing city and various scenarios (addition of street trees, green roofs, and other green infrastructure) demonstrated the capacity to moderate climate change impacts on the urban area (Gill et al. 2007, 2008).

Yet, the "urban morphological types" are for the most part, defined by land use, i.e. farmland, residential, retail, industry and business, transport. Subcategories attempt to deal with form. Retail is divided into two categories, "town center" and "retail," suggesting a difference between traditional urban and suburban forms. Residential is divided in low, medium and high density, which makes an essential distinction, and may be effective for the Manchester case study, but fails to effectively encompass differences in form that may be essential elsewhere. For instance, a district comprised of town houses (attached houses) may have the same density as a district comprised of garden apartments (walk-up apartments separated by swaths of parking/and/or greenspace), but the consequence of each for the heat island could vary considerably. Further, though form emerges in response to use, the latter is flexible and may change over time. A street of residential row houses may be converted to mixed use with retail and offices (Sheer 2010).

Researchers have also examined forest fire risk management in Mediterranean areas by classifying types of settlement "according to their morphology" and "types of landscape" and then combining the two into one typology (Galiana-Martin et al. 2011). This approach focused more directly on form rather than use, measuring distance between houses and extent of settlement area to define three types: towns (concentrated layout and high building density, clear differentiation from surrounding agrarian space), urbanizations (groups of residential developments removed from agrarian use) and scattered rural settlements (sets of residential buildings of low density, not necessarily forming an urban structure). The authors point out that this local scale data provides valuable information to planning for fire wildfire resilience on the regional scale.

Both of these cases rely on remote sensing to obtain smaller scale detail and link it to a larger scale analysis. The data remains course and the focus is just one hazard, but they suggest a path forward. Remote sensing and aerial photography can rather quickly deliver a great deal of information on horizontal surfaces, such as roofs, streets and open spaces. Local government plans and building records require more effort to glean information, but can provide essential complimentary data about building construction, building heights, placement of emergency facilities, etc. Combining these sources would provide detailed knowledge on urban morphology at multiple-scales, as pertinent to resilience. This would require an extensive effort and the result may never be all-encompassing. However, it would certainly advance resilience indices beyond their current state. Exploratory work is essential to move towards a standardized framework of analysis. The field of urban morphology provides a vocabulary, or multiple vocabularies, for this task. Further research is required to sieve through the details and determine which units of analysis are most important and how they relate to each other in the study of resilience.

10.4 Conclusion

Literature on planning for resilience is highly fragmented and attempts to measure metropolitan resilience remain superficial. Many researchers agree on the need to analyze resilience at multiple scales and examine their impact upon each other. Literature on resilience has examined the impacts of specific hazards multiple-scales, but individual studies remain isolated from each other. This work speaks to the importance of urban form, but lacks a vocabulary for comprehensively studying its relationship to resilience. The field of urban morphology has highly developed frameworks for studying urban form that can be used to assemble data on resilience, its aggregation and disaggregation, and impacts on smaller and larger-scale units of analysis. A few studies have begun to draw connections between these fields, opening the door to more thorough analyses. As the ability to analyze data in GIS systems has become more powerful, the potential to examine the impact of forces and responses at multiple scales exists, yet a great deal of work remains in order to realize this possibility.

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Chapter 11
Is Connectivity a Desirable Property in Urban Resilience Assessments?

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11.1 Introduction

The need to look at environmental-related problems from a systemic perspective has been increasingly recognised during the past years. In resilience thinking (Kinzig et al. 2006) and sustainability thinking (Liu et al. 2015), coupled human and natural systems are treated in an integrated way so that nexus issues, cascading effects and spill-overs can be taken into account. It has no sense to consider problems only from one perspective (either environmental, economic or social) when there might be other interacting variables that could affect the system and alter future scenarios.

Urban areas as complex adaptive systems (hereafter CAS) (Alberti et al. 2003) are formed by coupled human and natural systems (Ernstson et al. 2010; Liu et al. 2007) and thus their resilience and sustainability should be conceptualised, developed and planned also following this systemic integrated thinking. From a theoretical point of view, the system or network perspective in resilience theory has been argued to be useful to assess system's characteristics i.e. robustness, connectivity and dependency (Janssen et al. 2006). In this line, some systemic

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approaches to resilience assessment have been proposed for different purposes such as to assess the robustness of infrastructural systems (Hosseini et al. 2016; Labaka et al. 2015) or ecosystems health (Alberti and Marzluff 2004), but also to evaluate the social network capacities (Wallace and Wallace 2008). However, so far, and to our knowledge, the implications of these networks within urban complex dynamics have been loosely addressed and discussed from both theoretical and evidence-based studies.

To contribute to this debate, this chapter focuses on the connectivity of the urban system as a potential measure of resilience, and discusses the role that this feature may have in the resilience management of the system, i.e. including its transformability. We use a case study on urban energy resilience in the city of Bilbao (Spain) to illustrate the discussion.

Next section elaborates on the conceptualisation of urban areas as complex adaptive systems and its implications for connectivity assessment. Section 11.3 explores how connectivity has been treated in the resilience literature and specifically in urban resilience assessments. Section 11.4 describes the network perspective in socio-ecological research and the main characteristics of networks including measurements of connectivity. In Sect. 11.5, we describe the case study of Bilbao where Fuzzy Cognitive Mapping methodology is used to generate an integrated map that accumulates existing knowledge on the system. Sections 11.6 and 11.7 present the results and discussion and Sect. 11.8 draws some conclusions on the implications of connectivity for resilience management.

11.2 Urban Systems' Complexity

Complexity is an embedded characteristic of urban systems (Portugali 2000), arising from the interdependencies of social, infrastructural, ecological and economic realms which cascade into different spatial and temporal scales. Both quantitative sciences (e.g. Allen 2012), through models from the late 40 s and mainly from the 70 s onward (see "cellular automata", "agent-based modelling", "fractals" propositions) and qualitative sciences (e.g. Castellani and Hafferty 2009) have addressed complexity in cities.

Urban complexity starts with the characterisation of the urban area itself. Urban areas vary in terms of size, economic profile, urbanisation patterns etc. These differences are often influenced by geo-political needs, history and cultural heritage among other factors. Together with lifestyle patterns, they determine to a large extent the energy and material consumption levels that can be credited to urban areas. Resource availability and environmental conditions in urban areas are critical factors for supporting urban metabolism and resilience to gradual environmental changes or unexpected shocks. These factors are influenced by contextual characteristics such as location and orography. However, even when the huge divergences in urban areas' social, ecological, economic and institutional contexts and their development stage are acknowledged, not all urban areas have the same level of complexity or are complex in similar ways. This means that equal challenges and targets that urban areas might be facing could be solved differently or if the same mechanisms are utilised, they may have different outcomes. This is the result of seeing urban areas as CAS.

Certainly, one of the most important characteristics of considering urban areas as CAS is that complexity may be hidden in a very simple system, and that complex global systems patterns may emerge from interactions at local level. This is called emergence in complexity thinking (Lansing 2003). Emergence translates into an unpredictable adaptive behaviour of the elements of the system which evolve responding to exogenous and endogenous drivers (Levin et al. 1998). Complex systems are those composed of many individual parts that interact. These groups of interacting entities show a collective behaviour that might be different from the one manifested at individual scale or the one expected by scaling it up to the group level (Samet 2013). As CAS, urban areas are seen as microstructures that coalesce to form systems of cities that function better and are more adaptive as a macrostructure rather than individually. This leads to a series of cross-scale interactions between urban technical and social networks generating those energy, material and information flows (Ernstson et al. 2010). Because of this, in order to assess the consequences of potential interventions, urban areas, as inclusive systems, should be analysed considering their multiple constituent parts (infrastructures, norms, agents…). Other issues that need to be considered are contextual enablers (environmental, social and economic capital…) and internal or external connections.

In fact, defining the boundary limits of an urban system is difficult. In this endevour, the physical scale of the social and economic network that affects urban areas becomes relevant. This is particularly the case regarding the implications for energy, material and information flows. These system dynamics cause a higher degree of complexity which results in urban areas presenting multiple challenges to decision-makers and therefore to those that aim at studying urban change (Grimm et al. 2000; Pickett et al. 2001; Ruth and Coelho 2007).

The view of urban areas as CAS is required to encapsulate the dynamics of at least these three dimensions (Olazabal 2017): (i) natural biophysical processes and metabolic flows generated by the demands of urban users; (ii) the effects of exogenous changes in the flow of ecosystem and human services on human well-being; and (iii) the gradual reactive socio-technical and economic adjustment of cities to shifts in their contextual landscape such as those that may arise in the context of global economic and environmental change.

