Defining urban resilience: A review

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Review

Defining urban resilience: A review

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HIGHLIGHTS

- Bibliometric analysis reveals the influential literature on urban resilience.
- The concept of resilience is beset by six conceptual tensions.
- Urban resilience has been inconsistently defined.
- The paper proposes a new, inclusive definition of urban resilience.
- The paper asks us to consider resilience for whom, what, when, where, and why.

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ABSTRACT

Fostering resilience in the face of environmental, socioeconomic, and political uncertainty and risk has captured the attention of academics and decision makers across disciplines, sectors, and scales. Resilience has become an important goal for cities, particularly in the face of climate change. Urban areas house the majority of the world's population, and, in addition to functioning as nodes of resource consumption and as sites for innovation, have become laboratories for resilience, both in theory and in practice. This paper reviews the scholarly literature on urban resilience and concludes that the term has not been well defined. Existing definitions are inconsistent and underdeveloped with respect to incorporation of crucial concepts found in both resilience theory and urban theory. Based on this literature review, and aided by bibliometric analysis, the paper identifies six conceptual tensions fundamental to urban resilience: (1) definition of 'urban'; (2) understanding of system equilibrium; (3) positive vs. neutral (or negative) conceptualizations of resilience; (4) mechanisms for system change; (5) adaptation versus general adaptability; and (6) timescale of action. To advance this burgeoning field, more conceptual clarity is needed. This paper, therefore, proposes a new definition of urban resilience. This definition takes explicit positions on these tensions, but remains inclusive and flexible enough to enable uptake by, and collaboration among, varying disciplines. The paper concludes with a discussion of how the definition might serve as a boundary object, with the acknowledgement that applying resilience in different contexts requires answering: Resilience for whom and to what? When? Where? And why?

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1. Introduction

In recent years, the popularity of "resilience" has exploded in both academic and policy discourse, with numerous explanations for this dramatic rise (Meerow & Newell, 2015). Above all perhaps, resilience theory provides insights into complex socio-ecological systems and their sustainable management (Folke, 2006; Pickett, Cadenasso, & McGrath, 2013), especially with respect to climate change (Leichenko, 2011; Pierce, Budd, & Lovrich, 2011; Solecki, Leichenko, & O'Brien, 2011; Zimmerman & Faris, 2011). As socio-ecological resilience theory understands systems as constantly changing in nonlinear ways, it is a highly relevant approach for dealing with future climate uncertainties (Rodin, 2014; Tyler & Moench, 2012). As a term, resilience also has a positive societal connotation (McEvoy, Fünfgeld, & Bosomworth, 2013; O'Hare & White, 2013; Shaw & Maythorne, 2012), leading some to suggest that it is preferable to related, but more charged concepts like "vulnerability" (Weichselgartner & Kelman, 2014, p. 10).

In particular, resilience has emerged as an attractive perspective with respect to cities, often theorized as highly complex, adaptive systems (Batty, 2008; Godschalk, 2003). Unprecedented urbanization has transformed the planet from 10 percent urban in 1990 to more than 50 percent urban in just two decades (United Nations Department of Economic and Social Affairs, UNDESA, 2010). Although urban areas (at least 50,000 residents) cover less than 3 percent of the Earth's surface, they are responsible for an estimated 71 percent of global energy-related carbon emissions (International Panel on Climate Change, IPCC, 2014). As cities continue to grow and grapple with uncertainties and challenges like climate change, urban resilience has become an increasingly favored concept (Carmin, Nadkarni, & Rhie, 2012; Leichenko, 2011).

But what exactly is meant by the term 'urban resilience'? The etymological roots of resilience stem from the Latin word *resilio*, meaning "to bounce back" (Klein, Nicholls, & Thomalla, 2003). As an academic concept, its origins and meaning are more ambiguous (Adger, 2000; Friend & Moench, 2013; Lhomme, Serre, Diab, & Laganier, 2013; Pendall, Foster, & Cowell, 2010). Resilience has a conceptual fuzziness that is beneficial in enabling it to function as a "boundary object," a common object or concept that appeals to multiple "social worlds" and can, therefore, foster multidisciplinary scientific collaboration (Star & Griesemer, 1989). The meaning of resilience is malleable, allowing stakeholders to come together around a common terminology without requiring them to necessarily agree on an exact definition (Brand & Jax, 2007). But this vagueness can make resilience difficult to operationalize, or to develop generalizable indicators or metrics for (Gunderson, 2000; Pizzo, 2015; Vale, 2014).

