1

Urban Resilience and Spatial Economics

Zeynep Elburz, Karima Kourtit, and Peter Nijkamp

1.1 The Resilience Concept: Introduction

Resilience, which has its roots in the Latin word *resilire*, meaning ‘bouncing back’, is not a new concept. The resilience concept was first used in the field of ecology with the pioneering article of Holling (1973), and this concept is still considered to be relevant in many disciplinary fields at different scale levels, both living and non-living, such as an economy, a micro-organism or a child, in order to understand the process

Z. Elburz
Faculty of Architecture, Department of City and Regional Planning, IZTECH,İzmir, Turkey
e-mail: zeynepelburz@iyte.edu.tr

K. Kourtit · P. Nijkamp (✉)
JADS (Jheronimus Academy of Data Science),‘s-Hertogenbosch, the Netherlands

A. I. Cuza University, Iasi, Romania
e-mail: k.kourtit@jads.nl

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of anticipating, adapting and recovering in the face of major threats or shocks (Masten 2014). The exportability of the resilience concept from ecology to other disciplines, such as economics, engineering, sociology, etc., also plays a prominent role in the success and acceptance of the concept (De Montis et al. 2019). In particular, because of global concerns about major threats, such as disasters, economic crises, diseases, and other threats to human development, the notion of resilience has—despite adversity—become popular over the past decades and has attracted a great deal of international interest (Cassidy 2016; Masten 2014; Barasa et al. 2018).

As a contested concept, resilience is defined in many disciplines on the basis of their intrinsic use needs and priorities (Sharifi and Yamagata 2016). According to the theoretical ecologist Holling (1973), resilience is 'a measure of the ability of systems to absorb changes of state variables and still persist'. There are two ways to define resilience in the ecological literature (Holling 1996). The first concentrates on efficiency, constancy and predictability features, and underlines stability near an equilibrium steady state. This is called *engineering resilience* (see, e.g. Pimm 1984) and is defined as the return time to a single equilibrium state. The other concentrates on persistence, change and unpredictability attributes without any emphasis on one equilibrium steady state. It is called *ecological resilience* (after Holling 1973), and is defined as the amount of disturbance that can be absorbed by the system. The major difference between these two approaches is that—while engineering resilience (also termed the 'roly-poly toy principle') focuses on maintaining efficiency—ecological resilience focuses on maintaining the existence of functions (Holling 1996, p. 33; Gunderson 2000). Moreover, Pimm's resilience definition is based on the strength of the perturbation, while Holling's definition is based on the size of the attractor/stability domain (Reggiani et al. 2002). From an empirical point of view, the measurement of engineering resilience which is based on a simple cause–effect dynamics (Barasa et al. 2018) is easier than that of ecological resilience (Reggiani et al. 2002). However, from a conceptual point of view, while engineering resilience is about resistance to change in order to conserve existing structures (Folke 2006), ecological resilience is more about creating the capacity to work with that change (Walker and Salt 2006, p. 9). Besides, bouncing back to one steady state after a disturbance or a shock may not be a desirable attribute for systems, while the ability to adapt is clearly desirable (Klein et al. 2003).

Based on Holling's (1973) definition of resilience, a third interpretation of the resilience notion, which is called *socio-ecological* resilience, has emerged, as a result of the increasing awareness that ecosystems and human societies affect each other and need to be examined jointly (Sterk et al. 2017). Adger (2000) has highlighted the link between social and ecological resilience by defining social resilience as 'the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change'. Following the shift caused by Adger (2000)'s definition, Berkes et al. (2003) defined social-ecological resilience as 'the amount of change the system can undergo and still retain the same controls on function and structure', and emphasised the capacity for learning and self-organisation. In the social-ecological resilience interpretation, a disturbance can be seen not just as a threat but also as an opportunity to allow continuous development, renewal of the system, and learning to adapt (Folke 2006). Relating linked social-ecological systems to the concept of resilience (Berkes and Folke 1998), social-ecological resilience extends ecological resilience to embrace the human and cultural elements in a city (Sanchez et al. 2018).

However, there are two opposite views on applying the ecological resilience approach to social science phenomena. Davoudi et al. (2012) has advocated the resilience concept as a bridging concept between ecology and the social sciences based on the synergy that results from integrating different disciplines. It might well be possible that the resilience concept could contribute in a meaningful way to planning theory and practice in particular (Davoudi et al. 2012). Reggiani et al. (2002) demonstrated the great potential of the resilience concept, which stems from the ecological sciences, in dynamic socio-economic systems. It should be noted that there are also many critics of resilience and its use in the social sciences. For example, Swanstrom (2008) argued that this approach might result in dead ends. Moreover, noting the increasing use of the resilience notion in many fields, Davoudi et al. (2012) underlined the suspicion in planning disciplines about the potential of the resilience concept which is considered to be just a new hollow concept and buzzword, like sustainability. They questioned the wisdom of applying the resilience concept which emerged from the natural sciences without any political dimension into the planning discipline. Along with that, MacKinnon and Derickson (2012) criticised the resilience concept from a conceptual and political point of view. They questioned the idea that resilience is a concept that is not always applicable to the capitalist system, and argued that promoting resilience in the face of a crisis only serves 'to naturalize the ecologically dominant system of global capitalism'. Clearly, different views on resilience abound in the worldwide literature on adaptive systems.

