Chapter 4: Live with Risk While Reducing Vulnerability

Patricia Romero-Lankao, Olga Wilhelmi, and Mikhail Chester

4.1 Introduction

Urban areas can play a key role in the transformation that is required in humankind's ways of understanding and responding to climate and sustainability challenges. These new ways, however, will require bringing together urban planners, social scientists, business leaders, engineers, and other diverse knowledge and power domains – an undertaking that creates its own set of seemingly intractable complications. As documented by scholars studying diverse fields of human endeavor, from scientific inquiry to governmental planning and private or public sector construction of infrastructure, one of the most difficult problems in creating change lies in moving people beyond the mental models, ways of knowing, tools, and analytical systems they learn during their academic training and professionalization.

Scholarship on urban risk and vulnerability offers an example of this trend. While research on risk and vulnerability has grown considerably in recent years, it has consisted primarily of case studies based on the assumption that both risk and vulnerability depend on context. Often, scholars and practitioners offer conflicting theories and conceptualizations that tend to shed light only on certain aspects of the problem, while other areas remain in the dark. This trend has implications for politics, equity, and sustainability. For instance, the vast majority of epidemiological studies on health risks from heat waves quantify the relationship between heat waves and health outcomes, while controlling for age and other factors. However, these studies omit underlying historical processes of sociospatial segregation (such as land-use development) that explain urban populations' differentiated access to green areas, air conditioning, health services, and other assets and options – and thus, their differentiated exposure to temperature, capacity to adapt to heat stress, and ability to mitigate heat risks. The development of approaches that can explain these differences may help us move towards cohesive and policy-relevant narratives.

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This chapter starts with a brief discussion of existing definitions and approaches to the interactions between urbanization, urban risk, and vulnerability. We outline the necessary components of an interdisciplinary understanding of how environmental and societal processes, such as global warming and urbanization, contribute to intra- and interurban inequalities in vulnerability to heat waves, floods, droughts, and other climatic hazards. We highlight some of the mechanisms by which vulnerability and risk are shaped by the dynamics of urbanization, acting on urban centers as places with unique social and environmental histories, opportunities, and constraints. We close with some remarks on ways forward for reducing risk and enhancing populations' capacity, within and across urban areas, to deal with risk.

4.2 Conceptualizing Urbanization, Urban Vulnerability, and Risk

Before exploring the influence of urbanization and urban areas on risk, we will briefly consider the conceptualizations of "urbanization," "urban," and "risk." Urbanization dynamics and the urban areas they produce are altering forests, open spaces, agricultural lands, wildlife, energy, food, and water resources and, consequently, are altering risks in complex and accelerating ways. These changes not only threaten the quality of life that urban and rural residents have come to expect, but they also offer opportunities for innovative risk mitigation and adaptation options. Urban-regional infrastructure systems that facilitate critical services, such as the delivery of water and energy and the provision of mobility and shelter, have enabled the growth of urban areas, populations, and activities, but have often resulted in detrimental environmental impacts.

4.2.1 Urbanization and the Environment

Determining the impacts caused by urban areas is difficult, as little agreement exists about the definition of urbanization and urban areas (Marcotullio et al. 2014). We define "urbanization" as a series of interconnected development processes or dynamics that shift how humans interact with each other and the environment to create risks (Romero–Lankao et al. 2014b). These processes include:

- Particularly in middle- and low-income countries, an increasing number of people living in urban areas;
- Processes of stabilization and even population shrinkage related to post-industrialization and deindustrialization, particularly in high-income countries;

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- Changes in lifestyles and cultures (living on coasts, for example) that motivate people to live in hazard-prone areas;
- Economic shifts from primary activities, such as agriculture, to manufacturing and services, which compete for access to water, land, and ecosystem services;
- Changes in the patterns of land use of urban areas and associated infrastructure that affect shifts in resource use and hazard risk;
- The ecological and physical transformations implied by these processes.

At the local level, the effects of urbanization can exacerbate the climate changes affecting urban populations. These effects, such as the urban heat island, or UHI, effect, might amplify the outcomes of global climate change (Ntelekos et al. 2010). UHI refers to increased temperatures in urban areas compared to their rural surroundings, driven by human activities and alterations of land surface characteristics and their thermal properties. The UHI effect, which varies across and within cities, often in relation to affluence and urban planning, can increase human health risks differently across the urban-rural gradient (Miao et al. 2009). These variations are mostly due to physical and socioeconomic factors, such as land cover patterns, city size, and the ratio of impervious surfaces to areas covered by vegetation or water (Grimm et al. 2008; Harlan and Ruddell 2011). Also of importance are intra-urban sociospatial inequalities in access to air conditioning and green and open space. Based on these differences, lower socioeconomic and ethnic minority groups are more likely to live in warmer neighborhoods with greater exposure to heat stress and higher vulnerability (Harlan et al. 2007). In summary, urbanization dynamics entails shifts in land use, infrastructure, economic activity, demographic structure, and lifestyle. The patterns of interactions between society and the environment have created differences in risk and vulnerability within and across urban areas.