Although urban complexity research is not new (Batty 2007, 2008, 2013a; Castellani and Hafferty 2009; Portugali et al. 2012), it is not sufficiently spread between disciplines and it is not appropriately operationalised. This has prevented the research community from fully understanding urban areas and therefore, to manage them in the practice (Bettencourt 2013). In this regard, the analysis of the implications of connectivity within the system is one of the many steps that should be advanced.

11.3 Connectivity and Resilience

Urban complexity links with resilience through the evolutionary patterns of cities development, characteristics and capacities to deal with change. However, addressing resilience translates into the difficulty of operationalising this vague and metaphorical concept (Brand and Jax 2007) which in the last decades sprawled across policy frameworks from local to global scales (UN-HLPGS 2012). Indeed, as Bohland et al. (2017) recently argued that there's a "resilience machine"—referring to the seminal "The City as a Growth Machine" (Molotch 1976)—building on the value-neutral diffused perception about resilience in order to legitimize business-as-usual urban development projects. Different authors have put forward in this last decade their critical perspectives about resilience contesting its normative positive nature (Chelleri and Olazabal 2012; Meerow et al. 2016; Vale 2014). This aligns with the "non-equilibrium view" of resilience, and puts emphasis on dynamics and evolution rather than on returning to the equilibrium state (Pickett et al. 2004). In this line, the critical study of resilience attributes, their theoretical and their real-world cases' testing, becomes a central issue for advancing our understanding of cities as CAS.

With this in mind, it is important to recognise that any practice related to resilience could imply trade-offs (Chelleri et al. 2015) or social un-justice (Anguelovski et al. 2016), making relevant pose the questions of urban resilience for whom (Vale 2014) and why (Meerow and Newell 2016). The emergence of these trade-offs are a result of relate to the multiscalar dimensions of resilience and thus, examining the interactions of the elements of the system at different spatial scales are theoretically and in practice (Chelleri et al. 2015) a good strategy to manage resilience.

This said, connectivity as a characteristic of the urban system that explains the interactions of its elements is therefore a key aspect to be explored and assessed in cities.

Connectivity can be examined in the context of, and also across, different fields such as energy circulation, communication, transportation and mobility and landscape ecology (Ahern 2013; Sharifi 2016; Sharifi and Yamagata 2016). Therefore, it can be discussed in terms of the movement of various agents including, but not limited to, humans, vehicles, information, and species. Connectivity is an important feature in socio-ecological dynamics and therefore in socio-ecological resilience (Elmqvist et al. 2003). Connected socio-ecological systems are believed to provide better ecological functions and to exhibit higher capacity to survive, adapt and evolve (De Montis et al. 2016). In ecology, connectivity might be defined as "the degree to which habitat for a species is continuous or traversable across a spatial extent" and it can be classified in structural and functional connectivity (Andersson 2006, p. 3). In order to maintain resilience of socio-ecological systems it is important to develop management practices that enhance landscape connectivity so that services such as recreation, air and water regulation etc. can be maintained (Andersson et al. 2014; Elmqvist et al. 2003). Landscape connectivity (through well-connected blue and green networks such as rivers, parks, etc.) supports biodiversity which in turn facilitates a variety of benefits such as flood control and stormwater management, air pollution mitigation, reduction of the urban heat island effect, passive cooling, urban food production, environmental education, human stress alleviation, aesthetic improvement, property value enhancement, and urban safety (Ahern 2013). Ling and Dale (2011) argue that being placed along ecological edges (such as rivers, lakes, and mountains), and landscape connectivity can be considered as a measure of resilience and liveability of cities. They argue that the high quality of life, sense of place, economic vitality, liveability and creativity of Vancouver in Canada can be attributed to the permeability between the city's built environment and the mountain and sea landscapes beyond the built environment. Over time, the city has made efforts to maintain this connectivity and permeability of the city and avoid development plans that undermine this feature (Ling and Dale 2011).

In the specific case of cities as intensively managed coupled human and natural systems, maintaining connectivity of ecological units is challenging, therefore, putting at risk the ecological resilience of the system. Degradation or loss of connectivity may have severe short-and long-term consequences. Human interference in the landscape and ecosystem can disrupt the natural flow of energy and resources between landscape units and affect the natural evolution of ecosystems. For instance, a modelling study conducted in Italy (Gobattoni et al. 2011) shows that a 30% urban sprawl in the Traponzo watershed can have critical negative impacts and even completely remove the "exchange of biological energy". One of the main consequences of urban sprawl is fragmentation of the landscape leading to negative impacts on biodiversity and a reduction or even elimination of energy and matter exchanges. Maintaining connectivity is, therefore, essential to ensure tipping points related to natural equilibrium points of the landscape are not crossed (Gobattoni et al. 2011).

Probably as a consequence of the social and ecological origins of resilience thinking as illustrated above, connectivity is often taken as a key feature of resilience in the urban resilience literature (see e.g. Ahern 2011; Ernstson et al. 2010). Ahern (2011) argues that because cities need to continue functioning after shocks, the connectivity of an urban system's is generally high. It therefore correlates positively with increasing resistance, i.e. protecting the urban system against unexpected impacts. However, as put by Holling (2001) a system that is too tightly connected can potentially lead to undesirable outcomes as a result of a rigid control. The optimal structure of the system may vary depending on the underlying purposes. For instance, maximizing connectivity can provide benefits in terms of movement of people and species. However, over-connected systems (e.g. streets/ transit systems) could also intensify undesired effects and cause issues such as swift spread of diseases (epidemics) (Batty 2013b). Based on this and in line with the discussion on the trade-offs of resilience, we argue that more empirical evidence is required in this regard.

11.4 The Network Perspective

> There is no such thing as the "right" way to represent the social-ecological network of a given system, just useful and not so useful ones (Janssen et al. 2006, p. 3).

One of the challenges for urban human-ecological studies is to overcome the 'black-box' approach. Urban systems are characterised by elements (or nodes), processes (or functions) and distributive channels (or connections) of material, energy and information fluxes. This resembles the ecological view where "a network flow model is essentially an ecological food web (energy–matter flow of who eats whom), which also includes non-feeding pathways such as dissipative export out of the system and pathways to detritus" (Fath et al. 2007, p. 50). According to Zhang et al. (2009), ecological networks are divided into "compartments" and "pathways" where each compartment has a specific function, and pathways distribute materials, energy, and currency across compartments. Urban landscape ecology research (Pickett et al. 2011) argues that in the city, despite fragmentation, ecological processes may continue through patches and corridors. How these patches and corridors spatially distribute influence the actual performance of the city, in the face of shocks, by protecting it from natural disasters and climatic impacts (Aminzadeh and Khansefid 2009). Adapting this idea to social-ecological networks in urban areas, one could say that for example, the more robust the social connectedness is among citizens, the less vulnerable it becomes to natural disasters (Wallace and Wallace 2008). This opens the ground for expanding the study of urban systems' performance in relation to the webs or networks, which should not necessarily be restricted to the field of ecology. Social sciences, information, communication and technology-related research, mobility-related research and a range of different fields examining urban systems dynamic have already undertaken this kind of research perspective on cities (Batty 2013b; Castellani and Hafferty 2009).

In the context of resilience thinking, it is argued that a network perspective is helpful to analyse complex environments, given that it focuses on the interaction between components and how those interactions affect the system behaviour (Janssen et al. 2006).

In this chapter, we use the seminal paper by Janssen et al. (2006) as the main reference for the study of resilience from a network approach. Although their discussion very much relies on their ecological perspective, their approach can be useful and applicable to urban areas as CAS. Recognising the challenges of representing a CAS network, Janssen et al. (2006) identify three types of social-ecological networks (see p. 6): (1) ecosystems that are connected by people through flows of information or materials (for instance, in the urban context, a lake and the urban fauna), (2) ecosystem networks that are disconnected and fragmented by the actions of people (i.e. urban forests), and (3) artificial ecological networks created by people (i.e. irrigation systems). In theory and practice, all of these typologies would be possible to find in urban systems.

According to Janssen et al. (2006), **nodes** can represent both social (human-related nodes including built infrastructure) and ecological components, and **links** can represent physical flows between physical units or the exchange of information between social actors. It is possible that, some nodes and links are "asleep" in normal times or that they disappear in times of disruption. During a disruption, change or shock, a resilient system is able to maintain the capacity to reactivate nodes and links (Janssen et al. 2006) or to create new nodes and links to maintain functions if the original ones disappear (Walker et al. 1999).