To better understand how the term has been defined and used across disciplines and fields of study, this paper reviews four decades of academic literature on urban resilience beginning in 1973. Guided by bibliometric analysis, the paper identifies the most influential thinkers and publications in this rapidly expanding research area. This review reveals that definitions of urban resilience from this period are underdeveloped in the sense that they have not explicitly addressed important conceptual tensions apparent in the urban resilience literature. Moreover, where papers do discuss these tensions, the authors' positions are often inconsistent. The first five tensions (also evident in the broader resilience literature) are as follows: (1) equilibrium vs. non-equilibrium resilience; (2) positive vs. neutral (or negative) conceptualizations of resilience; (3) mechanism of system change (i.e., persistence, transitional, or transformative); (4) adaptation vs. general adaptability; and (5) timescale of action. The sixth conceptual tension is specific to the urban resilience literature and has to do with how 'urban' is defined and characterized.

Using the resilience concept in urban research and for policy contexts hinges on coming to terms with these tensions. Thus, to advance scholarship and practice, this paper proposes a new definition of urban resilience, one that explicitly includes these six conceptual tensions, yet remains flexible enough to be adopted by a range of disciplines and stakeholders. This definition is as follows:

> *Urban resilience refers to 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.*

In this definition, urban resilience is dynamic and offers multiple pathways to resilience (e.g., persistence, transition, and transformation). It recognizes the importance of temporal scale, and advocates general adaptability rather than specific adaptedness. The urban system is conceptualized as complex and adaptive, and it is composed of socio-ecological and socio-technical networks that extend across multiple spatial scales. Resilience is framed as an explicitly desirable state and, therefore, should be negotiated among those who enact it empirically.

The remainder of this paper focuses on the theoretical rationale for this definition. Section 2 describes the methodology used to conduct the literature review, including the classification of previous definitions of urban resilience. Section 3 analyzes the field's influential literature and expands on the six conceptual tensions. Section 4 parses the specific components of this new definition and the rationale for their selection. The paper concludes with a discussion of how urban resilience as a term can serve as a boundary object, enabling the collaboration necessary to contemplate resilience for whom, for what, for when, for where, and why.

2. Materials and methods

The academic literature on urban resilience was reviewed to (1) identify the most influential studies, (2) trace the theoretical origins and development of the field, (3) compare how urban resilience is defined across studies and disciplines, and (4) develop a refined definition of urban resilience that is grounded in the literature and addresses conceptual tensions.

First, Elsevier's Scopus and Thompson Reuters Web of Science (WoS) citation databases were used to identify the literature on urban resilience over a 41-year period, beginning in 1973 (when Holling wrote his seminal article on resilience) and ending in 2013. Although relatively comprehensive, these databases do not generally include books, and by focusing mainly on English-language publications, they have an Anglo-American bias (Newell & Cousins, 2015). Given the rapid development of the urban resilience field, additional definitions may have been published since the analysis was conducted. The search terms "urban resilience" and "resilient cities" yielded 139 results in Scopus and 100 in WoS. When combined, the urban resilience dataset included 172 unique publications from a variety of disciplines (i.e., articles, book chapters, conference proceedings, reviews, and editorials). "Discipline" in this paper refers to an "organized perspective on phenomena that is sustained by academic training or the disciplining of the mind" (Turner, 2006, p. 183) and "publication" is used to denote a specific academic study (journal article, book chapter, etc.).

Co-citation analysis was then conducted on this urban resilience dataset. Co-citation analysis is a bibliometric method used to quantitatively evaluate academic literature based on the rationale that shared references imply an intellectual relationship (Newell & Cousins, 2015; Noyons, 2001; Small, 1973). Co-citations measure how often two or more studies are cited together within a body of literature, thereby identifying influential publications and scholars in a given research domain and providing insight into a field's intellectual origins.

To assess these co-citations, the bibliometric software Bibexcel (Persson, Danell, & Schneider, 2009) was used. Files generated in Bibexcel were then imported into the open-source software Gephi (Bastian & Heymann, 2009) to visualize and analyze the co-citation network, thereby revealing the "intellectual structure" of the literature (Yu, Davis, & Dijkema, 2013, p. 281). Node size in the network reflects degree centrality (i.e., the more edges that connect to a node, the larger its size) and serves as an indicator of a study's influence.

The 172 studies were then reviewed to determine if they actually defined urban resilience. They were excluded if they (a) failed to define the term or (b) used another scholar's definition. This analysis unveiled 22 distinct definitions. Three additional definitions (Alberti et al., 2003; Brown, Dayal, & Rumbaitis Del Rio, 2012; Tyler & Moench, 2012) were uncovered during the review of the aforementioned articles, leading to a total of 25 definitions of urban resilience. Table 1 lists the 25 major definitions of urban resilience identified in the literature by citation count and their Scopus subject area.