4.2.2 Urban Areas

Notwithstanding the importance of urban areas, scholars and communities of practice disagree about what defines urban areas. Some define urban areas as a specific form of human association or settlement that can be characterized based on criteria of population size, physical form, and economic function. Others define cities as growth machines that tend elite interests, induce social inequality and injustice, and deteriorate the environment. Yet, others conceive of cities as socioecological systems (or SES) of interacting biophysical and socioeconomic components whose dynamic organization

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and management have many consequences for sustainability and resilience. As such, urban areas shape the level of environmental pressure populations exert on ecosystems and their natural resource base, and shape the vulnerability of urban populations to climatic and environmental hazards. Recent scholarship has pointed to the relevance of urban infrastructure as the sociotechnical system defining the material – and mostly unsustainable – metabolism of city regions (Monstadt 2009; Smith and Stirling 2010; McFarlane and Rutherford 2008). Metabolism refers to the flows of materials and energy through cities and regions (see Chapter 3). Infrastructure is a physical manifestation of metabolism and is deeply embedded in societal and political imaginations of how a city shall function. As infrastructure has become increasingly complex in terms of physical interconnectedness and the institutions and rules that govern it, the mechanisms by which we can significantly transform infrastructure to make it more sustainable have become less clear.

However, while the SES concept is useful, it is too abstract to yield an operational understanding of lower level system urban interactions. Therefore, we suggest a definition of "urban areas" as socioecological systems (Folke et al. 2005; Ostrom et al. 2007), with five dynamic development domains: sociodemographic, economic, technological, ecological, and governance (SETEG) (Arup 2014; Romero-Lankao and Gnatz 2016). These development domains reflect processes of change affecting risk and people's vulnerabilities. The sociodemographic domain includes a set of factors conditioning people's preferences for living in risk-prone areas based on lifestyles (including the aesthetic desirability of location); on social practices of living, commuting, or eating; or on lack of options. The economic domain shapes differences in wealth creation and inequality in access to assets and options (such as insurance) to respond to floods, water scarcity, and other hazards. The technological domain involves knowledge of techniques, processes, and so forth that can be embedded in machines, infrastructures, and the built environment, and can shape risk of environmental impacts, such as those that arise from lack of green areas to mitigate risks from floods and heat waves. Technology also offers options to retrofit or introduce "green" infrastructure or hazard protection measures, or to improve house quality and design in order to keep people protected (see Section 4.3 and Figure 4.1). The ecological domain, defined by such factors as topography, temperature, and precipitation, affects an urban area's endowment of natural resources, ecosystem services, susceptibility to and capacity to mitigate droughts, floods, and heat waves. The governance domain affects patterns of urban growth, land-use regulations, and proactive or reactive risk mitigation and adaptation responses.

Figure 4.1 A flooded house in Mexico City. Floods are major contributors to infrastructure and housing damage among poor populations in cities. Source: Patricia Romero-Lankao et al. 2014a.

4.2.3 Urban Vulnerability and Resilience

Human experience of the environment in terms of risks and threats constitutes a key theoretical foundation of vulnerability research (Blaikie et al. 2014). Studies on urban vulnerability portray it as the degree to which a city, a population, infrastructure, or an economic sector (that is, a system of concern) is susceptible to and unable to cope with and adapt to the adverse effects of hazards or stresses, such as heat waves, storms, and political instability (Field et al. 2012). Urban vulnerability is a relational concept. Besides referring to a system or group sensitivity to heat waves, floods, and other hazards, it is also a relative property defining the capacity of that system or group to adapt to and cope with those hazards.

Vulnerability is a function of exposure, sensitivity, and capacity (Adger 2006; Field et al. 2014). "Exposure" is the presence of populations, infrastructure, or economic, social, or cultural assets in places that could be adversely affected. "Sensitivity" refers to factors, such as age or preexisting medical conditions that determine susceptibility to hazards. "Capacity" is the potential of a population or a system to modify its features and behavior to respond to existing and anticipated hazards. Capacity relates to the unequally distributed pool of resources, assets, and options that governmental, private, and nongovernmental urban actors can draw on to manage environmental risks, while pursuing the lives and development goals they value. In a study of urban heat waves, for example, Wilhelmi and Hayden (2010) adopted this definition and proposed a people- and place-based vulnerability framework. This framework integrates quantitative and qualitative data and focuses on social and behavioral elements of capacity, including social networks, knowledge, attitude, and practices; household resources; and access to existing risk reduction programs.

For the most part, scholarship on urban vulnerability consists primarily of case studies and analyses based on incompatible theories and paradigms that can be grouped in three traditions: "vulnerability as impact" or top-down (the most commonly applied approach); "inherent or contextual vulnerability"; and "urban resilience"(Patricia Romero-Lankao and Qin 2011).