Janssen et al. (2006, pp. 4–5) also introduce some metrics and characteristics of socio-ecological networks: **level of connectivity** which can be represented by "the **density** of the links within the network, that is, the number of links divided by the maximum possible number of links" and "the **reachability** or the extent to which all the nodes in the network are accessible to each other"; and "the **level of centrality** which covers not only the distribution of links among the nodes in the network but also their structural importance".

11.5 Case Study and Method

This section presents a case study in the city of Bilbao (Spain), which deals with the planning and management of urban low-carbon transitions, i.e. transformation strategies to reduce urban energy use. This case is useful in exploring the relationship between complexity, connectivity and resilience through the analysis of the networks that can potentially build energy resilience.

Located in the Bizkaia province of the Autonomous Community of the Basque Country, Bilbao is a city of 41 km^2 and 353,300 inhabitants (Basque Government 2013). Traditionally based on the steel and shipbuilding, Bilbao turned itself into a service-led city after the industrial crisis of the 1980s. This caused a successful transformation of its economic structure and urban regeneration in the 1990s considered an example of sustainable renovation (Gonzalez 2011; Keating and Frantz 2004). As discussed by Olazabal and Pascual (2015), the efforts of City Council to reduce energy consumption through plans and programmes have not been successful indicated by the increasing use of energy and the low share of renewables in the city.

In order to analyse the links between connectivity and resilience in an urban area, we use the results of the case study developed in Olazabal and Pascual (2016) that performed a Fuzzy Cognitive Mapping (FCM) study in Bilbao. By applying FCM, the study of Olazabal and Pascual seeked to reveal the complexity of the energy system in the city of Bilbao with the final purpose of understanding indirect and unidentified impacts of potential transformative low-carbon interventions.

FCMs are fuzzy graphs that represent causal reasoning through "hazy degrees of causality" (Kosko 1986). One of the main advantages of FCMs is that their graph structures facilitates merging different FCMs, coming, for examples, from different participants describing the same or complementary phenomena (Kosko 1986).

The design and means of the elicitation process is defined depending on the objectives of the experiment (Özesmi and Özesmi 2004; Isak et al. 2009). FCM can be used to integrate views of diverse experts and stakeholders and thus provides an integrated lens on the ‘perceived’ mechanisms of a system. FCM has proven its potential for the analysis of systems’ structure, scenario building, decision-support and knowledge co-production (see Gray et al. 2015; Kok 2009; Vanwindekens et al. 2013) and has been used in the context of resilience (Gray et al. 2015; Olazabal and Pascual 2016).

In FCM, concepts relate to each other through directed, signed and weighted arrows representing causal relationships, thus forming a cause-and-effect diagram. The quantitative part of FCM takes the form of signs (positive or negative) and weights (e.g. from 0 to 1) that are assigned to each connection. In a FCM exercise the analyst collects individual maps or networks and later, treats this data to produce an aggregate network. The network that results from a FCM exercise can be described mainly in terms of its **density (D)** and the **centrality** of its components **(Ct)**. D indicates the general connectivity of the network and relates actual connections with the total potential connections among existing nodes. Following this, a larger number of concepts indicate a larger number of potential connections. It is thus often assumed that a higher density indicates more possibilities for change, as there are more connections in the network. However, change is only possible if these connections are perceived by the actors of the system, turning them into “catalysts of change” (Özesmi and Özesmi 2004). Ct not only indicates the level of connectivity of each concept but also the strength of such connections (i.e. how much and how strong the concept is connected). Ct is an additive function of the concept’s in-degree (I) and out-degree (O). ‘I’ is the result of aggregating the strength of concepts entering the concept being analysed and ‘O’ is the result of aggregating the strength of this concept on other concepts (Özesmi and Özesmi 2004). Such strength is calculated as an additive function of the weights of the connections to or from the concept under analysis. This way, the larger the number of connections to or from a concept, the larger the possibilities are for Ct having a higher value, i.e. the concept being characterised as having higher connectivity within the network. In other words, a network with high levels of Ct among its elements, suggests a high-density level, i.e. a high level of network connectivity, and vice versa (Table 11.1).

The FCM case study of Bilbao used face-to-face interviews with 14 experts in various issues related to energy, such as energy production, consumption, planning management, and energy business. Participants included representatives of the local authorities, energy facilities, social communities, energy cooperatives, researchers and others. Each individual was asked about their view of the factors that influence energy consumption in Bilbao and its impacts on other social, economic and environmental aspects of the city. With the help of the analyst, they translated their responses into a cause-effect map. Each connection was weighted on a scale from 0 to 1, or from 0 to 10 if the interviewee felt more comfortable with this scale. These weights were after normalised.

Table 11.1 Network characteristics in FCM (from Olazabal and Reckien 2015)

	Equation	Description
Equation 1	$\boldsymbol{D} = \frac{\sum C_i C_j}{N}$	Density (D) is calculated by dividing the number of actual connections (C_i C_j) by the number of total possible connections. It is an indicator of connectivity
Equation 2	$\boldsymbol{Ct_i} = \boldsymbol{O_i} + \boldsymbol{I_i}$	Centrality (Ct) is the sum of a concept's in- and out-degrees (I and O respectively). It denotes the individual importance of a concept in respect to other concepts in the network
Equation 3	$O_i = \sum_{k=1}^{k} \bar{W}_{ik}$	O_i is a the out-degree of a concept. It is calculated by adding up the absolute weights of all outgoing connections of a particular concept. It is a measure of the strength of the influence of one concept C_i on other concepts in the network
Equation 4	$I_i = \sum_{k=1}^{k} \bar{W}_{ki}$	I_i is the in-degree of a concept. It is calculated by adding up the absolute weights of all incoming connections of a concept. It is a measure of the dependency of a concept on other concepts in the network

11.6 Results

The 14 individual maps were digitalised, treated and later aggregated (for further details on the aggregation process see Olazabal and Pascual 2016). The final aggregated map conforms the final network which has been analysed in terms of its network characteristics. Network characteristics that represent connectivity such as D and Ct have been calculated. The final network is shown in Fig. 11.1.

The density (D) of the network calculated through Eq. 1 is 0.022. The maximum possible density is 1. This would mean that all concepts are linked to the rest, adding up to 7396, which is the total number of potential connections. The 14 stakeholders interviewed identified only 161, i.e. 2.2% of total potential connections. With no similar experiments to compare, it is difficult to reason if this is a high or low density. Clearly, not all connections have a sense in the urban context. This will be a good way of theoretically setting a threshold for density, but however, not reflecting real opportunities in the case study. For this reason, we will focus on the other metric related to connectivity: Ct.

To cluster the elements according to their importance, Fig. 11.2 displays the results of the Outdegree (O) and Indegree (I) indices calculation (centrality—Ct- is the sum of the two, see Eqs. 2, 3 and 4) in decreasing order for Ct > 20% of the maximum Ct found in the network (13.25 for "Energy price (households)").

Elements with higher Ct are located in the left-hand part of the graphic. However, the source of their Ct may come from different reasons: some of them are mainly transmitters i.e. high O (e.g. energy lobbies) some other are mainly receivers i.e. high I (e.g. energy efficiency). We observe the same pattern in Fig. 11.3 that goes deeper in the analysis and classifies 4 types of elements based on their Ct.

