Urban Resilience Assessment: Multiple Dimensions, Criteria, and Indicators

Chapter · August 2016

DOI: 10.1007/978-3-319-39812-9_13

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Urban Resilience Assessment: Multiple Dimensions, Criteria, and Indicators

Ayyoob Sharifi and Yoshiki Yamagata

Abstract Over the past few years, there has been a proliferation of studies that focus on enhancing resilience of cities against a multitude of man-made and natural disasters. There has also been an increase in the number of frameworks and tools developed for assessing urban resilience. As climate change advances, resilience will become an even more significant topic in the science and policy circles that influence future urban development. Resilience indicators, in particular, will be essential for helping planners and decision makers understand where their communities stand in terms of resilience and develop strategies and action plans for creating more resilient cities. This chapter draws on the extensive literature on urban resilience assessment and provides a set of principles and indicators that can be used for developing an urban resilience assessment tool. Selected indicators cover multiple dimensions of urban resilience. They are divided into five main categories, namely, materials and environmental resources, society and well-being, economy, built environment and infrastructure, and governance and institutions. It is argued that resilience indicators should be used to help planners understand how best to enhance the abilities to plan/prepare for, absorb, recover, and adapt to disruptive events. The chapter concludes with proposing a matrix to relate resilience indicators with the main underlying characteristics of urban resilience that are namely, robustness, stability, flexibility, resourcefulness, redundancy, coordination capacity, diversity, foresight capacity, independence, connectivity, collaboration, agility, adaptability, self-organization, creativity, efficiency, and equity.

Keywords Urban resilience · Indicator · Criteria · Measurement · Assessment tool · Adaptation · Matrix approach

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Y. Yamagata and H. Maruyama (eds.), *Urban Resilience*,
Advanced Sciences and Technologies for Security Applications,
DOI 10.1007/978-3-319-39812-9_13

1 Introduction

Cities as socio-ecological systems are facing the growing challenges posed by a broad array of stressors such as climate change, population growth, urbanization, natural and man-made disasters, and resource depletion. Recognition of the fact that not all these threats can be avoided has led to the diffusion of the concept of resilience (Renschler et al. 2010a). The increasing attention to resilience is reflected in the growing number of assessment tools and frameworks developed to measure resilience of urban communities and various activities and projects undertaken to operationalize assessment strategies. Resilience assessment tools are either focused on single sectors or take a multi-sectoral approach. Those falling under the latter category have a broad approach toward resilience and try to address different environmental, social, economic, and institutional aspects of urban resilience.

As resilience assessment is a relatively new and still growing field, there is a paucity of studies elaborating on different indicators that should be incorporated into urban resilience assessment tools. Indicators should be used to transform resilience into a measureable concept and provide a lens through which complexities of cities as socio-ecological systems can be better understood. These indicators can later be used to develop assessment tools that, among other things, can be used to determine baseline conditions, evaluate effectiveness of interventions, and measure progress in achieving community goals. These functions signify the important role of resilience indicators as building blocks of any assessment system. An appropriate assessment tool should feature characteristics such as multi-dimensionality and comprehensives, context-specificity, simplicity, replicability, updatability, and scalability (Cutter et al. 2010). This chapter tries to elaborate on the multi-dimensionality and comprehensiveness characteristic of urban resilience assessment indicators. For this purpose, the theoretical underpinnings of urban resilience and various resiliency principles are described in the next section. In Sect. 3 various indicators, which are drawn from an extensive review of literature on urban resilience assessment, are grouped under five major themes. Section 4 proposes development of resilience matrices that can better explain to which stages of the disaster risk management process each indicator relates. In addition, these matrices can provide information on resilience characteristics associated with each indicator. If developed, such matrices can help planners and decision makers make more informed decisions when prioritizing resource allocation for enhancing resilience of urban communities.

2 Underlying Characteristics of Urban Resilience

Resilience is a contested and normative concept. This could be explained by the fact that it has been adopted by various disciplines that have interpreted it differently according to their needs and priorities. It was originally developed in physics and

psychology. Over the past four decades it has been introduced to other fields such as ecology, engineering, and disaster risk management. Although introduction of resilience notion to urban studies occurred comparatively late, it has been rapidly gaining ground since the turn of the century (Sharifi and Yamagata 2014, 2016). Engineering resilience, ecological resilience, and socio-ecological resilience are three major approaches that can be found in the literature. The first approach conceptualizes resilience of a system as its physical resistance and its capacity to rapidly return to an equilibrium state in case the thresholds are exceeded (Sharifi and Yamagata 2016). The ecological approach to resilience acknowledges that shocks are not always predictable. It advocates enhancing the tolerance of the system and recognizes that the system may need to shift to new equilibrium state(s) in order to be able to retain its pre-disaster functionality (Sharifi and Yamagata 2016). The adaptive approach to resilience is based on the conceptualization of (urban) system as a dynamic socio-ecological entity that continuously undergoes transformation. Accordingly the system may not necessarily return to an equilibrium state after the disruptive event. System integrity, self-organization capacity, and learning are three main components that contribute to adaptive resilience of a system and enable it to not only bounce back from disruptions, but also bounce forward to a more desired state (Sharifi and Yamagata 2016).

The fact that cities are socio-ecological systems, that feature dynamic interactions across time and space, implies that the adaptive approach to resilience can provide a more suitable theoretical basis for conceptualizing urban resilience (Sharifi and Yamagata 2016). This approach is reflected in The National Academies' definition of resilience as "the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events" (TNA 2012, P14) which is adopted for the purpose of this chapter. To achieve, maintain, and strengthen these abilities, any urban system should entail the following characteristics: robustness, stability, flexibility, resourcefulness, coordination capacity, redundancy, diversity, foresight capacity, independence, connectivity and interdependence, collaboration capacity, agility, adaptability, self-organization, creativity and innovation, efficiency, and equity (Sharifi and Yamagata 2016). These criteria are distilled from the literature and only briefly explained here. These broad characteristics form the basis for development of a matrix approach that will be discussed later on in this chapter. A more detailed explanation can be found in Sharifi and Yamagata (2014, 2016). Robustness and stability refer to the system's strength against short-term and long-term shocks, respectively. Flexibility indicates the ability to rearrange structure and functions when facing disruptions. Resourcefulness relates to availability of resources needed for enhancing the above-mentioned four abilities of a resilience system. Coordination capacity is needed to make optimal use for resources at disposal of citizens, planners, and decision makers. Redundancy is important to ensure that, in case components of the system are out of function, they can be substituted by spare components that have been included for this purpose. Diversity refers to inclusion of different components in the system that can be used simultaneously and can make up for each other's dysfunction. Foresight capacity is directly related to the uncertainties innate in the urban system and preparatory work that needs to be done

to address potential disruptions. Independence gives the system a certain degree of self-reliance that may be needed to survive adversities. Connectivity refers to interactions and relations that need to be established with other systems that exist in a broader scale. This is particularly important for shock absorption and timely recovery. Collaboration highlights the need for an inclusive and bottom-up approach towards urban management. Agility is related to how fast an urban system can restore its functionality following a disruptive event. Adaptability is specifically related to the capacity to learn and to integrate the notion of "living with risk" in planning and everyday life practices. Self-organization includes establishing and strengthening community-based and voluntary activities centered on social institutions and networks. Creativity is required to find innovative solutions for addressing emergent and unprecedented problems. Efficiency entails considering costs and benefits of actions and developing strategies for maximizing benefits given the limited resources available. Last, but not the least, equity is important to ensure fair distribution of benefits and impacts across different groups in the society (Sharifi and Yamagata 2014, 2016).

When thinking about these characteristics it should not be forgotten that synergies and tradeoffs exist between some of them. For instance improving redundancy may have adverse implications for efficiency of the system. Or, a balance point between independence and connectivity may differ from one context to another and, generally, finding balance between these two may turn out to be very challenging (Sharifi and Yamagata 2016). In order to develop a comprehensive and informative assessment system, it is needed to further discuss these synergies and tradeoffs and also clarify how each of the characteristics is related to planning/preparation, absorption, recovery, and adaptation as the four major abilities integrated into resilient urban systems. Addressing the former is beyond the scope of this chapter. The latter will be briefly discussed in Sect. 4 when proposing a matrix approach to facilitate a transparent and informed assessment framework that can identify whether resilience characteristics have been reflected in the urban system.

3 Multiple Dimensions of Urban Resilience

Resilience is a multi-faceted aspect and, ideally, all different dimensions of an urban system should be addressed in a resilience assessment framework. This section provides a list of various criteria that can be used for developing a resilience assessment system. Although context specificity issues should be taken into account when developing assessment frameworks, paying attention to all relevant criteria is needed for enhancing integrity and content validity of the assessment system. A detailed content analysis of 29 resilience assessment frameworks was conducted to distill major dimensions and criteria related to resilience of urban systems.

A complete list of these assessment frameworks can be found in Table 1. The extracted criteria have been divided into five categories (each referring to a specific

Table 1 The analyzed resilience assessment frameworks [adapted from the draft version of Sharifi (2016). Thirty six tools have been analyzed in the published version]

Tool	Year	Primary developer(s)	Ref
CRC	2015	Bushfire and Natural Hazards CRC	Morley and Parsons (2015)
DRI	2015	Earthquakes and Megacities Initiative (EMI)	Khazai et al. (2015)
NIST	2015	National Institute of Standards and Technology	NIST (2015b)
RELi	2015	American National Standards Institute (ANSI)	http://c3livingdesign.org/
TCRI	2015	Australia Netherlands Water Challenge	Perfrement and Lloyd (2015) http://theresilienceindex.weebly.com/
CoBRA	2014	UNDP | Drylands Development Centre	UNDP (2014)
CRF	2014	The Rockefeller Foundation, Arup	TRF (2014)
FCR	2014	International Federation of Red Cross and Red Crescent Societies (IFRC)	IFRC (2014)
Grosvenor	2014	Grosvenor, real estate investor (industry)	Barkham et al. (2014)
ICLEI	2014	ACCCRN, Rockefeller Foundation, ICLEI	Gawler and Tiwari (2014)
UNISDR	2014	IBM and AECOM	UNISDR (2014)
CRS	2013	Community and Regional Resilience Institute (CARRI); Meridian Institute; Oak Ridge National Laboratory	CARRI (2013), White et al. (2014)
CDRST	2012	Torrens Resilience Institute	Arbon et al. (2012)
BCRD	2011	RAND Corporation	Chandra et al. (2011)
CART	2011	TDC/University of Oklahoma	Pfefferbaum et al. (2011)
CERI	2010	AWM (Advantage West Midlands) Strategy Team	Team (2010)
CDRI	2010	Coastal Services Center and the National Oceanic and Atmospheric Administration	Peacock et al. (2010)
CRI	2010	MS-AL Sea Grant/National Oceanic and Atmospheric Administration (NOAA)	Sempier et al. (2010)
PEOPLES	2010	National Institute of Standards and Technology (NIST)	(Renschler et al. 2010b)
CRT	2009	Bay Localize project of the Earth Island Institute	Schwind (2009)
SPUR	2009	San Francisco Planning + Urban Research Association	Poland (2009)
CARRI	2008	Community and Regional Resilience Institute	Cutter et al. (2008)
Hyogo	2008	UN/OCHA and UN/ISDR	UN/ISDR (2008)
USAID	2008	USAID	Frankenberger et al. (2013)

(continued)

Table 1 (continued)