"Vulnerability as impact" scholars conceive population vulnerability as an outcome (for example, a health impact or property damage) from exposure to heat waves, floods, and other hazards (O'Neill 2005). Thanks to this body of research, we have learned that the relationship between people's exposure to extreme temperature and mortality has a *V* or *J* shape, with mortality generally increasing both above and below some temperature threshold. These scholars have also examined the role of specific individual- and city-level characteristics (such as green areas) in modifying the temperature-mortality relationship. Furthermore, through epidemiological studies, we are able to state with some confidence that the elderly and people with preexisting medical conditions are particularly sensitive to extreme heat, and that higher levels of education in a population are associated with decreased risk of mortality. However, by looking at populations at the city level, urban vulnerability as impact studies fail to encompass intra-urban inequalities. For example, they do not examine what specific populations and places are at risk, to what they are vulnerable, and how and why they are differentially affected; whether they possess necessary skills, awareness, and assets to be able to adapt; and how their choices are constrained by the sociodemographic, economic, technological, ecological, and governance domains in which they operate.

The above questions *are* addressed by "inherent or contextual vulnerability" scholars, who examine the influence of historical patterns of sociospatial segregation on differences in populations' capacity to draw on income, education, social networks, and other resources to respond to hazards and to mitigate risk. Earlier approaches, rooted in geography, natural hazards, and livelihoods research, had already pointed out that hazards disproportionately affect poor and marginalized populations and those living in hazard-prone geographic areas (Moser 1998; Burton 1993; Hewitt 1983). Contextual studies shed light on the role of equity and affluence, the two faces of the urban development coin; on the capacity of upper income, privileged populations to live in lower density, greener, and cooler neighborhoods and, hence, to be more able to adapt to extreme heat, floods, and other hazards (Harlan et al. 2007). Structural disadvantages at the neighborhood level, such as concentrated affluence, formality, or commercial vitality, play a fundamental role in health and quality of life outcomes, such as heat wave mortality; fires from illegal connections to the electricity grid; or morbidity associated with exposure to hazardous materials (Hayden et al. 2011; Qin et al. 2015). For example, a study in neighborhoods of Buenos Aires, Argentina; Bogota, Colombia; Mexico City, Mexico; and Santiago, Chile found that low-income and informal neighborhoods are more at risk because they lack high-quality housing and easy access to jobs, and have precarious electrical connections. As stated by informants in Buenos Aires,

> Most of the families are hanging from the electrical network ... and these are bad connections, and the houses are made of wood and are very precarious. We have had several fires. Yes, in those cases we've had evacuees here" (Respondent from the Caritas NGO working in San Fernando, Buenos Aires). (Romero-Lankao et al. 2014a)

More integrative analytical approaches have emerged in recent years. The natural hazards and human ecology approaches to societal vulnerability have been increasingly expanded to include the concepts of complex human-natural system resilience to climate change (Hewitt 1983). Other approaches expanded the concepts of physical and place-based vulnerability to social factors, especially those related to coping and adaptive capacities, institutions, and governance systems (Adger 2006; Turner 2010; Romero-Lankao and Qin 2011). "Urban resilience" offers an example of integrative approaches.

While dozens of definitions of resilience exist, scholars tend to conceive of it as the ability of a system or population to absorb disruptions, persevere, self-organize, learn, and adapt. The notion of capacity is fundamental to connecting the analytic with the normative dimensions of urban resilience. This concept helps us in analyzing the unequally distributed pool of resources, assets, and options that populations and decision-makers can draw on to manage risks, while pursuing the lives and development goals they value. It also helps connect the underlying SETEG domain contexts that give rise to those resources and to explain inequalities in exposure and vulnerability. Urban resilience is related to normative and ethical principles such as the unequally distributed resources that individuals and organizations have (or potentially have) to effectively mitigate and adapt to the hazards and stresses they encounter.

Resilience has one of its two main roots in mathematics, physics, and engineering, where it is defined as the capacity of a system to "bounce back" or return to a steady-state equilibrium after such stressors as floods, political turmoil, or a banking crisis. In the second main root we find an ecological, or "bounce-forward" approach, in which resilience is defined according to how much disturbance an urban community or system can adapt to while remaining within critical thresholds, after which it can move to another regime. In this "safe-to-fail" paradigm, resilience is conceived of as the ability of cities and communities to change, adapt, and, crucially, transform in response to both internal and external hazards and pressures (Davoudi et al. 2012; Gunderson 2001; Ahern 2011).