These definitions were then compared and categorized based on their positions with respect to six conceptual tensions that were identified in the urban resilience literature. None of the definitions explicitly addressed all six tensions, so the authors' positions had to be inferred based on a reading of the publication. Although resulting categorizations admittedly represent a simplification of complex concepts and studies, the objective was to provide a general representation of how definitions theorize these tensions. Finally, a new definition of urban resilience and a conceptual schematic of the urban system were developed by drawing on this literature and the reviewed resilience and urban literatures more broadly.

3. Urban resilience research: influential thinkers, definitions, and conceptual tensions

Although the concept has a long history of use in engineering, psychology, and disasters literature (Matyas & Pelling, 2014), ecologist C.S. Holling's seminal paper (1973) on the resilience of ecological systems is often cited as the origin of modern resilience theory (Folke, 2006; Klein et al., 2003; Meerow & Newell, 2015). Holling's study is the largest node in the co-citation network (Fig. 1), confirming its central importance for the urban resilience field. By recognizing ecosystems as dynamic with multiple stable states, Holling's work was a marked departure from the traditional "stability" paradigm of ecology often associated with the work of Clements (1936). Effectively, Holling used resilience to describe the ability of an ecological system to continue functioning—or to "persist"—when changed, but not necessarily to remain the same. This contrasts with "engineering resilience," which focuses on a single state of equilibrium or stability to which a resilient system would revert after a disruption (Holling, 1996).

Non-equilibrium resilience is now paradigmatic in ecology, and Holling's writing on resilience sparked a rich body of work at the socio-ecological interface (Folke, 2006; Wu & Wu, 2013). Within the socio-ecological systems (SES) framework, resilience is often defined as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker, Holling, Carpenter, & Kinzig, 2004, p. 1). This work led to the formation of the Resilience Alliance, an interdisciplinary research network devoted to resilience thinking (Walker & Salt, 2006). Key members of the Resilience Alliance collaborated to develop the panarchy model, essentially a heuristic for understanding how complex systems progress over time through multi-scalar adaptive cycles of destruction and reorganization (Gunderson & Holling, 2002). Thus, the theory was extended from Holling's definition of resilience as a measurable, descriptive concept to "a way of thinking" (Folke, 2006, p. 260). As a result, resilience evolved from a system characteristic, which could be positive or negative, to more of a normative vision (Cote & Nightingale, 2011). The influence of established SES resilience scholars on the urban resilience literature is also evident; some of the most prominent nodes in the co-citation network are Folke (2006), Carpenter, Walker, Anderies, and Abel (2001), and Gunderson and Holling (2002).

However, resilience theory is by no means limited to ecological or SES research. It is increasingly applied across a growing number of fields and focus areas, including natural disasters and risk management (Coaffee, 2008; Cutter et al., 2008; Gaillard, 2010; Rose, 2007); hazards (Godschalk, 2003; Klein et al., 2003; Serre & Barroca, 2013); climate change adaptation (Nelson, Adger, & Brown, 2007; Tanner, Mitchell, Polack, & Guenther, 2009; Tyler & Moench, 2012); international development (Brown & Westaway, 2011; Perrings, 2006); engineering (Fiksel, 2006); energy systems (McLellan, Zhang, Farzaneh, Utama, & Ishihara, 2012; Meerow & Baud, 2012; Molyneaux, Wagner, Froome, & Foster, 2012; Newman, Beatley, & Boyer, 2009); and planning (Ahern, 2011; Davoudi et al., 2012; Wilkinson, 2011), among others.

As evidenced by the co-citation network (Fig. 1), the urban resilience literature spans and draws from diverse research domains. This includes work by urban ecologists (i.e., Grimm, Grove, Pickett, & Redman, 2000; Grimm et al., 2008) and urban theorists more generally (Harvey, 1996; Jacobs, 1961; McHarg, 1969). Also featuring prominently is Adger's (2000) research on social resilience and Cutter, Boruff, and Shirley (2003) on social vulnerability. A predominant topical focus of the literature is coping with disturbances due to climate change (Leichenko, 2011; Wardekker, de Jong, Knoop, & van der Sluijs, 2010) or hazards and disasters (Burby, Deyle, Godschalk, & Olshansky, 2000; Campanella, 2006; Godschalk, 2003; Pelling, 2003).

3.1. Existing definitions of urban resilience

As noted earlier, our review identified 25 definitions of urban resilience in the literature (Table 1). A reading of these definitions and the publications in which they appear confirms that urban resilience is a contested concept and lacks clarity due to inconsistencies and ambiguity. Given the challenges associated with defining and characterizing "urban" and "resilience" individually, and the numerous disciplines engaged in this field of study (Da Silva, Kernaghan, & Luque, 2012), it is not surprising that multiple definitions and conceptual tensions persist. What is surprising is just how few definitions of urban resilience explicitly address these tensions. In some cases an author's perspective on a particular tension can be inferred from the discussion, but, in many instances, it is unclear. These conceptual inconsistencies make it difficult to apply or test the theory empirically, although some specific resilience metrics and indices have been suggested (i.e., Cutter,

Table 1
Definitions of urban resilience.

	Author (year)	Subject area	Citation count	Definition
1	Alberti et al. (2003)	Agricultural and biological sciences; environmental science	212	"... the degree to which cities tolerate alteration before reorganizing around a new set of structures and processes" (p. 1170).
2	Godschalk (2003)	Engineering	113	"... a sustainable network of physical systems and human communities" (p. 137).
3	Pickett et al. (2004)	Agricultural and biological sciences; environmental science	101	"... the ability of a system to adjust in the face of changing conditions" (p. 373).
4	Ernstson et al. (2010)	Environmental science; social sciences	46	"To sustain a certain dynamic regime, urban governance also needs to build transformative capacity to face uncertainty and change" (p. 533).
5	Campanella (2006)	Social sciences	44	"... the capacity of a city to rebound from destruction" (p. 141).
6	Wardekker et al. (2010)	Business management and accounting; psychology	30	"... a system that can tolerate disturbances (events and trends) through characteristics or measures that limit their impacts, by reducing or counteracting the damage and disruption, and allow the system to respond, recover, and adapt quickly to such disturbances" (p. 988).
7	Ahern (2011)	Environmental science	24	"... the capacity of systems to reorganize and recover from change and disturbance without changing to other states ... systems that are "safe to fail" (p. 341).
8	Leichenko (2011)	Environmental science; social sciences	20	"... the ability ... to withstand a wide array of shocks and stresses" (p. 164).
9	Tyler and Moench (2012)	Environmental science; social sciences	11	"... encourages practitioners to consider innovation and change to aid recovery from stresses and shocks that may or may not be predictable" (p. 312).
10	Liao (2012)	Environmental science	6	"... the capacity of the city to tolerate flooding and to reorganize should physical damage and socioeconomic disruption occur, so as to prevent deaths and injuries and maintain current socioeconomic identity" (p. 5).
11	Brown et al. (2012)	Environmental science; social sciences	5	"... the capacity ... to dynamically and effectively respond to shifting climate circumstances while continuing to function at an acceptable level. This definition includes the ability to resist or withstand impacts, as well as the ability to recover and re-organize in order to establish the necessary functionality to prevent catastrophic failure at a minimum and the ability to thrive at best" (p. 534).
12	Lamond and Proverbs (2009)	Engineering	5	"... encompasses the idea that towns and cities should be able to recover quickly from major and minor disasters" (p. 63).
13	Lhomme et al. (2013)	Earth and planetary sciences	4	"... the ability of a city to absorb disturbance and recover its functions after a disturbance" (p. 222).
14	Wamsler et al. (2013)	Business management and accounting; energy; engineering; environmental science	3	"A disaster resilient city can be understood as a city that has managed... to: (a) reduce or avoid current and future hazards; (b) reduce current and future susceptibility to hazards; (c) establish functioning mechanisms and structures for disaster response; and (d) establish functioning mechanisms and structures for disaster recovery" (p. 71).
15	Chelleri (2012)	Earth and planetary sciences; social sciences	2	"... should be framed within the resilience (system persistence), transition (system incremental change) and transformation (system reconfiguration) views" (p. 287).
16	Hamilton (2009)	Engineering; social sciences	2	"ability to recover and continue to provide their main functions of living, commerce, industry, government and social gathering in the face of calamities and other hazards" (p. 109)
17	Brugmann (2012)	Environmental science; social sciences	1	"the ability of an urban asset, location and/or system to provide predictable performance – benefits and utility and associated rents and other cash flows – under a wide range of circumstances" (p. 217).
18	Coaffee (2013)	Social sciences	1	"... the capacity to withstand and rebound from disruptive challenges ..." (p. 323).
19	Desouza and Flanery (2013)	Business management and accounting; social sciences	1	"ability to absorb, adapt and respond to changes in urban systems" (p. 89).
20	Lu and Stead (2013)	Business management and accounting; social sciences	1	"... the ability of a city to absorb disturbance while maintaining its functions and structures" (p. 200).
21	Romero-Lankao and Gnatz (2013)	Environmental science; social sciences	1	"... a capacity of urban populations and systems to endure a wide array of hazards and stresses" (p. 358).
22	Asprone and Latora (2013)	Engineering	0	"... capacity to adapt or respond to unusual often radically destructive events" (p. 4069).
23	Henstra (2012)	Social sciences	0	"A climate-resilient city ... has the capacity to withstand climate change stresses, to respond effectively to climate-related hazards, and to recover quickly from residual negative impacts" (p. 178).
24	Thornbush et al. (2013)	Energy; engineering; social sciences	0	"... a general quality of the city's social, economic, and natural systems to be sufficiently future-proof" (p. 2).
25	Wagner and Breil (2013)	Agricultural and biological sciences	0	"... the general capacity and ability of a community to withstand stress, survive, adapt and bounce back from a crisis or disaster and rapidly move on" (p. 114).

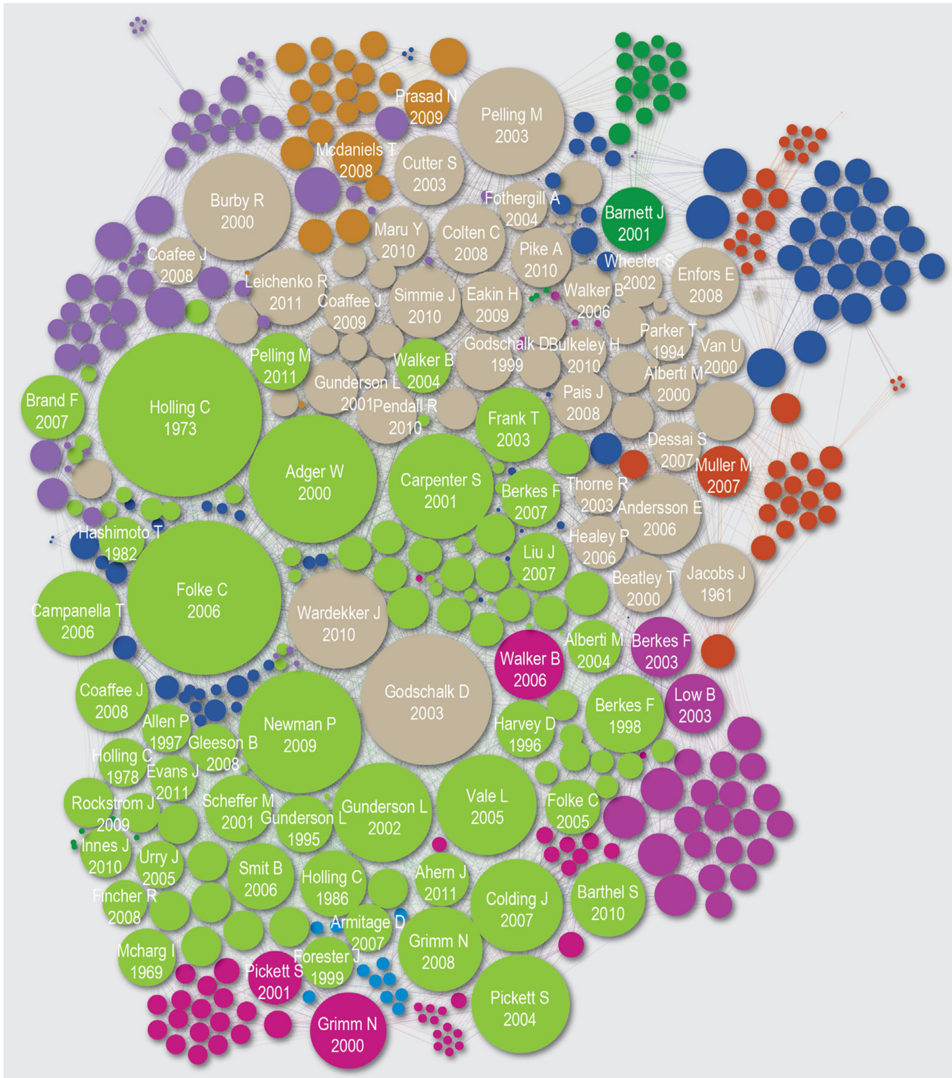

Fig. 1. Influential publications in the urban resilience literature: this figure illustrates the co-citation network for the compiled WoS dataset on urban resilience. The nodes or circles represent specific references cited, while edges (connecting lines) signify that two references are cited together. Nodal size reflects the number of connections a reference has in the network (degree centrality). Colors represent communities of more closely related publications. Nodes with degree values >45 are labeled with the lead author's last name, first initial, and year of publication. The figure used the Force Atlas algorithm for the layout, where more clustering indicates a closer relationship. (For interpretation of the references to color in this legend, the reader is referred to the web version of the article.)

Burton, & Emrich, 2010; Orencio & Fujii, 2013). As Klein et al. (2003, p. 42) rather pessimistically argue, "The problem with resilience is the multitude of different definitions and turning any of them into operational tools. . . After thirty years of academic analysis and debate, the definition of resilience has become so broad as to render it almost meaningless."

To briefly summarize the scope of the challenge, roughly half of the definitions are presented in the context of a specific threat (e.g., climate change or flooding), while the other half focus on the resilience of an urban system to respond to all risks. Definitions uniformly portray urban resilience as a desirable goal, a stance problematized by research that questions who benefits and who loses under resilience regimes. Fifteen definitions adopt non- or multi-equilibrium resilience, with 10 focusing on static resilience. More than half emphasize high levels of general adaptive capacity as opposed to adaptedness. But only 11 include a mechanism for changing from an undesirable state, and even fewer mention a timescale for action, post-disturbance. A majority of definitions fail to take a clear position on at least one of the six conceptual tensions. Fig. 2 summarizes how these six conceptual tensions are understood in the 25 publications that defined urban resilience. In the next section we analyze these conceptual tensions in detail.

3.2. Characterization of "urban"

To clearly define urban resilience, it is necessary to first specify what is meant by 'urban.' This can vary widely depending upon the discipline or theoretical construct through which it is viewed (Da Silva et al., 2012; Godschalk, 2003; Jabareen, 2013; Salat & Bourdic, 2011). Unfortunately, most definitions of urban resilience are rather vague with respect to what constitutes an urban area or city (i.e., Campanella, 2006; Lu & Stead, 2013). Seventeen of the 25 studies do acknowledge that urban areas are complex, with a number of these referring to cities as "complex systems" (Brugmann, 2012; Cruz, Costa, de Sousa, & Pinho, 2013; Da Silva et al., 2012; Lhomme et al., 2013). Furthermore, 14 out of 25 publications theorize urban systems as being composed of "networks." Still others refer to cities as comprised of both systems and networks. Desouza and Flanery (2013, p. 91), for example, understand "cities as networked complex systems." Godschalk (2003, p. 141)

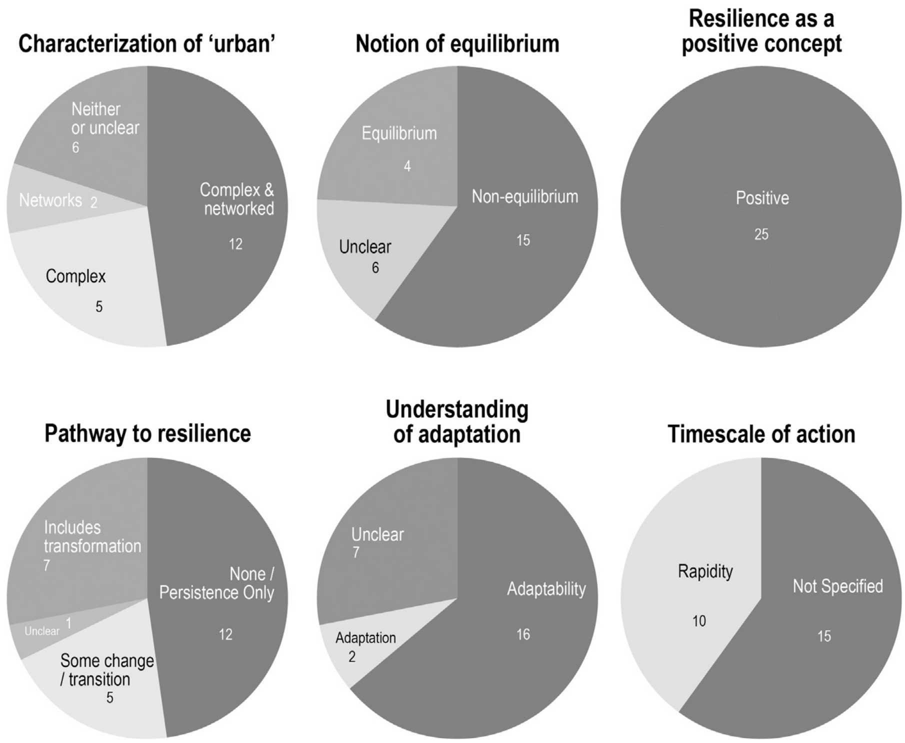

Fig. 2. Six conceptual tensions in definitions of urban resilience.

characterizes cities as "complex and dynamic metasystems" composed of "dynamic linkages of physical and social networks."

Urban systems indeed represent a conglomeration of ecological, social, and technical components; however, the terminology and focus varies across the literature. In urban ecology scholarship, for example, cities are often places where human and natural patterns and processes interact, evolving to form an "urban ecosystem" or an SES (Alberti et al., 2003; Pickett et al., 2013; Resilience Alliance, 2007). In urban and sustainability transitions literature, the connections between social and technical system interactions are emphasized, often using the term "socio-technical networks" (Graham & Marvin, 2001; Guy, Marvin, & Moss, 2001; Romero-Lankao & Gnatz, 2013). SES scholarship, however, rarely considers the dynamics of technological change in much detail (Smith & Stirling, 2010). This is problematic given socio-technical networks often profoundly affect the resilience of the SES's within which they are embedded. Consequently, some scholars like Ernstson et al. (2010) call for cities to be framed as complex socio-ecological systems composed of networks that are *both* socio-ecological and socio-technical.

The spatial and temporal scale considered also fundamentally shapes how urban resilience is characterized and, in this respect, the urban resilience literature is also inconsistent (Alberti et al., 2003; Brown et al., 2012; Desouza & Flanery, 2013; Ernstson et al., 2010). Globalization processes have intertwined cities with distant places and spaces through system interactions that include the exchange of materials, water, energy, capital (of many forms), and the like (Armitage & Johnson, 2006; Elmqvist, Barnett, & Wilkinson, 2014). City and 'hinterland' are highly interdependent, making clear delineation of urban boundaries problematic. Some urban resilience scholars recognize the multi-scalar dimensions of these social, ecological, and technical systems by illustrating how they extend beyond the boundary of the city proper (Desouza & Flanery, 2013; Elmqvist, 2014; Ernstson et al., 2010). However, many do not. Inconsistencies in how the various definitions address temporal scale are considered in Section 3.6 (timescale of action).

3.3. *Notions of equilibrium*

In the resilience literature, a divide exists between single-state equilibrium, multiple-state equilibrium, and dynamic non-equilibrium (Davoudi et al., 2012; Folke, 2006; Holling, 1996). Single-state equilibrium refers to the capacity of a system to revert to a previous equilibrium post-disturbance (Holling, 1996). Often identified as "engineering resilience," single-state equilibrium is also prevalent in the fields of disaster management, psychology, and economics (Pendall et al., 2010). Multiple-state equilibrium resilience (also known as "ecological resilience") posits that systems have different stable states and, in the face of a disturbance, may be transformed by tipping from one stability domain to another (Holling, 1996). In recent years, the concept of equilibrium has been challenged by notions of dynamic non-equilibrium, which suggests that systems undergo constant change and have no stable state (Pickett, Cadenasso, & Grove, 2004). This development has moved theory away from the idea of resilience as "bouncing back" (Matyas & Pelling, 2014, p. 54).

Urban resilience scholarship is also trending slightly more toward multi- or non-equilibrium conceptualizations of resilience (15 of the 25 definitions adopt such a position). For example, Ahern (2011, p. 341) maintains that resilient urban systems are "safe-to-fail" as opposed to "fail-safe," reflecting a non-equilibrium perspective. Similarly, for communities at risk from natural hazards, Liao (2012, p. 3) claims engineering resilience is an "outdated equilibrium paradigm." Alberti et al. (2003, p. 1170) point to a "newer non-equilibrium paradigm," stressing that "inherently unstable equilibria" exist "between the endpoints of the urban gradient." Other definitions do not take an explicit stance, but nonetheless acknowledge that cities are constantly changing (Desouza & Flanery, 2013) and may not return to a prior state (Lhomme et al., 2013; Lu & Stead, 2013). Nevertheless, some definitions suggest that recovering a previous equilibrium may be possible. For example, Campanella (2006, p. 141) focuses on a city's ability to "rebuild" and "recover" and Wagner and

Breil's (2013, p. 114) definition stresses the capacity to "bounce back."

3.4. Resilience as a positive concept

The definitions analyzed uniformly embrace resilience as a desirable attribute. As Leichenko (2011, p. 166) writes, the "idea that resilience is a positive trait that contributes to sustainability is widely accepted." Brown et al.'s (2012, p. 534) definition is the most explicitly positive: urban resilience as the ability not only to maintain basic functions but also to improve and prosper.

There is an emerging debate, however, about whether resilience is always a positive concept (Cote & Nightingale, 2011; Nelson et al., 2007), or even whether it should be conceptualized as such (Elmqvist, 2014; Elmqvist et al., 2014). In more equilibrium-focused definitions, urban resilience is understood to mean the ability to return to a "normal" or steady state after a disturbance (i.e., Campanella, 2006; Coaffee, 2013; Lhomme et al., 2013). But what if the original state is undesirable? Certain conditions (e.g., poverty, dictatorships, fossil fuel dependence) can be highly undesirable yet quite resilient (Gunderson & Holling, 2002; Scheffer, Carpenter, Foley, Folke, & Walker, 2001; Wu & Wu, 2013). Determining what is or is not a desirable state requires normative judgments (Brown, 2013; Cote & Nightingale, 2011; Liao, 2012; Weichselgartner & Kelman, 2014). Not all stakeholders will benefit equally from resilience-based actions, and the concept may be used to promote a neoliberal agenda or retain systemic inequality (Friend & Moench, 2013; Joseph, 2013; MacKinnon & Derickson, 2012). Thus, social theorists are asking "resilience for whom?" and of "what to what?" (Davoudi et al., 2012; Vale, 2014) Power inequalities can also determine whose resilience agenda is prioritized (Cote & Nightingale, 2011). Despite these tenable insights, just a small minority of the urban resilience literature explicitly acknowledges the socially constructed and contested nature of resilience (Brown et al., 2012; Liao, 2012; Romero-Lankao & Gnatz, 2013; Tyler & Moench, 2012).

3.5. Pathways to urban resilience

The literature indicates three mechanisms or pathways to a resilient state: persistence, transition, and transformation (Chelleri, Waters, Olazabal, & Minucci, 2015; Chelleri & Olazabal, 2012; Elmqvist, 2014; Matyas & Pelling, 2014). Persistence reflects the engineering principle that systems should resist disturbance (i.e., buildings being robust to storm impacts) and try to maintain the status quo (Chelleri, 2012). While retaining function is an important component of most definitions, many definitions also refer to the ability to incrementally adapt (transition) or more radically transform (Brown et al., 2012; Folke et al., 2002; Romero-Lankao & Gnatz, 2013). In particular, when a system is in a robustly undesirable state, efforts to build resilience might seek to purposefully and fundamentally change its structures (Folke, 2006; Jerneck & Olsson, 2008).

Urban resilience definitions focus largely on persistence, with more than half (13 out of 25) omitting a mechanism for change. Seven include transformation, five mention adapting or incremental change, and one does not take an explicit position. Only Chelleri's (2012) definition explicitly identifies resilience as consisting of all three (persistence, transition, and transformation). However, Brown et al. (2012, p. 534) suggest that transition falls somewhere in between, as resilience is "a spectrum from avoidance of breakdown to a state where transformational change is possible." Similarly, Wamsler, Brink, and Rivera (2013, p. 71) recognize that actions to forge a resilient city can be both "incremental and transformational." Several definitions include or acknowledge the need to adapt (Desouza & Flanery, 2013; Godschalk, 2003; Wardekker et al., 2010). However, this literature differs in its conceptualization and emphasis on transition versus transformation as the ideal mechanism of change. Some focus specifically on incremental changes or transition (Ernstson et al., 2010; Liao, 2012; Pickett et al., 2004), while others argue for transformation (Brown et al., 2012; Liao, 2012; Romero-Lankao & Gnatz, 2013; Thornbush, Golubchikov, & Bouzarovski, 2013; Wamsler, Brink, & Rivera, 2013). How "transition" is defined also differs, with some viewing it as closely aligned with incrementalism (Chelleri, 2012) and others with transformation (Ernstson et al., 2010).

3.6. Understanding of adaptation

The fourth conceptual tension relates to the distinctions between specific adaptations (i.e., high adaptedness) to known threats and more generic adaptability (Cutter et al., 2008; Elmqvist, 2014; Nelson et al., 2007; Pelling & Manuel-Navarrete, 2011). This is what Miller et al. (2010, p. 3) refer to as "specified" versus "general" resilience. It is argued that focusing too much on specified resilience undermines system flexibility, diversity, and ability to respond to inevitable unexpected threats (Wu & Wu, 2013). Cutter et al. (2008) use the terms "inherent" versus "adaptive," stating specifically that inherent qualities are better under normal conditions and adaptive qualities during disasters. Furthering this point, Pike, Dawley, and Tomaney (2010) highlight the distinction and potential tension between short-term adaptation—which means becoming highly specialized—and longer-term adaptability, as well as how this may explain differences in economic resilience between places.

SES scholars tend to view adaptability as synonymous with adaptive capacity, or flexibility necessary for confronting unexpected hazards (Carpenter & Brock, 2008; Folke et al., 2002; Pelling & Manuel-Navarrete, 2011; