Chapter 9
Resilient Urban Form: A Conceptual Framework

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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,

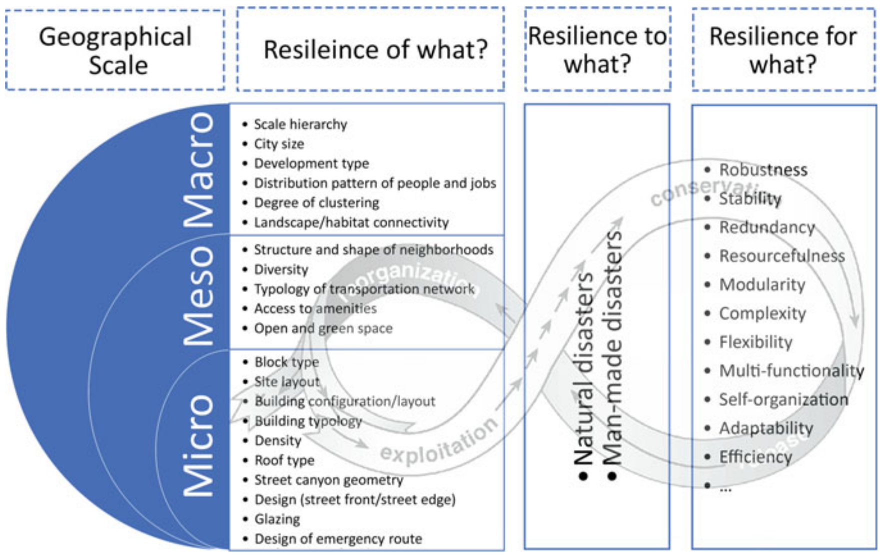

Fig. 9.1 Conceptual framework for assessing resilience of urban form

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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