Cities as diverse as Dhaka, Bangladesh, and Boulder, Colorado, in the United States are such examples of this capacity to bounce forward. After 1991, when a hurricane hit Bangladesh, killing at least 138,000 people and leaving 10 million people homeless, people undertook efforts – promoted by local authorities, the national government, and international organizations – to decrease the risks faced from tropical cyclones. These efforts included the development of an early warning system and the construction of public shelters to host evacuees; Cyclone Sidr, which hit Bangladesh in 2007, subsequently tested these infrastructural developments. Although between 8 and 10 million Bangladeshis were exposed to Sidr – perhaps the strongest cyclone to hit the country since 1991 – there were approximately 32 times fewer deaths (4,234 people lost compared to approximately 138,000), illustrating Bangladesh's capacity to learn and adapt (UN-Habitat 2011).

The unprecedented flood of September 11–18, 2013, in Boulder, Colorado – which killed 10 people, resulted in 18,000 evacuees, and caused the destruction of 688 homes, and damages to an additional 9,900 homes – brought into sight many of the interdependencies between urban risk and resilience (MacClune et al. 2014). Although Boulder was exposed to a flood estimated to be between a 25-year and 100-year magnitude (that is, a flood big enough to occur only once every 25 or 100 years), the city's Greenways Program allowed green areas to mitigate flood damage. Impact damages were also conditioned on historic development pathways and social, political, and economic factors. Apartments impacted by sewage upwelling, for instance, had been below-grade and frequently were occupied by lower-income families and university students. Although Boulder's utility staff was aware of the need to upgrade the sewage drainage system, the cost of such an improvement was prohibitively high. Combined with a fear of potential litigation, these factors led the city to either inaction or minimal action, which increased citywide vulnerability to the floods. Six out of seven key roads that follow creeks up mountain canyons in Boulder failed, leaving affected populations isolated and unable to leave flood-damaged areas. Yet, even amidst the near chaos and extensive damages wrought by the flood, strong preexisting relationships and a culture of cooperation among city and county governmental and nongovernmental actors were key assets that sped up response and enabled effective recovery through learning from previous experiences, such as the Four Mile Fire of 2010.

4.3 A System Approach to Risk

In recent years, scholars and practitioners have focused on the interface of urban areas and risk – how urban populations and actors from the private, public, and social sectors, including the institutions and infrastructure they create, affect the environment – and vice versa, encompassing how environmental impacts feedback and affect the social fabric of a city. To understand the risks and the challenges that cities face in reducing them, we need a system analysis of the interactions between multiple development and environmental domains. Yet, when it comes to understanding risk in cities, there is comparatively less knowledge about the interactions between the different SETEG domains shaping risks.

The concept of risk is characterized by differences in definition and scope (Renn 2008). Risk can be defined, for example, as the probability of occurrence of a hazard, such as a flood or landslide, multiplied by the consequences if the event occurs (Field et al. 2014). We define "urban risk" as the potential for uncertain outcomes, such as economic loss and mortality, where something of value such as lives, livelihoods, or property is at stake. Risk results from the interaction of the vulnerability and exposure of populations, assets, and economic activities to hazards, such as floods and heat waves (Figure 4.2). Urban populations are frequently exposed to multiple hazards. These hazards can be one-offs, extreme events of short duration – such as storms or landslides – often striking with little warning. They can also be slow-onset events (such as century-long increases in urban average temperatures), as well as a range of subtle, everyday threats that are the product of a variety of factors (for example, UHI). Hazards can result from broader drivers, such as climate change and climate variability (including sea-level rise and weather extremes), from regional environmental degradation (mudslides resulting from land-use changes induced by urbanization, for instance), and from broader social changes such as globalization, urbanization, and political turmoil that affect the well-being, wealth, and feasibility of urban populations' livelihoods (Figure 4.2).

While the majority of place-based studies focus on the links between urbanization and hazard exposure, or examine the interactions between exposure and sensitivity, fewer studies explicitly characterize or analyze the capacity of the affected populations to perceive and adapt to hazards (Morss et al. 2005; Hayden et al. 2011; Romero-Lankao et al. 2016). Scholarship suggests that there is a clear value of deepening analysis of capacity, which needs to be complemented by a wider understanding of how adaptive behavior and practices are likely to be socially and institutionally structured, and economically constrained and modified over time (Few 2012).

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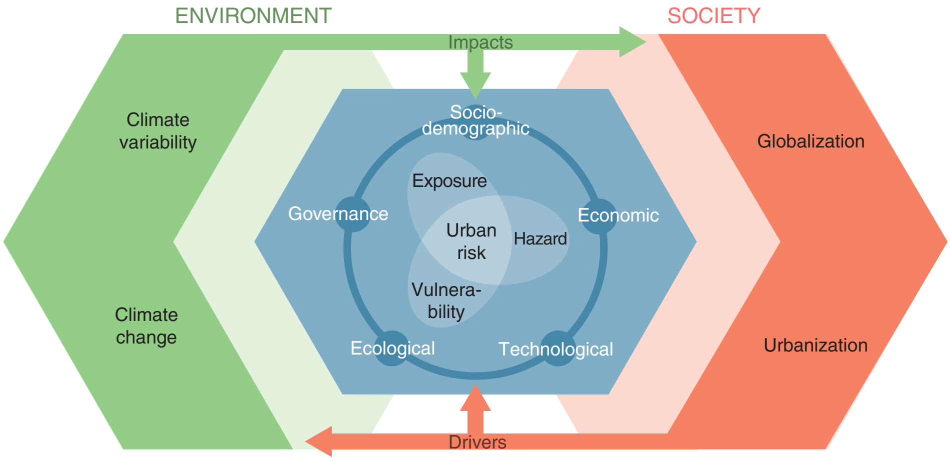

Figure 4.2 Urban risk. This conceptual diagram shows urban risk not only as a result of hazard exposure and vulnerability, but also as shaped by five interacting development domains: sociodemographic, economic, technological, ecological, and governance. These domains operate within a wider context of interactions between environment and society. Source: Romero-Lankao and Gnatz 2016 modified after Field et al. 2012. Design Jerker Lokrantz/Azote.

4.3.1 The Multiple Domains of Urban Risk

Understanding urban risk requires analyzing the complex, context-specific, and nuanced interactions between sociodemographic, economic, technological, ecological, and governance domains shaping hazard, exposure, and vulnerability (Figure 4.2).

Sociodemographic: There is increasing evidence that a population's capacity to mitigate and adapt to risks is not strictly an artifact of its intrinsic individual factors, such as age or preexisting medical conditions. Structural dynamics of the sociodemographic domain, such as the younger or older age population balance of cities, which is related to shifts to service-oriented economies, can make certain populations more sensitive to particular hazards, with the elderly being more sensitive to extreme temperatures. Because women experience unequal access to assets and decision-making processes, and are most often responsible for household needs, women can be more exposed and vulnerable to such hazards as indoor pollution.

Economic: Citywide economic vigor and advantages may enhance the effectiveness of urban safety nets by determining the city's capacity to respond to risks through avenues such as charitable organizations, churches, businesses, social services, and more formal social networks (Browning et al. 2006). Beyond that, in cities around the world, the dynamics of uneven economic growth shapes social inequality, thus influencing all dimensions of risk and urban populations' vulnerabilities. These dynamics create and perpetuate

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the relative differences in vulnerability between poor and wealthy populations. Because of uneven economic development, cities as diverse as Mexico City, Buenos Aires, Santiago, and Mumbai have deficits in key determinants of capacity, such as health services and education, as well as high-quality housing and water and sanitation infrastructure – key elements of the technological domain. However, context-specific differences also exist. For example, access to sanitation in Mumbai is low, with 35 percent of people living in informal settlements having sanitation, and revolves around the use of improved toilet facilities that are not shared with other households. In Latin American cities, access to single-family toilets is relatively higher, and relates more to connection to sewage systems (Chatterjee 2010; Romero-Lankao et al. 2014b and 2016).

Technologic: Particularly in urban contexts, this domain materializes in water, energy, sanitation, and other infrastructure areas that shape availability of and access to resources and services that define populations' capacities to respond. Technology shapes response capacity because infrastructure unequally mitigates or amplifies people's resilience to climatic and non-climatic threats. However, the mechanisms by which infrastructures unequally shape risk are context-specific and result from economic and political processes of investment, which privilege some technologies, sectors, and places over others. For instance, in cities of developing countries, such as Mumbai, the proportion of people with access to reliable electricity tends to be much higher (80.8 percent) than the proportion with access to water (61 percent) (Romero-Lankao et al. 2016). Three reasons explain why, historically, economic compulsions led to a fast expansion of Mumbai's electricity distribution network and not of the water network (Zérah 2008). While public policies facilitated investments in electricity, public investments in water and sanitation suffered from competition with other priorities. Once an electricity grid is constructed, the cost of individual connection is marginal, while the costs of extending connections to the water distribution network and transporting water are high. Hence, in contrast with electricity, the spread of the water network correlates with the spread of formal housing development. Because over half of Mumbai's population lives in informal settlements, its water distribution is also one of its most profound expressions of social inequality and differentiated vulnerability.

Ecological or environmental: This domain refers to the biophysical, climatic, ecological, and hydrological factors (such as topography and precipitation) affecting an area's susceptibility to hazards, such as floods. New insight into how this domain interacts with the technological to affect urban populations' ability to mitigate risk and protect themselves from hazards is emerging, as illustrated by research on extreme heat. A number of studies have shown that having a low income, advanced age, preexisting health conditions, social isolation, linguistic isolation, limited access to healthcare, and working

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outdoors increase an urban population's vulnerability to heat (Harlan et al. 2013; Hondula et al. 2015; O'Neill 2005). Yet, limited but increasing knowledge exists of how ecological and built environmental services can mitigate or exacerbate this vulnerability. Consider two scenarios. In the first, a vulnerable person lives in an older structure of poor heat-protective design (with low-quality insulation and inexpensive doors that absorb a large amount of incoming solar radiation, for example) and has to spend more on electricity to keep their unit running to cool the living space. In the second, the same person lives in a newer structure with modern energy codes and central air conditioning. We could hypothesize that the person in the second scenario is less vulnerable given that their residence offers protective features against the hazard. Similar hypotheses could be developed for tree shading, xeriscaping, material use, and a plethora of other factors related to ecological and built environmental services.

In Phoenix, Arizona, in the United States, we have observed that, over time, households with higher incomes have been able to afford to plant and shade their properties in a way that may reduce their vulnerability to heat (Jenerette et al. 2011). Related questions exist about the built environment. As we have mentioned, air conditioning is a critical protective measure; those without air conditioning, those who are unable to afford to use it; or those who have inefficient air conditioning may be more vulnerable to heat (Fraser et al. 2016). Yet home (private) air conditioning represents only a fraction of the heat refuge space that we experience. We spend a good deal of our day in publicly cooled spaces, whether those be our offices or shopping areas. A comparison between Los Angeles and Phoenix shows that the mixed land uses of Los Angeles, coupled with its gridded roadway network, make obtaining access to publicly cooled spaces easier than in Phoenix (Fraser et al. 2016). Additionally, the thermal characteristics of residential and nonresidential buildings can make air conditioning more costly. Thus, as buildings have gotten newer, their ability to retain cooled air for a longer period has also improved (Nahlik et al. 2016). However, it is possible that affording to live in a newer building requires one to have a relatively high income. As we advance our understanding of vulnerability to climate change, it will become more and more important to understand not only the effects of social, ecological, and technological factors, but – perhaps more importantly – how these factors interact.

Governance: This domain shapes risk inequalities through the legacies of political decisions and policies around urban land-use planning and investments in infrastructures and services; through some of the mechanisms of social exclusion (by class and race, for example); and through decisions made about where to locate energy, water, and other infrastructure networks. In many cities of low- and middle-income countries, growth of both low-income informal housing and higher-income gated communities often occurs in areas that provide ecosystem services (such as wetlands or forests providing flood

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protection and water infiltration) or are prone to storm surges, landslides, and floods. Still, while some forms of growth in risk-prone areas enjoy state sanction, others are criminalized. In these cases, informal status becomes both a source of stigmatization that disempowers populations living in informal neighborhoods *and* a systemic determinant of lack of access to land tenure, high-quality housing, infrastructure, services, and other assets and options to mitigate risks and/or to adapt (Box 4.1) (Roy 2009).

Box 4.1 Informality, risk, and vulnerability

In urban areas of middle- and low-income countries, large sections of the population work within the informal economy or are living in housing that was constructed informally. As such, they face the possibility that governments may forcibly remove them from sites deemed to be vulnerable to risks – and away from their means of livelihood. They may also be moved simply because other actors want the land they occupy for more profitable uses. Informality is a state of regulatory flux, where land ownership, land use and purpose, access to livelihood options, job security, and social security cannot be fixed and mapped according to any prearranged sets of laws, planning instruments, or regulations (Roy 2009; McFarlane 2012). This leads to an ever-shifting relationship between the legal and the illegal, the legitimate and the illegitimate, and the authorized and the unauthorized. Informality can create advantages and disadvantages along lines of sociospatial stratification. For instance, informality becomes the site of considerable state power when some forms of growth in risk-prone areas enjoy state sanction while others are unauthorized and criminalized. Informal status becomes a systemic determinant of lack of access to assets and options to mitigate risks and/or to adapt. Conversely, the regular, legal, or formal status of a source of livelihood, neighborhood, and/or settlement provides security from eviction; formal recognition becomes an incentive to invest in more structural adaptation actions (such as house improvements to effectively prevent fires and respond to floods). Obtaining formal status not only is a requirement for infrastructure and service provision for urban populations, but also helps to prevent stigmatization and disempowerment. Studies of informal settlements in Buenos Aires found that their residents tended to be stigmatized. As suggested by a respondent in Greater Buenos Aires: "There were times that services would not come in the neighborhood because it was considered a red (dangerous, insecure) zone" (Romero-Lankao et al. 2014a: 5). This study documented that similar arguments are frequently offered as reasons not to provide services in Bogota, Colombia; Mexico City, Mexico; Mumbai, India; and Santiago, Chile (Romero-Lankao et al. 2014a).

4.3.2 The Relevance of Scale

Urban risk depends on scale. Hazards and adaptation capacities, and their domains and drivers, vary through time and across households, neighborhoods, and city regions (Figure 4.3). For example, a family with a two-level house may only have enough economic resources to move its belongings to the upper part of the house when faced with a flood (as happens in many coastal cities, such as Mumbai and Buenos Aires). This action, however, is not as effective a long-term response at the city and region levels as the construction of flood protection infrastructure, or the implementation of urban policies that strengthen the asset base of low-income groups, can be.

While we need citywide studies to compare patterns and differences in risk and vulnerability across urban areas, they can obfuscate the importance of understanding how variation in SETEG factors can contribute to people's vulnerability. While we are accustomed to seeing maps of variations in socio-economic conditions, such as income, ecological services and physical infrastructure can also vary significantly across a city. Consider the metropolitan

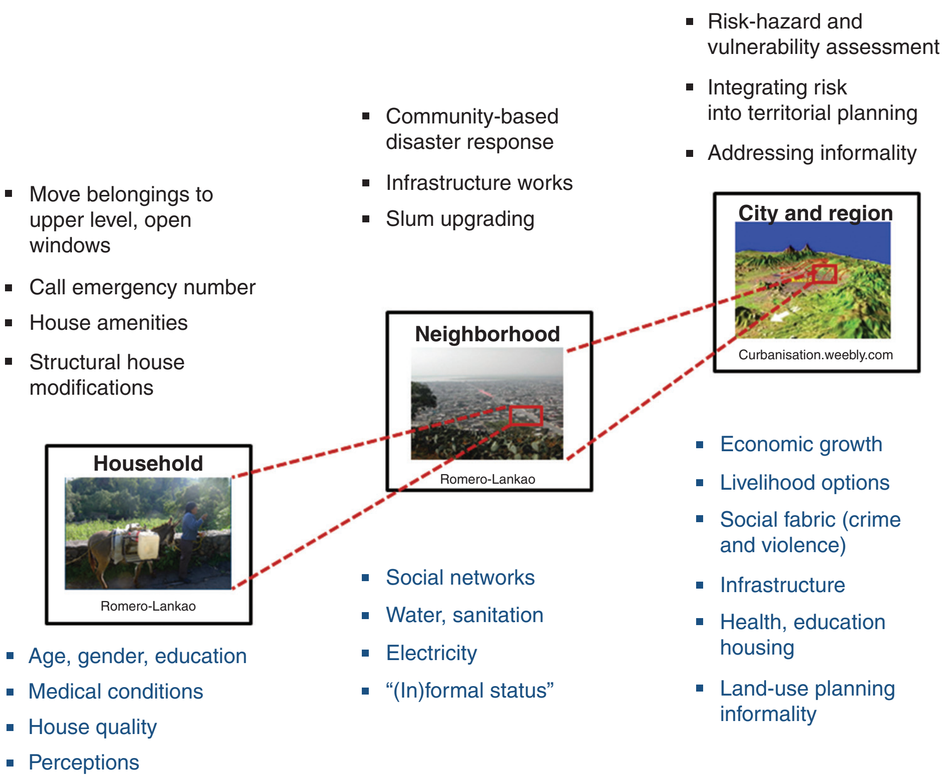

Figure 4.3 Capacity and actual responses vary across scale, that is, across a household, neighborhood, and city region. Source: Romero-Lankao et al. 2014a.

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area of Phoenix, Arizona, where residential structures constructed in the middle of the twentieth century dominate the city's downtown core, while its outlying regions – largely constructed from 1990 onward – use modern energy codes and thermally preferable materials, which protect people from extreme temperatures. These examples highlight the importance of assessing vulnerability at neighborhood scales, where we can capture the largest differences in the underlying SETEG factors.

One of the challenges in understanding urban risk and vulnerability is our ability to assess spatial heterogeneity of social and environmental characteristics in a changing urban landscape. While prior research offers theoretical and methodological conceptualizations of vulnerability in cities, many studies do not explicitly connect vulnerability concepts to actions we can take to reduce vulnerability to weather hazards and to improve overall quality of life. Observing, mapping, and modeling human behavior, social practices, and decision-making in the context of climatic and meteorological hazards are intricate research problems. Whether people take protective measures during a hurricane event such as evacuating, or alter daily routines or go to air conditioned places, to prevent heat-related illnesses, action is influenced by a combination of individual characteristics and capacities, such as risk perception, social capital, and access to resources – which vary across space and over time (Riad et al. 1999).

Determining the differential vulnerabilities and adaptive capacities at a neighborhood to household level is essential to reducing negative outcomes from hazards (Morss et al. 2011). Smit and Wandel (2006: 282) note that "in the climate change field, adaptations can be considered as local or community-based adjustments to deal with changing conditions within the constraints of the broader economic-social political arrangements." This highlights the importance of scale as internal to the system, indicating that what occurs at the household level also affects the community, which is in turn influenced by the citywide and macroscopic forces that shape the ability of individuals to adapt to or cope with challenging conditions. Previous research on extreme heat, for example, emphasizes the variability within cities, especially in terms of differences among households and communities, on adaptive capacity (Uejio et al. 2011; Harlan et al. 2013). At the individual level, factors such as advanced or very young age, preexisting medical conditions, and disability contribute to higher vulnerability, while exposure and capacity vary among neighborhoods. In Indian and Latin American cities, researchers have found that low-income neighborhoods have relatively more precarious working, housing, and living conditions than in middle-income neighborhoods, and inhabitants still rely on neighbors and family to respond to disruptions. Households in higher-income neighborhoods are able to move beyond coping to undertaking structural building modifications to withstand floods and extreme temperatures. However, it is common for a low proportion of households across socioeconomic statuses to have strong social networks on which to fall back to mitigate risks and adapt (Romero-Lankao et al. 2014a; Romero-Lankao et al. 2016).