In the energy network of the city of Bilbao as perceived by stakeholders there are some elements that have clearly more importance than others. Results show that

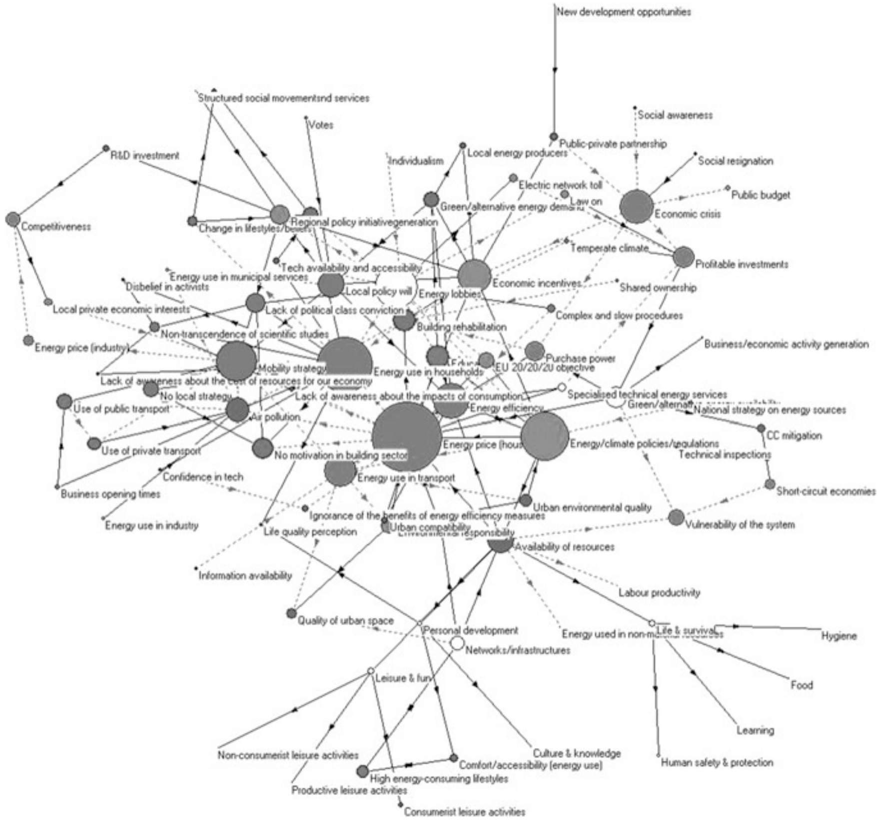

Fig. 11.1 FCM of the energy network of the city of Bilbao (adapted from Olazabal and Pascual 2016; Olazabal and Reckien 2015). The size of the Ci concepts denotes the number of connections of Ci to other variables and also indicates the degree of centrality (Ct). Dashed arrows indicate negative connections (negative wij) and normal arrows indicate positive connections (positive w_{ij})

some of the variables have a high Ct due to a high O and high I (set here as higher than 4 in both cases), such as ‘energy price (households)’ and ‘energy use in households’ (see top-right area in Fig. 11.3 and actually both elements obtaining the maximum scores in Fig. 11.2). Both represent very important aspects of the energy system in Bilbao as the size of their nodes indicates in the network shown in Fig. 11.1. However their potential role as transmitters or receivers is uncertain. Other variables have a high Ct caused by a high O but a low I (e.g. ‘mobility strategy’, ‘energy/climate policies/regulations’ and ‘energy lobbies’). This means that these variables could potentially act as drivers of change in the system as they have a high level of influence on other variables, and would allow to control de process of transformation, given that they receive low influence from other (low I). Another group of variables have a high Ct caused by a high I but a low O (e.g. ‘energy efficiency’, ‘air pollution’ and ‘no motivation in the building sector’). This

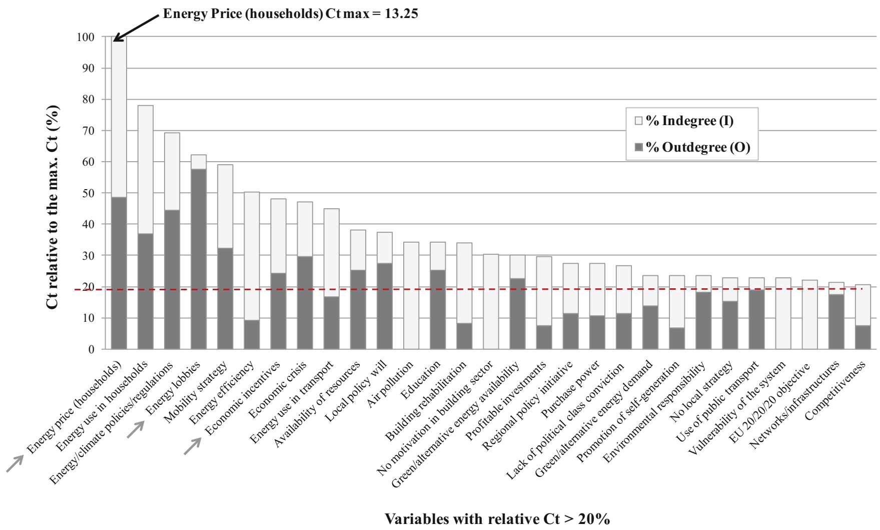

Fig. 11.2 Network indices: Out-degree (O), In-degree (I) and Centrality (Ct) = O + I. Only elements of the network with Ct > 20% are shown. (Olazabal and Pascual 2016)

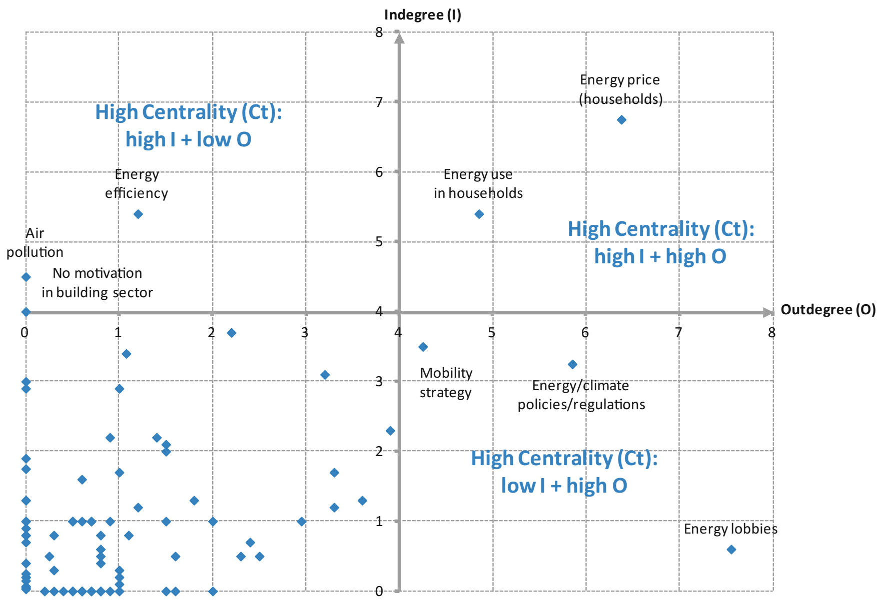

Fig. 11.3 Centrality (Ct) of the elements of the system (Olazabal and Reckien 2015)

means that these variables are receptors of change and impact when other variables of the system vary.

11.7 Discussion

Indicators and metrics are common instruments used for assessing resilience. As pointed out by Albers and Deppisch (2013), some of them may have tradeoffs and conflicts with each other. In networks research, centrality (Ct) and density (D) are two frequently used measures of connectivity. Connectivity is often seen as a positive characteristic of urban resilience: intra- and inter- connectivity of cities is a key characteristic in resilience thinking (Ahern 2011; Ernstson et al. 2010). As above argued, context-specificity is an important aspect to consider when assessing connectivity and resilience. In the case study of the urban energy system of the city of Bilbao, we cannot make concrete claims on the level of connectivity of the whole system (D = 2.2%). For making such claims either a reference system with exact same characteristics or longitudinal baseline assessments of the case study city is needed. Having the density of the system assessed in different points in time would help to compare structures and evaluate the benefits of high or low connectivity under different scenarios. As previously raised, it would also help to establish a theoretical limit for density if one identifies feasible connections to other elements. However, this theoretical exercise would involve many uncertainties derived from the bias of the analyst and the need to contextualised the feasibility of such connection in the case study.

For the urban energy system of Bilbao, in a classification of four, we identify three types of high centrality (Ct) (high connectivity of the elements in the system): they differ on the combination of sources of Ct: outdegree (O) or indegree (I) i.e. outgoing or incoming connections. We observe that the system is highly driven by the offer and demand since the two more connected elements that have both high O and high I are "Energy price" (representing offer) and "energy use" (representing demand). Elements with high Ct resulting from a high O are good examples of elements that can be used to drive the system into another different state (urban strategies, regulations and policies and lobbies). Elements with high Ct resulting from a high I are those that will be highly impacted (efficiency and pollution).

Results demonstrate how exploring the concepts' cause-effect relationships helps better understanding patterns of stability or transition.

The map (Fig. 11.1) and most influential concepts (either because of high I or high O, see Figs. 11.2 and 11.3) illustrate how enabling sustainability transitions may require a focus on business-as-usual practices to guarantee agency of desirable change.