Tool	Year	Primary developer(s)	Ref
DFID	2007	Department for International Development and other Agencies	Twigg (2009)
USIOTWT	2007	U.S. Indian Ocean Tsunami Warning System Program	USIOTWSP (2007)
ResilUS	2006	US, Resilience Institute is part of Western Washington University's Huxley College of the Environment	Miles and Chang (2011)
THRIVE	2002	Prevention Institute	THRIVE (2004)
CRM	2000	Canadian Center for Community Renewal	Rowcliffe et al. (2000)

dimension) according to their similarities. These are materials and environmental resources, society and well-being, economy, built environment and infrastructure, and governance and institution. Each of these dimensions will be further discussed in the following sections.

3.1 Materials and Environmental Resources

Criteria mentioned in Table 2 are mainly related to quality, availability, accessibility, and conservation of resources. Through providing ecosystem services, environmental resources play a significant role in enhancing resilience of communities. Some resources such as wetlands are necessary for absorbing impacts of disasters such as flood and improving recovery process. Availability and accessibility to clean and affordable resources is essential for survival and prosperity of human communities. Therefore, appropriate measures in terms of resource protection and management should be taken for achieving resilient communities.

Table 2 Criteria related to materials and environmental resources [adapted from Sharifi (2016)]

Code	Criterion
M1	Ecosystem monitoring and protection
M2	Using local and native material and species
M3	Erosion protection
M4	Protection of wetlands and watersheds
M5	Availability and accessibility of resources (air, energy, water, food, soil, etc.)
M6	Reduction of environmental impacts (various types of pollution)
M7	Quality of resources
M8	Biodiversity and wildlife conservation
M9	Material and resource management (production, consumption, conservation, recycling, etc.)

3.2 Society and Well-Being

Criteria related to this dimension can be found in Table 3. This dimension has received considerable attention in the urban resilience literature and is believed to have a strong influence on the achievement of community self-sufficiency and resilience. This signifies the recognition of the fact that physical and engineering measures alone will not be sufficient for creating resilient communities.

Table 3 Criteria related to society and well-being [adapted from Sharifi (2016)]

Asset	Code	Criterion
Socio-economic characteristics	S1	Population composition
	S2	Language abilities
	S3	Car ownership, mobility
	S4	Land and home ownership
	S5	Diverse skills (to pool skills at the time of disaster)
Community bonds, social support, and social institutions	S6	Degree of connectedness across community groups
	S7	Volunteerism and civic engagement in social networks
	S8	Collective memories, knowledge, and experience
	S9	Trust, norms of reciprocity
	S10	Shared assets
	S11	Strong international civic organizations
	S12	Place attachment and sense of community and pride
	S13	Existence of conflict resolution mechanisms
	S14	Empowerment and engagement of vulnerable groups, social safety-net mechanisms
Safety and wellbeing	S15	Crime prevention and reduction
	S16	Security services such as police
	S17	Physical and psychological health
	S18	Preventive health measures
	S19	Responsive health measures
Equity and diversity	S20	Gender norms and equality
	S21	Ethnic equality and involvement of minorities
	S22	Diverse workforce in culturally diverse places
	S23	Decency, affordability, and fair access to basic needs, infrastructure and services
Local culture and traditions	S24	Past experience with disaster recovery; learning from the past
	S25	Cultural and historical preservation (identity); awareness of indigenous knowledge and traditions
	S26	Considering and respecting local culture and specificities in the process
	S27	Positive social, cultural, and behavioral norms