The literature on resilience is wide ranging and covers many topics, illustrations and applications. There is also a strand of literature that voices serious criticism. There are several caveats in the use of resilience concepts for socio-economic and spatial dynamics. Examples are: the definition of a shock, the question whether a perturbation is endogenous or exogenous, the evolution of resilience as a positive or negative phenomenon for society, the demarcation of the dynamic system under consideration (e.g. local or national), the effect of governance or policy on the stability of a system, the question of the nature of final equilibrium state, the quantitative assessment of a dynamic system's equilibrium point in one summary indicator, etc. (see for a review also Batabyal et al. forthcoming).

In this chapter, we look at the resilience concept from different perspectives with many dimensions, determinants and levels within a new and broader framework for both the natural and the social sciences. Since there is no universal agreement on the definition of the resilience concept, the existence of various types of definitions from various fields and studies leads to a very complex analysis framework. By adopting the view that this heterogeneity in the definitions arises from a lack of the spatial dimension, we focus here on the urban resilience concept in order to define and measure it in an appropriate operational way.

The present study will zoom in on the significance of resilience for urban systems, hence the concept of *urban* resilience. It will summarize the literature and outline some prominent research and policy challenges. The aim of this chapter is thus to present a new framework on urban resilience with an additional dimension called *spatiality*, by taking into account the spatial advantages and disadvantages of existing urban resilience arguments in the literature. The spatiality dimension includes the spatial characteristics of urban areas, such as urban morphology, urban size, transport network patterns, and accessibility. This study is a novel attempt to map out the spatial characteristics of urban areas in the context of urban resilience with an emphasis on spatial units, spatial heterogeneity and spatial correlation issues.

The rest of the chapter is organised as follows. Section 1.2 presents the different definitions of resilience at different scale levels and discusses their similarities and dissimilarities. Section 1.3 provides a review of the various dimensions of urban resilience, while Sect. 1.4 demonstrates urban resilience measurements and indicators. Finally, Sect. 1.5 concludes our study with a discussion and suggestions for how policy makers can enhance resilience.

1.2 Scale Levels of Resilience

There have been many attempts from different fields to define resilience, but there is a lack of consensus about a clear and broad definition of this concept. In the related literature, resilience, which is simply a measure of a system's integrity (Levin et al. 1998), has been addressed at different scale levels, including the individual (households, businesses), community (faith-based groups, refugees), local area (markets, cities, urban areas), country (national economy) and global (international economy) level (Rose 2017). In this section, we focus on the first three levels of resilience: individual (personal) resilience, community (social) resilience, and urban (city/region) resilience, and, in particular, their definitions of resilience (Table 1.1).

Defining resilience is a complex issue, and it depends on whether resilience is being seen as an attribute, as an outcome or as a process (Southwick et al. 2014). Individual resilience, which is the simplest level to examine (Boon et al. 2012), has been seen as a personal trait (e.g. Kobasa 1982) and also as a process in the early psychological studies. Bonanno et

Table 1.1 Resilience definitions from different disciplines

Author, Year	Level of analysis	Field	Character	Definition
Holling (1973)	Ecological system	Ecology	Attribute	The persistence of relationships within a system; a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist
Gordon 1978)	Physical system	Physic	Attribute	The ability to store strain energy and deflect elastically under a load without breaking or being deformed
Egeland et al. (1993)	Individual	Psychology	Process	The development of competence despite severe or pervasive adversity
Adger (2000)	Community	Ecology and social sciences	Attribute	The ability of communities to withstand external shocks to their social infrastructure
Godschalk (2003)	City	Social sciences	Attribute	A sustainable network of physical systems and human communities
Allenby and Fink (2005)	Community	Social sciences	Attribute	The capability of a system to maintain its functions and structure in the face of internal and external change and to degrade gracefully when it must
Folke (2006)	Social–ecological system	Ecology	Attribute and process	A self-organizing capacity of a (social) system while undergoing (ecosystem) change so as to maintain the same function and structure
Campanella (2006)	Urban areas	Social sciences	Attribute	The capacity of a city to rebound from destruction
Gillespie et al. (2007)	Individual	Psychology	Process	An ongoing process of struggling that can be learned any time

Ultramari and Rezende (2007)	Urban areas	Social sciences	Attribute	The ability to transform and retransform urban spaces
Hill et al. (2008)	Region	Economy	Attribute	The ability of a region to recover successfully from shocks to its economy
Norris et al. (2008)	Community	Psychology	Process	a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance
Lang (2010)	Urban areas	Social sciences	Process	The stability of a system when faced with interference
Zhou et al. (2010)	Social–ecological system	Geography	Attribute	The capacity to resist and recover from loss
Thomas et al. (2013)	Social system	Economy	Attribute	The capacity of a health system to deal with economic contraction and reorganise so as to retain essentially the same policies and functions
Lu and Stead (2013)	Urban areas	Social sciences	Process	An ongoing process, a timescale of reshaping, reorganising and developing new adaptive strategies
Coaffee (2013)	Urban areas	Social sciences	Attribute	The capacity to withstand and rebound from disruptive challenges
Walker et al. (2004)	Ecological system	Ecology	Attribute	The capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks

(continued)

Table 1.1 (continued)

Author, Year	Level of analysis	Field	Character	Definition
Masten (2014)	Individual	Psychology	Attribute	The capacity of a dynamic system to adapt successfully to disturbances that threaten system function, viability or development
Meerow et al. (2016)	Urban areas	Social sciences	Process	The ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity
De Montis et al. (2019)	Ecological system	Ecology	Attribute	The ability of complex systems to be resistant to very critical disturbances, keep their original characteristics, self-organise and adapt, and eventually evolve by achieving further and stronger conditions

al. (2011) took resilience as an outcome and investigated the factors affecting an individual's resilience after a potentially traumatic event. They found that there are multiple independent determinants of resilience such as personality, demography, socio-economic resources, etc. Similarly, Fraser et al. (1999) defined resilience by referring to 'individuals who adapt to extraordinary circumstances, achieving positive and unexpected outcomes in the face of adversity'. They also categorised three aspects of resilience: overcoming the odds, adapting successfully to high risk, and recovering from trauma, which lead to resilience being characterised as 'to learn from success'. Similarly, Walsh (2006) described resilience as 'the capacity to rebound from adversity strengthened and more resourceful'. On the other hand, some researchers have emphasised the importance of a process when they attempt to define resilience. Hegney et al. (2007) recognised that there is no one steady state within personal resilience: actually the level of resilience changes over time. Gillespie et al. (2007) also described resilience as an ongoing process of struggling that can be learned at any time. Also, according to the American Psychological Association (APA), resilience is 'the process of adapting well in the face of adversity, trauma, tragedy, threats or significant sources of stress. It means 'bouncing back' from difficult experiences' (APA 2019). On the process–outcome debate, van Breda (2018) claimed that the outcome definition of resilience only observes the outcomes without explaining them, while the process definition of resilience concentrates on mediating processes that lead to an outcome, and thus he suggested using the process definition of resilience. Van Breda (2018) defined resilience as 'the multilevel processes that systems engage in to obtain better-than-expected outcomes in the face or wake of adversity'. However, the first challenge in defining resilience, which is whether resilience is a process or attribute, is still open not only at the individual level but also at other levels of resilience.

As a second level of resilience, community (social) resilience has many different definitions and, basically it concerns the stability of the population and thus individual resilience (Boon et al. 2012). Adger's (2000) simple social resilience definition has affected subsequent attempts to define it. Cacioppo et al. (2011) defined community resilience as 'the capacity to foster, engage in, and sustain positive relationships and to endure and recover from life stressors and social isolation', while Norris et al. (2008) described it as 'a process linking a set of networked adaptive capacities to a positive trajectory of functioning and adaptation in constituent populations after a disturbance'. Even though communities are composed of individuals, it is not easy to conclude that resilient individuals generate resilient communities due to the complex composition of the relations between the natural, built, social and economic environment in communities (Norris et al. 2008). According to Kimhi (2016), similar to individual resilience, community resilience is also an important predictor of coping with traumatic experiences such as disasters. Zhou et al. (2010) broadly described resilience as the capacity to resist and recover from loss, and they proposed a new model for disaster resilience which has three dimensions: time (before, during and after the disaster); space (community, town, country etc.); and attribute (economic, institutional, social and environment). On the other hand, Davoudi et al. (2012) argued that the resilience concept is often reduced to post-disaster emergency responses in the community resilience literature and policy reports. This causes a mis-measurement of the concept, since emergency responses focus on damage mitigation in the short term, while resilience is about constructing long-term adaptive capacity for cities or regions.

Compared with the first two scale levels, defining the urban resilience concept is more arguable. From a historical point of view, even though cities are vulnerable to human-made or natural disturbance, they also tend to survive destructions and exist afterwards (e.g. ancient cities such as Istanbul, Rome). Campanella (2006) asserts 'the persistence of place' view by claiming that modern cities are more durable and indestructible, and advocates that no major city has vanished since the nineteenth century. However, according to Ahern (2011), an urban system can only be considered resilient if it is able to retain the ability to adapt to unforeseen challenges. Ergo, the urban resilience concept appears to be more complicated than the ability to survive disasters or the ability to resist change.