From the results, we can extrapolate critical factors determining Bilbao's business-as-usual energy practices, for instance (see Fig. 11.2):

(i) local political will is perceived less influential than lobbies but more influential than regional policy initiatives,
(ii) green alternative energy availability is more influential than demand, and demand would be hardly turn into an agent of change because its high role as receptor (high I related to O),
(iii) environmental responsibility scoring seems very low, and, finally
(iv) energy is not seen as a profitable investment and competitiveness is scoring last regarding its importance in the system.

These results enable the process of understanding how to inform policy makers and manage factors which should be relevant for sustainability transitions, but that currently are not perceived as key. It should be noted that this network represents the aggregated knowledge on how the system works so it would always reflect a view closer to reality.

Results also indicate that increasing the number of connections per se is not obligatory related to better resilience performance. Increasing connectivity leads to an increase of non-linear feedbacks and thus, of the complexity of the system. When planning for transformation, more variables and connections among variables would need to be considered and the number of possible futures might increase exponentially. Seen this way, the connectivity of the network might not be necessarily desirable (Olazabal and Pascual 2016). For this reason, building scenarios based on potential policy options that consider cascading impacts and the systemic perspective of cities can be helpful for decision-making.

So far, we have argued and discussed connectivity in terms of its role during intended transformations. We find that connectivity may support the agency of change, however, a trade-off might also exist in cases of undesirable transformations resulted from unexpected shocks. A high connectivity might also translate into a situation where a shock spreads more widely and quickly and produces a higher number of failures due to a high number of connections between its elements. Again, this proves the double-edged sword that connectivity represents for resilience of the system.

11.8 Conclusion

In this chapter, we have examined connectivity as a characteristic of the system and its role in the management of the resilience of the system. To do this, we used a network approach and fuzzy cognitive mapping as a methodology. We used the case study presented by Olazabal and Pascual (2016) to provide a deeper analysis on the theoretical and practical implications of connectivity in the system.

We demonstrated how FCM can be utilised to identify system elements that can play essential roles in driving transformations. The technique can also be used for determining those characteristics of the system that are likely to be act as drivers of change or be influenced by changes in the system configuration. Therefore, this technique should be considered as an effective decision-support and learning tool for planners and policy makers that would like to assess and enhance the resilience of their urban system. Results of FCM also show the relative importance of different elements of the system and this feature can help planners decide which elements (factors) should be prioritized in future plans.

A closer examination of the case study provides evidence that increasing the connectedness of the energy sector as a business-as-usual strategy will further consolidate the current patterns, while no space is left for transition. Networks and connectedness principle should be handled in the same way: information on connectivity (measured by centrality, outdegree and indegree) should serve as a strategy-guiding map, in order to act with the most appropriate policies that are able to reverse perverse interactions and feedbacks. In line with the objectives of adaptive management, this should be done in an iterative way, until the desired configuration of the network, e.g. that one that provides higher opportunity options and higher low-carbon reductions in an equitable way, is achieved.

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Chapter 12
Spatially Explicit Land-Use Modelling for Assessing Climate-Resilient Sustainable Urban Forms

Yoshiki Yamagata and Daisuke Murakami

12.1 Introduction

In December 2015, 196 countries agreed the Paris Agreement toward sustainable development to hold the increase in the global average temperature well-blow 2°, to increase the adaptability to the climate change and foster climate resilience, and to make the financial flow consistent with a pathway towards low greenhouse gas emissions and climate-resilient development (UNFCCC 2015; url: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf).

Achievement of these goals is not necessarily straightforward. While economic development and energy intensity are the major determinants of future emissions (Marangoni et al. 2017), further economic development is projected in many developing countries (e.g., O'Neill et al. 2014; Murakami and Yamagata 2016). If high emissions are allowed, the global temperature raises up to 3.2–5.4 °C by 2100 relative to 1850–1900 (RCP 8.5). By contrast, the temperature increase is 0.9–2.3 °C in a low emission scenario (RCP 2.6) (Fuss et al. 2014). The difference is a matter. Actually, people in deadly heat area, which is 30% of the global population currently, is projected to increase up to 74% in 2100 in the high emission scenario whereas 48% in the low emission scenario (Mora et al. 2017). The temperature change increases the global flood risk approximately 187% over the risk in 2050 without climate change (Arnell and Gosling 2016). Achievement of the goals is a crucial task.

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It is critically important to make cities low carbon and adaptive to climate change. Actually, world total cities account for more than 70% of the total emissions (Gurney et al. 2015), and the percentage is projected to increase rapidly. Because the use emissions of new infrastructure constitutes the major part of future emissions (Creutzig et al. 2016), carbons are potentially reduced considerably by implementing low carbon urban systems.

It is important to note that climate change impacts changes regions by regions as shown in the Fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC AR5; see Stocker 2014). For example, flood risk is increasing especially in South and South-East Asian countries whereas heatwave risk is increasing especially in African countries. Adaptation policy must be considered while understanding possible climate risks in each city.

Cities have not only climate issues but also many other issues relating sustainability. For example, "urban shrinkage" is required in cities facing population decrease, which is becoming a typical path in developed countries (Turok and Mykhnenok 2007; Großmann et al. 2013). Effective policy making is needed to reshape cities while saving infrastructure management cost, increasing greens, and reducing carbons. Just like adaptation policy that must be considered city by city, there is no 'one-size-fits-all' approach to urban shrinkage (Haase et al. 2016) because desirable city shape changes depending on population composition, industrial structure, existing transportation network, and so on.

This study focuses on especially how to achieve urban shrinkage in the developed countries, where massive population decrease is expected in the near future, considering trade-off/synergy among factors, including low carbon, climate resiliency, eco-urbanism and so on. To achieve such a "wise shrink", we show how a urban form assessment tools can be used to compare possible land use scenarios (e.g., business as usual scenario and wise shrink scenario) quantitatively. A land-use modeling approach is introduced for that purpose.

12.2 Land-Use and Sustainability

Quantitative approaches for evaluating urban policies include top-down approaches (e.g., material flow analysis; see Ayres and Kneese 1969), bottom-up approaches [e.g., agent-based approach (Benenson 2004); land-use modeling approaches (e.g., Yamagata et al. 2013)], and their hybrid (e.g., Chrysoulakis et al. 2013) (see, Chen et al. 2014). Among them, we focus on the last one. Section 12.2.1 introduces a background about why we focus on the land-use modeling, Sect. 12.2.2 reviews the modeling approaches, and Sect. 12.3.3 reviews quantitative analysis results on land-use and sustainability.

12.2.1 Local Climate Zones (LCZs) and Land-Use Modeling

Land-use is known as a key factor determining sustainability; it influences urban temperature, emissions, disaster risks, and natural environment. Under such a background, Local Climate Zoning (LCZ) classification scheme is launched by Stewart and Oke (2012). LCZs consist of 17 zones that are based on their impact for urban climate (see, Stewart et al. 2014); the zones are clarified based on height and density of building and trees, perviousness, and thermal admittance. The LCZ scheme is applying in an increasing number of cities towards a globally consist land classification [see, the World Urban Databased and Access Portal Tools (WUDAPT; http://www.wudapt.org/)].

If a tool to evaluate goodness of sustainability policies using the LCZs is developed, sustainability policy in each city can be evaluated in a unified scheme. The tool would be beneficial to make cities across the world sustainable efficiency.

Thus, we focus on land-use modeling that potentially contribute to establish such a tool.

12.2.2 Review on Land-Use Models

Based on Van Schrojenstein et al. (2011), land-use models are classified as follows:

(a) Extrapolation of past trend of land-use changes to the future
(b) Estimation of land use based on the characteristics of each zone, such as accessibility and soil. For example, zones with good access to railway station would need a greater chance to become urban land than zones with poor accessibility. Regression model is typically used for the estimation (see, Hoek et al. 2008).
(c) Estimation of land use based on neighboring relationship. For example, a zone surrounded by wasted lands tends to be a wasted land zone as well. The cellular automata (Walfman 1983), Markov-Chain methods (e.g., Muller and Middleton 1994) are classified into this approach. Statistical land-use models considering both (b) and (c) in the former classification have been extensively studied in the last decade (e.g., Chakir and Parent 2009; Brady and Irwin 2011; Li et al. 2013; Yoshida and Tsutsumi in press).
(d) Estimation of location of residences, offices, industrial firms, and so on, and the resulting land-use, through a modeling of agents' behavior. The spatially-explicit urban land-use model (SULM; e.g., Ueda et al. 2013; Yamagata and Seya 2013), which we focus, is categorized herein.

Recently, land-use models describing agents' (actor's) behavior (d) is becoming popular as computer performance advances and more of micro-scale spatial data (e.g., road network data, district level statistics), which are useful to model urban activities, are available. Among agent-based models, the SULM is advantageous in that its agent's behaviors are described based on an economic equilibrium theory (e.g., Brady and Irwin 2011; Koomen et al. 2015). For example, the SULM for Japan (e.g., Ueda et al. 2013; Yamagata and Seya 2013) describes the utility maximization behavior of households and profit maximization behavior of developers and landlords. Since the late 1980s, the effectiveness of this model has been demonstrated through benefit evaluations of transportation policy (e.g., Sato and Hino 2005; Chen et al. 2013), land-use policy (e.g., Nakamichi et al. 2013; Yamagata and Seya 2013; Yamagata et al. 2013), and so on.

12.2.3 Land-Use, Compact City, and Sustainability

Urban compaction has been alluded as an idealized urban form that reduces carbons, saves maintaining cost, increases greens, and revitalize central areas, which are typically declining in the car dependent society. In recent years, in which city populations in developed countries are declining, wise urban shrinkage is even more important. Thus, quantitative analyses is now needed to achieve wise shrink.

Numerous studies have shown benefits of urban compaction in terms of low carbon (e.g., Taniguchi and Ikeda 2005; Kennedy et al. 2009; Baur et al. 2013, Mishalani et al. 2014), revegetation (e.g., Beatley 2012), transportation cost reduction (Kaido and Kwon 2008; Howley 2009), and infrastructure cost saving (e.g., Burchell et al. 2002; Morikawa 2011). At the same time, a number of studies have negative comments on city compaction. Mindali et al. (2004) and Longden (2015) suggested that compaction city policy does not necessarily have statistically significant contribution on carbon reduction. Newman (2005) suggested that a compaction, which increases population density and decreases greens, lowers livability. Besides, concentration of people and stocks in one area can make a city vulnerable against natural disasters and man-made risks (see, Dodman 2009).

In sum, urban compaction/shrinkage policy must be designed in a sensible way; if not, it does not contribute to sustainability.

12.3 The Spatially-Explicit Urban Land-Use Model (SULM)

12.3.1 Overview

SULM estimates the behaviors of households, developers, and landlords, aggregated into N zones indexed by $i \in \{1, 2,\ldots N\}$. In Japan, SULM is slightly modified to reflect the situation of the real estate market that the land price market and the real estate market are separated. Figure 12.1 shows an overview of the model. In this model, households select their own residential locations, developers supply

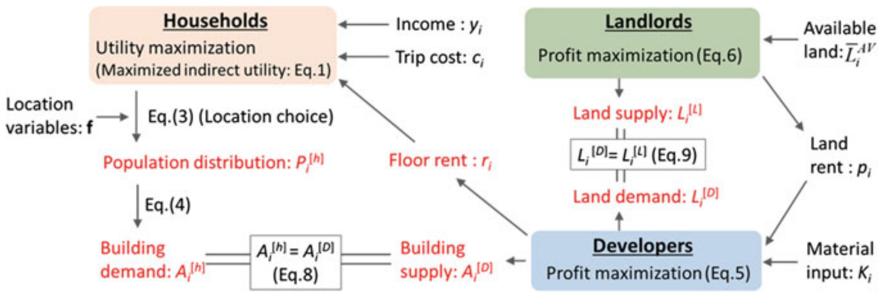

Fig. 12.1 Image of SULM. Red: endogenous variables to be calibrated; black: exogenous variables that are assumed to be fixed (*Source* Yamagata et al. 2016)

buildings to the households with a certain floor rent, and absentee landlords supply land to build the buildings to the developers. In other words, households and developers transact in a building market whereas the developers and landlords transact in a land market. During the transactions, households maximizes their own indirect utility, and the developers and the landlords maximize their own profits. The SULM describes a partial equilibrium state under these utility/profit maximization behaviors, and estimate the resulting population, total floor area, building area, and floor rent in each zone.

Models for households, developers, and landlords are described below:

12.3.2 Model for Households

The households' indirect utility function in i-th zone, V_i, is formulated as

$$V_i = \ln y_i - \alpha_a \ln r_i - \alpha_x \ln c_i. \quad (12.1)$$

y_i is the average income per capita, r_i is the residential floor rent per area, c_i is the generalized cost of a private trip. Equation (12.1) assumes that the utility of households increases if income, y_i, is large relative to floor rent, r_i, and travel costs, c_i. In Eq. (12.1), y_i and c_i are assumed given, and the floor rent, r_i, is estimated by maximizing V_i. The coefficients α_a and α_x may be given specified based on Roy's identity equation as follows (see Yamagata and Seya 2013):

$$a_i = \alpha_i \frac{y_i}{r_i},\ x_i = \alpha_x \frac{y_i}{c_i},\ z_i = \alpha_z y_i, \quad (12.2)$$

$$s.t.\ \alpha_a + \alpha_x + \alpha_z = 1\ \alpha_* > 0$$

where a_i is the presidential floor area per person, and z_i is the composite good per person. The coefficients α_a, α_x, and.α_z are estimated by applying the ordinary least squares (OLS) to each of the equations in Eq. (12.2).

The residential location choice behavior of household type h (e.g., one-person, married couple, and so on; see Table 12.1) is modeled using V_i. Specifically, the ratio for the type h households to select the zone i as their own residential location, $P_i^{[h]}$ is described by the following (aggregated) multinomial logistic regression model:

$$P_i^{[h]} = \frac{\exp(v_i^{[h]})}{\sum_j v_j^{[h]}},\ v_i^{[h]} = \delta^{[h]} V_i + \mathbf{f}'_i \chi^{[h]}, \quad (12.3)$$

where $\delta^{[h]}$ is the coefficient on V_i, which is given by Eq. (12.1). $\mathbf{f}_i$ is a vector variables explaining the residential location choice and $\chi^{[h]}$ is a vector of their coefficients. The suffix "$[h]$" means that the coefficients $\delta^{[h]}$ and $\chi^{[h]}$ change depending on the household types h. These coefficients can be estimated by applying the aggregated multinomial logistic regression approach. Equation (12.3) simply assumes that the indirect utility and other explanatory variables determine the residential location choice.

Once $P_i^{[h]}$ is estimated, the floor area demand in the i-th zone is estimated as follows:

$$A_i = a_i \sum_{h \in H} \bar{N}^{[h]} s_i^{[h]} P_i^{[h]}. \quad (12.4)$$

$\bar{N}^{[h]}$ is the total number of type h households across the study area. $s_i^{[h]}$ is the number of persons for each household of type h in zone i.

12.3.3 Model for Developers

Developers are assumed to obey the following profit maximization behavior:

$$\underset{i}{\overset{[D]}{\Pi}} = \max_{A_i^{[D]}, L_i^{[D]}} \left(r_i A_i^{[D]} - p_i L_i^{[D]} - mK_i \right), \quad (12.5)$$

Table 12.1 6 sub-scenarios (Compact/Wise shrink scenarios × revegetation scenarios)

Revegetation scenario Conversion of building lands reduced by policies	Compact scenario	Wise shrink scenario
- To any land-use type (leave it to chance)	Compact_0	Wise shrink_0
- To any type of green land (i.e., paddy fields, agricultural areas, forest, wildland, or park/recreation areas)	Compact_g1	Wise shrink_g1
- The same with g1 except that only park/recreation areas are allowed for districts with population increase.	Comact_g2	Wise_shrink_g2

$$A_i^{[D]} = v\left(L_i^{[D]}\right)^{\mu_1} \left(K_i\right)^{\mu_2}$$

$A_i^{[D]}$ is the floor area supplied from the developers to the households, $L_i^{[D]}$ is the land area supplied from the landlords to the developers, and p_i denotes the land rent. K_i is the material inputted for the production of floor service, and m is the price for the material construction. The parameters μ_1, μ_2, v can be estimated by applying OLS to equations derived by solving Eq. (12.5) (see, Yamagata and Seya 2013). Equation (12.5) assumes that the developers determine $A_i^{[D]}$ and $L_i^{[D]}$ to increase their benefit $r_i A_i^{[D]}$ while reducing the cost for land purchase $p_i L_i^{[D]}$, and, material input, mK_i.