Criteria grouped under socio-economic characteristics can be used to measure community's status in terms of capacity and diversity of human resources. The second group of criteria are related to social capital. Both structural criteria such as existence of civic organizations and cognitive ones such as norms of reciprocity and trust should be taken into account (Sherrieb et al. 2010). Both trust between citizens and trust in official information sources are important. Place attachment and strong sense of community are indicators of commitment to the future of the community and enhance chances of building networks and establishing relationships with other community members (Chelleri et al. 2015). As mentioned earlier, however, the issue of tradeoffs should not be undermined. For instance although place attachment enhances recovery process, strong attachment to place may result in lack of willingness to move to safer places. This will exacerbate the suffering from losses and accordingly it can be said that place attachment can in some cases "impair, rather than facilitate" resilience (Norris et al. 2008). Safety and well-being criteria improve stability of communities. Safe and healthy communities are more capable of withstanding and responding to shocks (Chandra et al. 2011). Equity and diversity are important because impacts of disasters are often experienced unevenly in communities, with vulnerable groups suffering the most. Enhancing equity will be an effort to tackle this problem. Finally, respecting local cultures and traditions is an important element of the learning process which, among other things, can improve the adaptation aspects of resilience.

3.3 Economy

The economic dimension of urban resilience includes criteria related to the structure of the economy, its security and stability, and its dynamism (Table 4). Economic resilience of a community depends on the capacity and skillfulness of its working population to support the dependent population. Availability of reasonably-paid jobs can also be associated with resilience (Burton 2014).

Appropriate planning is needed to reduce potential business interruptions. For this purpose, availability of business mitigation plan will be essential. Such a plan should include financial instruments and insurance plans to ensure economic security of the community. Community members should be aware of the importance of community savings for enhancing redundancy and resourcefulness and also recognize the importance of collective resource ownership for maintaining access to resources for which severe competition exists (Schwind 2009).

Inward investment and economic diversity are indicators of community's ability to attract and retain businesses and avoid negative impacts of economic decline (NIST 2015a). Communities reliant on a single industry are expected to be more vulnerable to disruptions. Both large and small businesses are needed to ensure inward investment and business continuity.

There is evidence suggesting that, compared to large chain stores, local small businesses are more effective in keeping the money circulating within the local economy. This also provides other co-benefits such as additional tax revenues and

Table 4 Criteria related to economy [adapted from Sharifi (2016)]

Asset	Code	Criterion
Structure	E1	Employment rate and opportunities
	E2	Income (equality, multiple sources,…), poverty
	E3	Age structure of working population
	E4	Qualifications of working age population
	E5	Individuals with high and multiple skills; literacy (education)
	E6	Job density (housing-work proximity; extent of out commuting)
Security and stability	E7	Individual and community savings (stockpiles of supplies, monetary, etc.)
	E8	Collective ownership of community assets
	E9	Business mitigation, response and redevelopment plan
	E10	Insurance (domestic and non-domestic) and social welfare
	E11	Financial instruments (contingency funds, operating funds, capital funds etc.)
	E12	Stability of prices and incomes, property value
Dynamism	E13	Inward investment
	E14	Investment in green jobs and green economy (self-sufficiency, urban farming, etc.)
	E15	Integration with regional and global economy
	E16	Business cooperative or working relations (inter and intra)
	E17	Diverse economic structure and livelihood strategies
	E18	Openness to micro enterprises and micro-finance services, self-employment and dispersed ownership of assets; entrepreneurialism
	E19	Public-private partnership
	E20	Private investment
	E21	Locally owned businesses and employers
	E22	Balance of local labor market supply and demand

strong networks wherein local businesses collaborate and employ local workers (Schwind 2009). Large businesses should also exist since evidence suggests that they tend to be better capable of coping with change and recovering from disruptions (Sherrieb et al. 2010). Integration with the regional economy and collaboration agreements are also important for better absorption of shocks and for facilitating a timely recovery process. Also, public-private partnership is needed to adequately prepare individual businesses and also encourage them to engage in collective actions (CARRI 2013).

3.4 Built Environment and Infrastructure

Criteria related to the built environment and infrastructure are listed in Table 5.

Infrastructure has often a long lifetime. Therefore, careful attention is needed to avoid the risk of lock-in into vulnerable and inefficient urban infrastructure.