A specific challenge in describing urban resilience derives from the long-standing debate about defining the *urban* area. The urban area can be identified as an administrative area or a functional economic area. However, in any case, with a reference to the geographical level, the urban (city) resilience concept is complex, dynamic, non-deterministic and uncertain in nature (Jabareen 2013). Since urban areas can be considered as adaptive socio-ecological systems, the social-ecological resilience approach is more suitable for the conceptualisation of urban resilience, which tends to emphasise transformation, learning, reorganisation, and renewal (Folke 2006). Yet, there are definitions of urban resilience in the literature which stress the 'bouncing back' concept in the context of single-state equilibrium also known as 'engineering resilience' (e.g. Wagner and Breil 2013; Campanella 2006). More recently, building upon the multi-state equilibrium resilience (ecological resilience), the equilibrium concept has evolved into a dynamic non-equilibrium notion which suggests there is no stable state to bounce back to at all. Following the trends in the debate on the equilibrium concept in the resilience literature, urban resilience is inclined to move to a multi- or non-equilibrium state, also known as evolutionary resilience (Pickett et al. 2004; Matyas and Pelling 2015; Meerow et al. 2016; Sharifi and Yamagata 2016; Figueiredo et al. 2018).

Regarding this discussion, Jabareen (2013) defined the resilient city in terms of 'the overall abilities of its governance, physical, economic and social systems and entities exposed to hazards to learn, be ready in advance, plan for uncertainties, resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner'. Taking into account the non-static and complex characteristics of cities, UN-Habitat (2018) describes urban resilience as 'the measurable ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses, while positively adapting and transforming toward sustainability'. More briefly, Leichenko (2011) defined urban resilience as 'the ability of a city or urban system to withstand a wide array of shocks and stresses'. Recently, Figueiredo et al. (2018) described urban resilience as 'the ongoing capacity of cities to absorb, adapt, transform and prepare for shocks and stresses along the economic, social, institutional and environmental dimensions, with the aim of maintaining the functions of a city and improving response to future shocks'. According to Meerow et al. (2016) who reviewed 172 publications with 25 definitions of urban resilience, a new, dynamic, and comprehensive but flexible definition of urban resilience is required. They define urban resilience as 'the ability of an urban system– and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales– to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity'.

Considering the multiple definitions of resilience from many disciplines which may lead to various policies and actions (Gunderson 2000), Rose (2017) argued the importance of a broader definition of resilience which unifies the various sets of definitions instead of only the intersections. According to Zhou et al. (2010), the heterogeneity in the definition of resilience originated from distinct epistemological orientations and methodological practices. On the other hand, Rose (2017) advocated that the existing discrepancy between the resilience definitions originates from the spatial dimension. Moreover, Jabareen (2013) stated that defining and measuring resilience is mostly related to capacity using quantitative indicators and claimed that the literature overlooks cities and space. As a solution, Cutter (2016) proposed an integration of the spatial sciences (planning and geography) with resilience concepts from different disciplines by considering their focus on the spatial need to integrate. By taking into account these existing attempts to define *urban resilience* in the literature, we describe it here as: 'a continuous learning ability of urban areas to absorb any kind of expected or unexpected disturbance or threat, to adapt, to evolve, and then to improve the distinctive features of urban areas in the face of probable future shocks'.

1.3 Dimensions of Urban Resilience

Urban resilience is a complex and multidisciplinary concept with many dimensions to consider (Sharifi and Yamagata 2016). Since it is not appropriate to neglect this multidimensional approach in order to frame urban resilience, the pillars of the concept have been investigated by many scholars. On the bases of a large body of works on urban resilience and its components, it can be argued that, amongst other dimensions, social, economic and institutional dimensions are prominent (Patel and Nosal 2016). The dimensions of urban resilience, including social, economic and institutional, have been named differently by researchers in the litera-

Table 1.2 Dimensions of urban resilience

Author/Year	Measure	Dimensions
ARUP (2014)	City resilience index	Health and well-being Economy and society Infrastructure and environment Leadership and strategy
Cutter et al. (2008)	Community resilience	Social vulnerability Built environment and infrastructure Natural systems and exposure Hazards mitigation and planning
Fu and Wang (2018)	Urban resilience capacity index	Ecological-physical conditions Economic conditions Institutional service Social capacity
Foster (2007)	Resilience capacity index	Economic capacity Socio-demographic capacity Community connectivity capacity
OECD (2014)	Urban resilience drivers	Economy Society Institution Environment
Wang et al. (2018)	Urban resilience	Economic Social Ecological
Yu et al. (2018)	Urban economic resilience evaluation index system	Economic growth index Opening up index Social development index Environmental protection index Natural condition index Technological innovation index
Kontokosta and Malik (2018)	Emergencies and disasters index	Social Infrastructure & Community Connectivity Physical infrastructure Economic strength Environmental conditions
Sharifi and Yamagata (2016)	Urban resilience dimensions	Materials and environmental resources Society and well-being Economy Built environment and infrastructure Governance and institution
Rus et al. (2018)	Urban resilience components	Buildings Infrastructure Community Open space