12.3.4 Model for Landlords

Landlords are assumed to obey the following profit maximization behavior

$$\overset{[L]}{\underset{i}{\Pi}} = \max_{L_i^{[L]}} \left(p_i L_i^{[L]} - C(L_i^{[L]})\right) \tag{12.6}$$

$$C(L_i^{[L]}) = -\sigma_i \bar{L}_i^{AV} \ln\left(1 - \frac{L_i^{[L]}}{\bar{L}_i^{AV}}\right), \tag{12.7}$$

where $L_i^{[L]}$ denotes residential land supplied from the landlords, $C(L_i^{[LH]})$ denotes the land maintaining cost, $\bar{L}_i^{AV}$ represents the available land area and σ_i denotes a parameter. Equation (12.6) assumes that the landlords determines $L_i^{[L]}$ to increase the benefit $p_i L_i^{[L]}$ and reduce the cost, C($L_i^{[L]}$).

12.3.5 Equilibrium Condition

As illustrated in Fig. 12.1, there are two markets in this model: the building markets between households and developers; and. the land transaction between developers and landlords. Under a partial equilibrium, supply and demand must be balanced in these two transactions. These equilibriums are formulated by Eqs. (12.8) and (12.9), respectively:

$$A_i^{[h]} = A_i^{[D]}, \tag{12.8}$$

$$L_i^{[h]} = L_i^{[L]} \tag{12.9}$$

Roughly speaking, population, the building area, and other variables shown in red in Fig. 12.1 under a partial equilibrium are estimated by iteratively maximizing the objective function for each agent under the constraint of Eqs. (12.8) and (12.9) until the values of the estimated variables converge.

For further detail about the SULM and its calibration, see Yamagata and Seya (2013).

12.4 Application of the SULM in the Tokyo Metropolitan Area

12.4.1 Outline

This section illustrates an application of the SULM to the Tokyo metropolitan area. The analysis units are 22,603 micro districts in that area. For full descriptions, see Yamagata et al. (2016).

Based on Voss (2006), the Tokyo metropolitan area has the highest insurance risk among megacities in the world. Actually, based on the Headquarters for Earthquake Research Promotion, Japan (http://www.jishin.go.jp/main/index-e.html), the probability of suffering from an earthquake with magnitude 8.0 class within the next 30 years is estimated 70% as of January 1, 2017. Besides, extreme climate events are projected to increase gradually in Asian countries including the Tokyo area (e.g., Stocker 2014), and the flooding risk will also increase as well (Hirabayashi et al. 2013). Adaptation to climate risks is an emergent task is in the target region. On the other hand, depopulation is another problem in Japan. Although the population around Tokyo is still growing, it is projected to decrease from around 2020. Urban compaction is also an important issue in this area.

12.4.2 Scenario

Based on the above, we developed the following scenarios for 2050 emphasizing urban compaction and disaster risk adaptation:

- Business-As-Usual (BAU) scenario: Any regularization is not introduced, and the past trend on populations and number of households in each districts (source: National Census) are projected by the log-linear extrapolation method.
- Compact scenario: Compact policy is introduced. In that policy, residents living within 500 m from central areas are subsidized by 1200 USD/year, which is the same amount as the subsidy in the successive compact city policy in Toyama, Japan (e.g., 1200 USD/year is added in their income, y_i). The central areas are defined by the minor districts whose office densities are statistically significantly greater than the other districts. The statistical significance is evaluated based on the local Moran's I statistics (Anselin 1996) (see Yamagata and Seya 2013).

– Wise shrink scenario: Compact policy and adaptation policy is introduced. The former is the same with the policy in the Compact scenario. The latter haves the available residential land $\bar{L}_i^{AV}$ in districts whose average flooding depth is more than 0.5 m.

Figure 12.2 displays zones subsidized in the Compact and Wise shrink scenarios. Figure 12.3 shows the flood hazard [anticipated flooding death (source: the National Land Numerical Information download service [NLNI]: http://nlftp.mlit.go.jp/ksj-e/)], which is considered in the Wise shrink scenario, and earthquake hazards [seismic intensities exceeding 6.5 within 30 year (source: Japan Seismic Hazard Information Station: http://www.j-shis.bosai.go.jp/en/)]. Although we does not explicitly consider the earthquake hazard, because flood hazard and earthquake hazard have similar spatial patterns, the regulation imposed in the Wise shrink scenario mitigates the earthquake risk too.

For further information on the SULM implementation, see Yamagata et al. (2016).

12.4.3 Result: Population Distribution

The populations, building areas, floor areas, and floor rents in each district in 2050 under the BAU, Compact, and Wise shrink scenarios are estimated by applying the SULM.

Differences of estimated district populations under the Compact and Wise shrink scenarios relative to the BAU scenario are plotted in Fig. 12.4. As expected, the Compact scenario concentrates populations in the central area. By contrast, the Wise Shrink scenario does not concentrates like that. This is because the flood risk is high in the central area (see Fig. 12.3). The Wise shrink decreases the population by 23,996 people inside the area with a flooding depth of more than 0.5 m, while the Compact scenario increases the population by 1617 people. It is also found that the Wise shrink scenario decreases population in areas with high earthquake risk

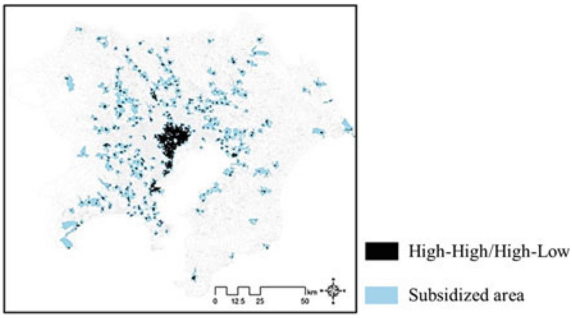

Fig. 12.2 Central areas (black) and areas subsidized areas in the compact policy (blue) (*Source* Yamagata and Seya 2013)

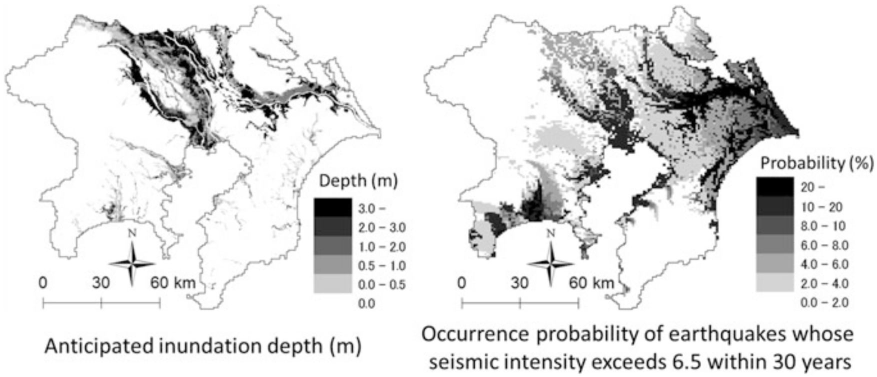

Fig. 12.3 Flood hazard (left) and earthquake hazard (right) (*Source* Yamagata et al. 2013)

whereas the opposite is true for the Compact scenario. The result clearly shows that usual compact city policy can make cities inadaptive to climate risks, and that an explicit consideration of disaster risks is important to avoid it.

12.4.4 Result: Revegetation

The SULM estimated building land areas in each district (i.e., L_i in Fig. 12.1) together with the populations (because the distributions of building lands are similar to population distributions shown in Fig. 12.4, it is not shown here). It is an interesting topic to clarify how to convert building land areas, which are reduced by the compact policy or the disaster mitigation policy, to green areas. To clarify it, the Compact and Wise shrink scenarios are subdivided into the 6 scenarios summarized in Table 12.1. Roughly speaking, these scenarios are (the Compact/Wise shrink scenarios) $\times$ (3 revegetation scenarios).

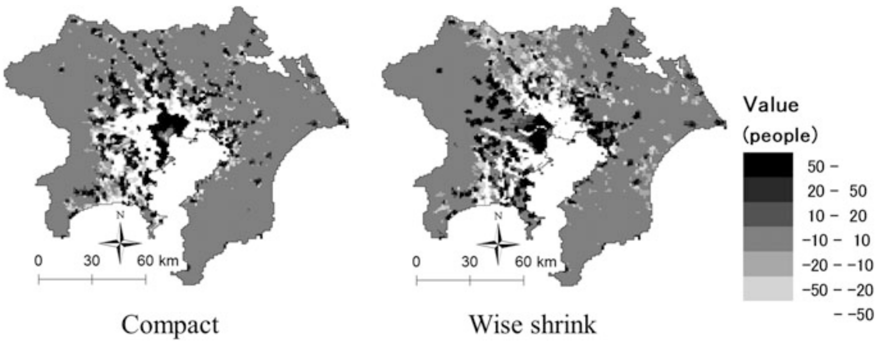

Fig. 12.4 Difference of estimated populations (2050) relative to the BAU scenario (left: the Compact scenario; right: the Wise shrink scenario). Black represents larger populations relative to the BAU scenario whereas white represents smaller populations relative to BAU

Composition of the 10 types of land uses, including 5 urban lands (Building land, Industrial land, Road, Land for public facilities, Vacant land) and 5 green lands (Paddy fields, Other agricultural land, Forest, Wild land, Park/recreation areas) under each scenario are estimated by a spatial compositional regression analysis (see, Pawlowsky-Glahn and Buccianti 2011). In this analysis, the relationship between the land-use composition in 2006 (source: NLNI) and the explanatory variables are analyzed. The variables includes populations (it is estimated from the SULM), distance to the nearest railway station, road density, elevation, distance to the nearest primary river, and dummy variables indicating urbanization control area, lake, alluvial fan, natural levee, back marsh, delta, and sandbar, respectively (source: Japan Seismic Hazard Information Station, National Research Institute for Earth Science and Disaster Prevention). Based on the relationship analysis result, the probabilities of converting the reduced building lands into each of the 10 land-use types are estimated by district. Land-use composition under each scenario are estimated by replacing the reduced building lands into other land-use following the probabilities (see Yamagata et al. 2016 for further detail).

Figures 12.5 shows estimated increases in park/recreation areas relative to the BAU scenario. The green areas under the Wise Shrink scenarios are much greater than those in the Compact scenarios. It is verified that the Wise Shrink scenarios are preferable in terms of revegetation. It is also conceivable that the degree of revegetation changes considerably depending on revegetation policy. Increase of green area is limited in the Compact_0 and Wise_0 scenarios whereas the increase is substantial under the Compact_g2 and Wise_g2 scenarios.

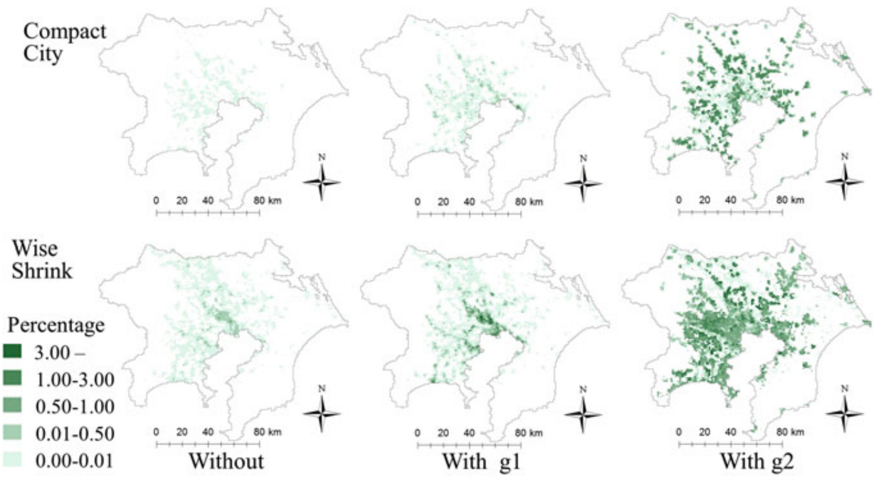

Fig. 12.5 Estimated revegetation in 2050: Park and recreation areas (*Source* Yamagata et al. 2016)

12.4.5 Result: Economic Value Assessment

This section applies the SULM analysis result to quantify the economic value of each of the 6 scenarios shown in Table 12.1. The assessment is conducted by the following steps:

(i) A hedonic analysis (Rosen 1974) is conducted to evaluate the economic values of the variables explaining accessibility, disaster risk, urban area, green area, and water area. The explanatory variables are as summarized in Table 12.2. Suppose that $x_{i,p}^{S}$ is the *p*-th explanatory variable, a hedonic analysis regresses $x_{i,p}^{S}$s on residential land price (we used the officially assessed land price in 2006 provided by NLNI). The resulting coefficient estimate β_p represents the economic value of the *p*-th explanatory variable. See Yamagata et al. (2016) for further detail.

(ii) Population and land-use distributions under each scenario are estimated using the SULM.

(iii) Economic value of each scenario is evaluated by the following equation:

$$V_{S,p} = \sum_{i} (P_i^S - P_i^{BAU}) x_{i,p}^{S} \beta_p, \tag{12.10}$$

where P_i^S is the population in *i*-th district estimated under the *S*-th scenario, and P_i^S is the population under the BAU scenario. Equation (12.10) evaluates [population change] × [economic value of each explanatory variable] by district. By

Table 12.2 Explanatory variables in the hedonic analysis

Category	Variables	Description		
Accessibility	Tokyo_dist	Logarithm of the distance from the Tokyo Station to the nearest railway station (km)		
	Station_dist	Logarithm of the distance from the nearest railway station (km)		
Disaster risk	Flood_depth	Anticipated flood depth (m)		
Urban land	Industry	Area of	Industrial land	in 1 km grids (10 km^2)
	Road		Road	
	Public		Land for public facilities	
	Vacant		Vacant land	
Green land	Paddy		Paddy fields	
	Agriculture		Other agricultural land	
	Forest		Forest	
	Wild		Wild land	
	Park/green		Park and recreation areas	

Source Yamagata et al. (2016)
All of these variables are collected from the National Land Numerical Information (NLNI) download service (http://nlftp.mlit.go.jp/ksj-e/index.html)

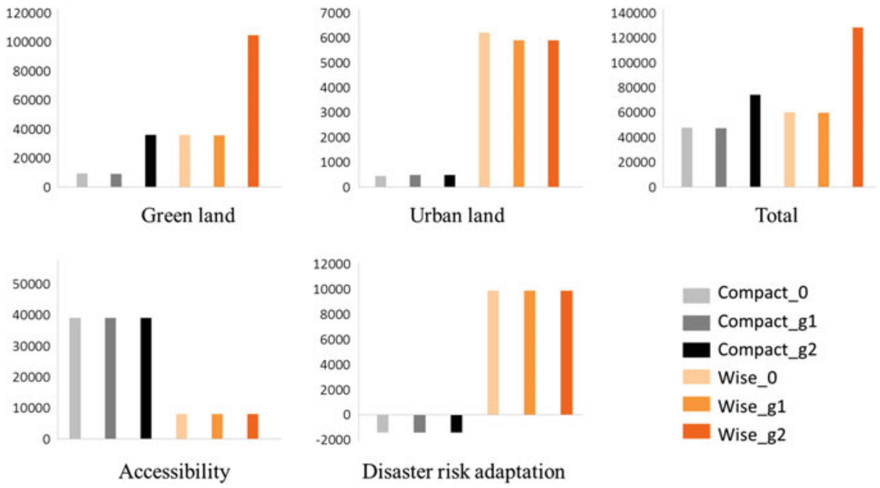

Fig. 12.6 Economic value of the scenarios (*Source* Yamagata et al. 2016)

aggregating $V_{S,p}$, which is evaluated for each $x_{i,p}^{S}$, the with respect to factors (i.e., accessibility, disaster risk, urban area, green area, and water area; see, Table 12.2) they explain, economic value of each of these factors are evaluated.

Figure 12.6 summarizes the estimated economic values of these four factors under the 6 scenarios. The values are positive if they are greater than those in the BAU scenario, and negative if they are smaller than those in the BAU scenario. The Compact scenarios greatly increase accessibility because they concentrate people around nearby railway stations. Benefits from urban land variables are also increased because more people live in urban areas, which is highly valued in the hedonic analysis (see, Yamagata et al. 2016). As a result, the total benefits from urban compaction are positive (top right in Fig. 12.6). Still, compact scenarios tend to concentrate people in high risk areas whose economic values are low (bottom middle of Fig. 12.6).

By contrast, the Wise shrink scenarios significantly increase adaptability to flood risk compared with the BAU scenarios. The benefits from all of the other factors are also higher in the Wise Shrink scenario than those in the BAU. The effectiveness of the Wise Shrink scenarios is verified. There are significant differences among the three Wise Shrink scenarios. The total benefit received in Wise_g2 is 2.15 times greater than that in Wise_0 and 2.13 times greater than that in Wise_g1. The result suggests that urban compaction must be accompanied by an effective eco-urbanism as well as disaster risk adaptation.

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