Redundancy facilitates substitutability of infrastructure in case some parts stop functioning. Robustness implies enhancing resistance of infrastructure and fortifying them against shocks. This may, however, result in complacency and a false perception of safety in the community. Multi-functionality of urban spaces and facilities improves diversity and efficiency characteristics which are essential for shock absorption and timely recovery. For instance, while parks and green spaces are mainly used for purposes such as recreation, thermal comfort provision, and air pollution mitigation, they can provide additional benefits in terms of evacuation and flood mitigation. Similarly, sport arenas and educational facilities can be used for temporary sheltering when needed.

In order to enhance infrastructure efficiency, regular monitoring is needed to inform planners and citizens of the need for actions such as retrofit, refurbishment, and technology update.

Of the various types of infrastructure, more emphasis has been put on communication and transportation systems. Good communication and information sharing are regarded as fundamental for enhancing resilience (Norris et al. 2008). The main role of transportation infrastructure systems is in survivor evacuation, and rescue and aid operations (Faturechi and Miller-Hooks 2015).

Criteria related to land use and urban design have major implications for resource security and management in cities. They can also provide resilience against threats such as urban flooding and extreme heat events. It must be kept in mind that the optimum state with respect to some of these criteria may vary depending on the context and type of disruption. For instance while higher levels of density increase energy resilience of cities, there is evidence showing that lower density is better for resilience against floods and hurricanes (Burton 2014).

3.5 Governance and Institutions

Governance is a cross-cutting dimension that has various inter-relationships with the other dimensions explained above. Governance and institutional criteria are shown in Table 6 and can be used to evaluate the efficiency and effectiveness of relationships between and within community organizations and entities.

Governance and institutional rules define how different activities are communicated and what mechanisms exist to make contingency and mitigation plans and ensure that they are implemented. Strong leadership enhances resilience by strengthening linkages between various elements of the system and empowering bonding and bridging social networks (Frankenberger et al. 2013).

Also, bottom up citizen involvement and transparent decision making is needed to enhance legitimacy of actions and make sure that they have a high level of buy in from the local community. Decentralized and bottom-up initiatives reduce hierarchical complexities. This provides a platform for civic collaborations, encourages community mobilization, and facilitates exchange of ideas and experiences leading to better preparation and response to disasters (Renschler et al. 2010b). A shared

Table 5 Criteria related to the built environment and infrastructure [adapted from Sharifi (2016)]

Asset	Code	Criterion
Robustness and redundancy of critical infrastructure	B1	Redundancy of critical infrastructure, facilities, and stocks
	B2	Robustness and fortification (of critical infrastructure, buildings, vital assets, ecosystems, etc.)
	B3	Spatial distribution of critical infrastructure (measure against cascading effects)
	B4	Location of critical infrastructure and facilities
	B5	Consolidation of critical utilities and collaboration between utility providers
	B6	Multi-functionality of spaces and facilities
	B7	Shelter and relief facilities and services
Infrastructure efficiency	B8	Regular monitoring, maintenance, and upgrade of critical infrastructure
	B9	Retrofit, renewal, and refurbishment of the built environment
	B10	Promotion of efficient infrastructure (technology update, metering, etc.)
ICT infrastructure	B11	Diverse and reliable information and communication technology (ICT) networks
	B12	Emergency communication infrastructure (before, during, after disaster)
Transportation infrastructure	B13	Capacity, safety, reliability, integratedness (connectivity), and efficiency of transportation
	B14	Inclusive and multi-modal transport networks and facilities
Land use and urban design	B15	Accessibility of basic needs and services throughout different stages (food, water, shelter, energy, health, education)
	B16	Site selection and avoiding risk areas and habitat areas (floodplain, flood prone; exposed coastal zone, greenfield)
	B17	Urban form (compact, dispersed, etc., SVF, aspect ratio)
	B18	Mixed-use development
	B19	Street type and connectivity
	B20	Density of development
	B21	Public spaces and communal facilities (for recreation, physical activity, etc.)
	B22	Green and blue infrastructure
	B23	Amount (percent) of impervious surfaces
	B24	Aesthetics, visual qualities, walkability
	B25	Landscape-based passive cooling
	B26	Passive lighting
	B27	Passive heating
	B28	Passive cooling

Table 6 Criteria related to governance and institutions [adapted from Sharifi (2016)]

Asset	Code	Criterion
Leadership and participation	G1	Strong leadership
	G2	Stability of leadership and political stability
	G3	Shared, updated, and integrated planning vision (long term)
	G4	Transparency, accountability, corruption etc.
	G5	Multi-stakeholder planning and decision making
	G6	Decentralized responsibilities and resources
Management of resources	G7	Efficient management of resources (funds, staff, etc.)
	G8	Skilled personnel and emergency practitioners
	G9	Population with emergency response and recovery skills (first aid, etc.)
	G10	Redundant capacity in terms of personnel
Contingency, emergency, and recovery planning	G11	Integration of risk reduction and resilience into development plans and policies
	G12	Existence of climate change and environmental policy and plans
	G13	Understanding risk patterns and trends
	G14	Continuous and updated risk assessment; scenario making for different kind of infrastructure and services (costs, losses, etc.)
	G15	Emergency planning and existence of emergency operation center that integrates different agencies and organizations
	G16	Availability and update of contingency plans (e.g. post-storm traffic management)
	G17	Availability of mitigation plan
	G18	Early warning, evacuation plan, and access to evacuation information
	G19	Inclusion of transient population (tourists, etc.) in emergency planning
	G20	Inclusion of disaster resilience and lessons learned in the recovery plan
	G21	Speed of recovery and restoration
	G22	Ongoing process of revising and monitoring plans and assessments
	G23	Standardized, updated, and integrated databases for action planning, monitoring and evaluation purposes

(continued)

Table 6 (continued)

Asset	Code	Criterion
Collaboration	G24	Cross-sector collaboration (alignment of aims) and partnership among organizations
	G25	MOUs and MOAs with neighboring communities and agencies within the broader region
	G26	Knowledge and information transfer and best practice sharing (inter and intra city)
R&D	G27	Innovation and technology update
	G28	Research (funds, facilities) on risks and academy-society collaborations
Regulations/enforcement	G29	Availability and enforcement of legislations (policing, crime, building code, environmental law, business law, etc.)
	G30	Management of informal settlements
Education and training	G31	Behavioral issues and demand management
	G32	Education (from elementary or secondary school), training, and communication
	G33	Drills and exercises
	G34	Education and training for all linguistic groups; and all groups generally
	G35	Capacity building and enhancing awareness; dissemination of data and assessment results
	G36	Incentives for encouraging mitigation and adaptation (including self-mobilization, self-organization, etc.)

vision should be established and guide all the planning activities in the community. This is argued to be essential for enhancing resilience (Norris et al. 2008).

Due to the complexity of various stressors such as climate change, it would be unlikely that communities be capable of addressing various problems independently. Therefore, collaboration, learning, and information exchange should be necessary components of any resilience planning efforts. Organizational connectivity and presence of interconnected networks is argued to be important for enhancing resilience (Norris et al. 2008). Establishing an integrated network of organizations and individuals can also be effective in increasing trust and knowledge exchange among the members and improve their willingness to partake in mitigation and preparation, and recovery plans (Chandra et al. 2011).

4 Proposed Resilience Matrices

In Sect. 2 resilience was defined as "the ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events" (TNA 2012, P14). It was also discussed that any resilient system should entail different characteristics, namely robustness, stability, flexibility, resourcefulness, coordination capacity, redundancy, diversity, foresight capacity, independence, connectivity and interdependence, collaboration capacity, agility, adaptability, self-organization, creativity and innovation, efficiency, and equity. The main purpose of any resilience assessment framework should be the achievement of better-informed decisions. Following the "Resilience Matrix" approach proposed by Fox-Lent et al. (2015), here, it is argued that creating matrices that specify to which ability each characteristic may relate could further aware planners and decision makers of the importance of each ability and characteristic. The proposed matrix would have a structure as shown in Table 7.

It would also be useful to develop other matrices based on abilities, characteristics, and criteria mentioned in this chapter. First, a set of matrices that identify to which ability each criterion mentioned in Tables 2, 3, 4, 5 and 6 is related. Second, a set of matrices that show which characteristics are influenced as a result of inclusion of the resilience criteria in the planning process. The relationships can be indicated by checking the respective cells in the matrix. However, as some of the relationships (or influences) may be characterized as either positive or negative, it is preferable to also display the direction of the relationships. As demonstrated in Fox-Lent et al. (2015), it can also be possible to use qualitative and/or quantitative indicators to calculate estimated scores for performance of each cell [e.g. score in terms of planning/preparation for "ecosystem monitoring and protection" (M1)]. This matrix approach can be used for prioritization of activities and resource allocation and lends itself to better planning towards urban resilience. The proposed structure for these matrices is shown in Tables 8 and 9. Here only the proposed matrices for criteria related to materials and environmental resources are shown. Similar matrices should be developed for criteria related to the other four dimensions of urban resilience.

Table 7 Proposed matrix to indicate the relationship between resilience abilities and characteristics

	Robustness	Stability	Flexibility	Resourcefulness	Coordination capacity	Redundancy	Diversity	Foresight capacity	Independence	Connectivity	Collaboration	Agility	Adaptability	Self-organization	Creativity	Efficiency	Equity
Plan/prepare for																	
Absorb																	
Recover																	
Adapt																	

Table 8 Proposed matrix structure to explore association between resilience abilities and urban resilience criteria

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Plan/prepare for									
Absorb									
Recover									
Adapt									

Table 9 Proposed matrix structure to explore association between resilience characteristics and urban resilience criteria

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Robustness									
Stability									
Flexibility									
Resourcefulness									
Coordination capacity									
Diversity									
Foresight capacity									
Independence									
Connectivity									
Collaboration									
Agility									
Adaptation									
Self-organization									
Creativity									
Efficiency									
Equity									

5 Conclusions

Resilience thinking is rapidly gaining ground in science and policy circles. Among other benefits, developing resilience assessment frameworks can be regarded as useful for reducing the complexities of urban resilience and clarifying the inter-relationships between various aspects of resilience. To this end, it is necessary to understand different characteristics of resilience systems and also identify various dimensions of resilience. In addition to identifying major resilience characteristics, this study introduced five major dimensions of urban resilience and an extensive list of criteria related to them. Subsequently a matrix approach was proposed that can be used to further explore the relationship between these criteria and characteristics. Also, it was suggested that additional work is needed to investigate how the four defining abilities of resilience are related to resilience characteristics and criteria. What discussed in this chapter provides a conceptual framework for developing resilience assessment tools. This should be regarded as a preliminary work that needs to be further developed in the future. The next step should be focused on methodologies to complete the matrices proposed in Sect. 4. The matrices could be completed by either using stakeholder/expert opinions, or by taking evidence-based approaches such as literature review and/or analysis of actual behavior of urban systems in response to disasters. Although some components of the matrices could be regarded as generic, some others may be context specific and the final output is likely to vary from one context to another. Resilience assessment will also require identifying specific indicators related to each criterion. This will also be a highly context-specific task. Due to context-specificity issues, it is likely that not all criteria mentioned in this chapter will be useful for application in all contexts.

Another essential task required for building comprehensive and informative resilience assessment tools would be explaining synergies and tradeoffs that may exist between the different components of the system. This would be necessary for achieving better-informed decision making.

Acknowledgements The authors appreciate the financial support of the Asia-Pacific Network for Global Change Research.

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