ture, but it is apparent that most of them are used as synonyms (Table 1.2). For instance, OECD (2014) addresses urban resilience with four strongly interconnected dimensions which are: economic, social, institutional and environmental dimensions, while Delgado-Ramos and Guibrunet (2017)'s *pyramid of urban resilience and sustainability* is composed of the ecological, economic, socio-cultural and governance dimensions. The World Bank (2012) defines urban resilience by breaking down its four components: economic, institutional, infrastructural and social, while Sharifi and Yamagata (2016) investigate urban resilience with its five main dimensions, namely materials and environmental resources; society and well-being; economy; built environment and infrastructure; and governance and institutions, in order to develop an urban resilience assessment tool. And finally, Kontokosta and Malik (2018) have developed an index to calculate regional resilience capacity from the dimensions: social infrastructure and community connectivity; physical infrastructure; economic strength and environmental conditions.

Another attempt to monitor urban resilience by creating an index with four key dimensions: health and well-being; economy and society; infrastructure and environment; and leadership and strategy, comes from The Rockefeller Foundation and ARUP (2014)'s study. Cutter et al. (2010) examine urban resilience based on social, economic, institutional, natural and physical dimension, whereas Wang et al. (2018) conceptualise urban resilience with three main aspects, including ecological, economic, and social resilience, which are all interrelated. Yet these studies fail to contain any spatial characteristics rather than a simple distinction between the urban and the rural area. More recently, Rus et al. (2018) divided complex urban systems into two basic components—physical (buildings, open space, infrastructure) and social (the community)—as well as the dynamic interactions between them in order to assess urban resilience to natural disasters, especially earthquakes. Based on their review of the assessment of urban system resilience, partial approaches (e.g. resilience of infrastructure, resilience of buildings) which neglect the links and interaction between the components can only present an incomplete view of an urban resilience level.

Considering the overlapping in assessing the dimensions of urban resilience in the related literature, we examine urban resilience with its five

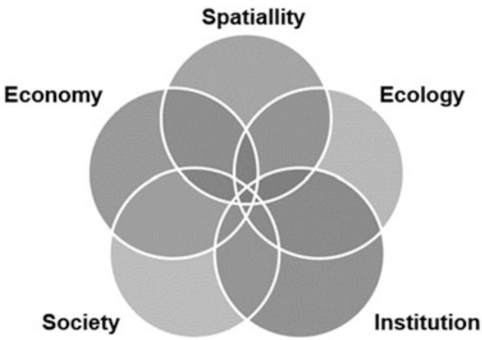

Fig. 1.1 The dimensions of urban resilience

dimensions including *economic*, *social*, *ecological* and *institutional* which are typical, and the *spatiality* dimension which is distinct from previous studies (Fig. 1.1). The spatiality dimension differs from the preceding physical or infrastructural dimensions by comprising the spatial characteristics of urban areas, such as urban morphology, urban size, transport networks, and location attributes of the urban areas, and bridging with the other four dimensions.

Urban morphology, which is the study of urban forms that include buildings, streets, and open spaces, is used to understand the spatial characteristics of the built environment (Schirmer and Axhausen 2016). In the discipline of urban planning, spatial characteristics affect the quality of the urban landscape and thus people's perception of it and that is why urban form is considered to promote a sense of community in an urban area (Eizenberg and Jabareen 2017). However, urban form has attracted attention in the literature mostly because of its relationship with sustainability and quality-of-life concepts, not with the resilience concept. Since Jacobs (1961), and Lynch (1984), it has been accepted that quality of life in an urban area is linked with its shape and the distribution of land uses. In the 1990s and early 2000s, the compact city and urban sprawl have been examined by focusing on urban development density to determine which urban forms are more sustainable and desirable. It is argued that in a compact city with high density and mix-land uses, it is easier to access services in a short time compared with a city with urban sprawl. Hege (2012) indicated that high-density space enhances walkability and social interaction, and reduces greenhouse emissions and thus increases the quality of life in a city. On the other hand, Dempsey and Jenks (2010) criticised high-density urban areas because of congestion and problems of overcrowding. However, high-density urban areas may create negative externalities but also positive externalities which are related to urban agglomerations from an economic point of view.