Vulnerability studies also highlight the importance of sociodemographic factors such as social practices, perceptions, and behavior at an individual or household scale (Hayden et al. 2011; Morss et al. 2005; Qin et al. 2015). Knowledge, attitudes, and practices (KAPs), as well as social capital, household resources, and access to community programs that reduce hazard risk, play important roles in minimizing vulnerability. For example, insofar as it relates to hurricane risk, KAP can substantially influence individual and collective responses, though the literature recognizes gaps in our knowledge about the links between perceptions and actions (Pidgeon and Butler 2009; Pidgeon and Fischhoff 2011). People rely on knowledge, media coverage, local weather patterns, and their perceptions of organizations to create their personal views of reality (Dessai and Sims 2010). Natural hazards research has examined how perception of risk is determined by prior experience, knowledge, proximity to a hazard, and demographic characteristics, (Botzen et al. 2009; Lindell and Hwang 2008), finding that prior experience may either increase *or* decrease perception of risk, depending on local context and other sociobehavioral characteristics (Riad et al. 1999). Studies of evacuation decisions after Hurricanes Hugo and Andrew concluded that a simple warning is often not enough. Instead, individuals and communities require a multifaceted and tailored approach. For example, Hayden et al. (2011) illustrate that extreme heat vulnerability is nuanced and may be offset by information that is not readily captured through demographic data, such as important social ties and reliance on neighbors for help during emergencies. These connections among households at a neighborhood level may provide a degree of protection in the event of a weather hazard.

Work in cities from low- and middle-income countries shows the nuanced ways in which socioeconomic status determines the extent to which urban populations rely on their networks and which sources of information they rely on to respond to extreme events such as floods, storm surges, and heat waves. In Mumbai, for instance, a low percentage of households relies on more formal social networks, such as political organizations). Although wealthier, more resilient households had more frequently participated in social networks as safety nets, more vulnerable household groups were more likely to fall on personal support during extreme emergencies (Romero-Lankao et al. 2016). In Latin American cities, people with higher socioeconomic status were more likely to rely on individual means, such as by searching the Internet for state-supplied hazard information, while people with lower socioeconomic status relied on neighborhood networks and personal knowledge to respond to floods, landslides, and other hazards. These varied results point to the need to understand the importance both of scale (Figure 4.3) and of context-specific combinations of vulnerability attributes at play within and across urban households and neighborhoods.

4.4 Looking Forward: Critical Pathways for Reducing Risk and Vulnerability

Research on urban vulnerability and risk has grown considerably in recent years. Still, it is characterized by differences in conceptualizations and scope. More narrowly focused studies have helped identify many of the numerous parts of the risk puzzle. However, we still lack a cohesive picture of the dynamic whole created by the interaction of these parts. Through the application of more integrated approaches and frameworks, such as the examples in this chapter, scholars and communities of practice working across traditions, disciplines, and framings might be able to create an integrative knowledge that will aid in the design and implementation of more sustainable risk mitigation and adaptation actions and policies.

Decision-makers and stakeholders involved in designing and implementing risk mitigation and adaptation actions need to consider not only the multiple local hazards to which a population is exposed, but also the set of SETEG domains that shape differentiated vulnerabilities and adaptive capacities of populations. These factors arise from household, neighborhood, and citywide processes and from the larger, countrywide social and environmental drivers that may support or undermine the capacity to respond. Both urbanization and climate change are two such large forces; they are simultaneously fueled by local conditions and the imperatives of individual lives and livelihoods, hopes for a better life, and challenges to pursuing that life. In order to understand the whole, we need to pull it apart and look at its hazard exposure, sensitivity, and capacity facets; to understand these parts, we must look back and see the whole. It is only through such iterative approaches that we may hope to understand urban vulnerability and risk.

We must recognize that cities – like people, ecosystems, infrastructure, and governing bodies – are complex. Therefore, the context-specific and dynamic interactions between the urban system SETEG domains leads to emergent behaviors that we still struggle to understand. We must recognize this complexity when developing strategies that reduce climate and environmental change risk. We need to be acknowledged that solutions that target a single system domain are likely to lead to effects in the others, including outcomes that we may not have experienced in the past. In an increasingly urban world with greater hazards ushered in by climate and environmental change, scholars, decision-makers, and communities need to bring together their knowledge systems in search of integrative and socially relevant solutions.

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