Another urban form study area is the link between urban forms and their environmental effects. Makido et al. (2012) investigated the relationship between urban form and energy consumption in Japanese cities, in order to calculate the effect of urban design on urban energy usage by using various spatial metrics. Another study by Xu et al. (2017) focused on urban morphology and climate change with a novel highly accurate satellite-based approach and claimed that high-density buildings create larger heat islands. However, the main aim of these studies is to understand the effect of urban morphology on sustainable urban living, and of enhancing sustainable cities for the future or the effect of urban form on resilience with a special focus on, for instance, energy (e.g. Yang and Quan 2016). Even though resilience invokes related terms, such as sustainability, adaptability and vulnerability, an integration of the urban resilience concept as a whole into urban morphology is missing in the literature.

For the case of the relationship between the transport network and resilience, Reggiani et al. (2015) observe that the studies that dominate transport network resilience in the literature interpret transport resilience in terms of robustness or reliability, which is similar to the single equilibrium approach of engineering resilience. However, the number of studies that measure network resilience with empirical applications or simulations is limited. Among them, Knoop et al. (2012) examine robustness, while Vromans et al. (2006) focus on the reliability issue for the Dutch road and railway network. However, it is also possible to state that interest in network resilience is increasing for all transport modes, for example, public transport networks, telecommunication, aviation, etc. at different scale levels with a special focus on shocks (Reggiani et al. 2015). To address transport network system resilience, accessibility—or connectivity—measures are used, but accessibility is also associated with the economic performance of an urban area, since higher accessibility creates lower transport costs, fosters agglomeration, and thus increases the productivity level of the area. Likewise, higher accessibility which emerges from transport infrastructure developments or land-use changes also increases the spatial interaction between places. But it is clear that accessibility varies in space, and is very sensitive to the spatial unit of analysis (Condeço-Melhorado et al. 2014).

To overcome the problem of an incomplete view of urban resilience, we propose to include the spatial characteristics of an urban area, as well as its interaction with other dimensions. The next step is quantifying urban resilience dimensions with the use of indicators and then creating an index for empirical analysis.

1.4 Measurement of Urban Resilience

The lack of consensus on both the definition and the measurement of resilience creates the danger of trivializing of the concept. One way to consider the resilience concept, not as a new buzzword or vague and umbrella concept for all desirable attributes, is to define it with measurable and observable attributes (Klein et al. 2003). This causes resilience to be seen by policy makers as an operational and practical concept. Thus, quantitative tools, indexes and indicators are preferred by policy makers to measure resilience and to formulate policies which enhance resilience.

In order to measure resilience, Reggiani et al. (2002) focused on Pimm's definition of resilience, which is more practical than Holling's, by taking into account the problems of measuring resilience in socio-economic terms. They applied the engineering resilience approach to identify non-resilient trends in regional labour markets in West Germany with the Lyapunov exponents method. Regional economic resilience was investigated by Chapple and Lester (2010) by looking at only one indicator: the changes in average real earnings per worker, from 1980, 1990 and 2000, while Swanstrom et al. (2009) investigated regional resilience in the face of foreclosures in three regions in the United States, and showed that resilience is diversified across space with different characteristics.

Table 1.3 Indicators of regional/urban economic resilience measurement

Author/Year	Spatial unit	Country	Indicator	Variable
Davies (2011)	10 countries	EU	Unemployment	Unemployment rate
Fingleton et al. (2012)	12 regions	UK	Employment	Employment growth
Lapuh (2018)	212 municipality	Slovenia	Output	Change in GVA per employee
Martin (2012)	12 regions	UK	Employment	Number of employees
Reggiani et al. (2002)	327 region	Germany	Employment	Number of employees
Chapple and Lester (2010)	191 metropolitan regions	USA	Income	Average earnings per worker
Di Caro (2014)	20 regions	Italy	Employment	Total employment Industrial employment
Swanstrom et al. (2009)	6 metropolitan regions	USA	Economic	Foreclosures
Simmie and Martin (2010)	2 city regions	UK	Economic	Employment growth Manufacturing employment Service sector employment Number of new firms

Recently Cai et al. (2018) synthesised 174 articles on disaster resilience measurement and found that the most common indicators for economic resilience are income and employment, and that only 17.8% of the articles had created a quantitative resilience index (Table 1.3).

Adger (2000), who relates social and ecological resilience, claims that different aspects of resilience have various indicators, and there is no single indicator to control resilience as a whole. Hence, he examined the social resilience with economic, demographic, and institutional variables. Likewise, Rose (2017) argued that the components of the existing resilience indicators in the literature are actually unimportant for the recovery process, and prior resilience indexes are not useful for the short run. He claimed that constructing a resilience index should serve both to study and to improve the recovery process, and instead of using a single resilience indicator, creating a resilience index is more popular. He constructed a resilience index (RI) for the recovery process from a disaster, while Girard (2011) defined qualitative and quantitative indicators for economic resilience criteria along with those for social and environmental resilience in order to make a multidimensional evaluation of resilient, creative and sustainable cities. Kontokosta and Malik (2018) developed the Resilience to Emergencies and Disasters Index (REDI) by integrating physical, natural and social systems measures in order to benchmark neighbourhood resilience. REDI consists of 24 indicators in order to calculate the regional resilience capacity for Hurricane Sandy. For monitoring disaster resilience in the case of the US counties, Cutter et al. (2010) created an index with social, economic, institutional, infrastructure and community dimensions. They underlined the presence of spatial variations in disaster resilience between urban and rural areas. However, Rose (2017) criticised the index derived by Cutter et al. (2010) for including indicators that are not based on a solid economic conceptual framework.

More recently, Sharifi and Yamagata (2016) aimed to address all urban system dimensions in an urban resilience assessment framework by creating five categories of criteria. The economic dimension of urban resilience is one of these five categories, and includes criteria for the economic structure, security and stability, and dynamism. They underlined the fact that the criteria for the different dimensions can be context-specific, and thus using all criteria for all contexts may not be meaningful (Sharifi and Yamagata 2016). Fu and Wang et al. (2018) criticise existing urban resilience capacity indicators for not being a comprehensive quantitative evaluation, but instead focus on resilience capacity enhancement. Thus, they develop a new urban resilience capacity index with currently available indicators extracted from the literature, instead of creating new resilience indicators. The study claims to create an index based on urban form and spatial attributes related to the urban planning discipline, but includes only a landscape shape index and a Shannon diversity indicator. More recently, Figueiredo et al. (2018) suggested a set of indicators to measure urban resilience based on four urban resilience dimensions. Eight out of 52 indicators are created for the economic dimension which focuses on innovation, diversity and employment aspects, whilst none of the indicators have a spatial reference. Similarly, for Chinese cities, Yu et al. (2018) use six dimensions which are: economic growth; opening up; social development; environmental production; natural condition; and technological innovation, and 25 indicators to measure urban economic resilience. However, except for the population density indicator of cities, the study ignores the spatial characteristics of the urban areas just like previous studies.

To date, the need to integrate spatial science into the resilience concept has not been successful, mainly because urban designers and urban planners opt to assess resilience with a qualitative conceptual framework rather than from a quantitative and measurable perspective (Cutter 2016; Rus et al. 2018). For example, Lu and Stead (2013) focus on the urban resilience concept in the spatial planning policies, and claim that planning strategies and the decision-making process can address the notion of resilience. They also emphasise that the resilience concept is important for cities to respond to uncertainty and to develop strategies to deal with change in cities. Similarly, to map out the characteristics of urban resilience, other studies (e.g. Sharifi and Yamagata 2016; Allan et al. 2013; Brand and Nicholson 2016) work on qualitative resilience attributes such as modularity, diversity, ecosystem services, variability, robustness, stability, flexibility, resourcefulness, redundancy, coordination, capacity, foresight capacity, independence, connectivity, collaboration, agility, adaptability, self-organisation, creativity, efficiency, equity, spare capacity, safe failure, rapid rebound and constant learning. In order to overcome the problem of the lack of spatial characteristics dimensions in the existing urban resilience literature, we believe that it is necessary to integrate the spatiality dimension with quantitative indicators into the urban resilience concept. Hence, we have created an urban resilience index with 5 main dimensions, and 14 subcategories using more than 50 indicators (Table 1.4). The spatiality dimension is composed of the subcategories urban size, urban sprawl, urban form, land use and transport network. With the development of GIS-based analysis and more utilisation of highly accurate

Table 1.4 Measuring urban resilience dimensions

Dimension	Category	Variable
Economy	Income and equality	GDP growth rate
		GDP per capita
		GINI coefficient
	Labour market	Employment rate
		Female employment rate
		Youth unemployment rate
	Innovation	R&D expenditure
		Number of patent applications
	Sector capacity	Economic diversity index
		Single-sector employment dependence
		High-tech industry ratio
		Number of new businesses
Society	Socio-demographic capacity	Population growth
		Life expectancy
		Number of doctors per 10,000
		Number of hospital beds per 100,000
		Insurance rate
		Adult literacy rate
		Education expenditures
		Pre-primary education ratio
		Percentage of homeownership
		Percentage of car ownership
	Community capacity	Poverty level
		Disabled population rate
		Elderly population rate
		Migration rate
		Accessibility index for services
		Households with access to broadband rate
Ecology	Environmental degradation	Population density
		Open space ratio
		Green area ratio
		Built-up area ratio
		Energy consumption per capita
		CO_2 emission rate
		Urban solid waste rate

(continued)

Table 1.4 (continued)

Dimension	Category	Variable
Institution	Civic infrastructure	Number of community organisations
		Number of local authorities
		Voter participation rate
	Government	Percentage of buildings with insurance
		Land-use plans for hazards
		Mitigation expenditure
Spatiality	Urban size	Urban density rate
		Urbanisation ratio
	Urban sprawl	Number of high-density peaks
		Percentage of population residing outside the high-density peaks
	Urban form	Medium block size
		Medium plot size
		Destination accessibility
	Land use	Simpson diversity index
		Dissimilarity index
	Transport network	Average streets per node
		Average street length
		Number of nodes and edges
		Space syntax

satellite images in land-use attributes, it is possible to measure urban size, urban sprawl, and urban form with temporal and spatial evolution included. By taking advantage of using population and land-use metrics with GIS-based methods, which generate more reliable dynamic spatial data on urban areas, one can observe the past and current state of the morphology of the urban areas. But in order to control the spatiality dimension, we also need more detailed spatial unit data, because the elements of urban form are not only streets and blocks, but also plots and buildings and their size and proportion. For the case of transport network connectivity, space syntax can play an important role in understanding the patterns of movement, interaction, and density.

Developing indicators for measuring urban resilience is problematic, since factors affecting urban resilience are miscellaneous, and these factors cause cities to have dissimilar capacities to adopt, recover and transform. Therefore, suggesting a one-size-fits-all approach is not relevant for the urban resilience concept, which is all about context. It is not appropriate to compare and rank different cities based on their inherent capacities by ignoring the need for a tailored/specified methodological approach for each case (Schiappacasse and Müller 2015). Using the standard internationally recognised indicators, such as the employment rate, creates sufficient conditions to compare different urban areas. However, standard metrics are too general and rigid to capture the local characteristics of cities. On the other hand, context- and space-specific indicators are able to control cities' own priorities and objectives more directly. Considering the differences in context, characteristics and size of the urban areas, it is more useful and proper to compile space-specific indicators and combine them with basic indicators which matter for all urban areas (Figueiredo et al. 2018; Winderl 2014; Yu et al. 2018).

Quantifying resilience by measuring it with created indexes and indicators, policy makers can enhance urban resilience. Many factors, including social, economic, geographical, and environmental, influence urban resilience and many indicators have been proposed in the literature to capture those factors. However, there is a need for weighting indicators that are used to measure urban resilience based on the priorities, problems and objectives of the city. Also bearing in mind that cities have different attributes and characteristics, the process of selecting the most appropriate indicators and weighting the indicators needs to be city-specific, rather than employing national resilience indexes which exclude place-specific indicators and local knowledge (Frazier et al. 2013). Taking into account the omission of differential weighting and the spatial context of resilience indicators, Frazier et al. (2013) examined spatial factors that were identified by the local focus groups and plans at the county level. Moran's I and LISA statistical analyses reveal that all spatial indicators vary across space and tend to show spatial clustering characteristics. The results give clear evidence that some indicators are more important in some areas than in others, and thus spatial autocorrelation between indicators should be considered (Frazier et al. 2013). Another important issue is controlling the spillover effects of the resilience indicator to give a clear answer to the question: Does a resilient urban area also affect the neighbouring regions' resiliency? With data from different scale levels, from plot size to satellite images, to measure the spatiality dimension, we assume it is possible to investigate not only the direct but also the indirect effects of each indicator on neighbouring regions. This would bring urban resilience into the realm of spatial statistics and econometrics.

1.5 Conclusion

Resilience has become a new and popular buzzword in the social sciences. This chapter has presented a new framework to understand the urban resilience concept at different scale levels and in terms of different dimensions. Based on our review of various definitions, dimensions and measurement types of urban resilience, we introduced a new dimension called 'spatiality' to capture the spatial characteristics of urban areas. It is clear that the existing literature overlooks space and its effects on other dimensions, and this partial approach can only lead to an incomplete view of urban resilience. As far as the authors know, this is the first study to underline the importance of spatial characteristics when conceptualising and measuring the notion of urban resilience and its interaction with other dimensions. In this study, we create—on the basis of a new comprehensive definition of urban resilience—a general index for the quantitative assessment of urban resilience by including urban form, urban size, and transport network categories. This index can be a useful tool for cities to examine their past and current state and thus prepare for all kinds of disturbance in the future. But it is crucial to stress that this index is only a first step for measuring resilience, and each city should consider and take into account its own special and unique conditions, and then combine them with this index to have a clearer idea of its degree of resilience. Resilience has both an analytical and a political meaning, and its use and relevance depends on various internal and external circumstances; against this background, one might speak of contextual resilience. Lastly, it is also worth mentioning that urban resilience variables vary across space and also affect neighbouring spatial units. Therefore, it would be more appropriate to look, on a broader scale, at not only the city itself but also its neighbours in order to analyse spillover effects. From an analytical perspective, there is a clear promising research agenda for urban resilience theory and methodology.

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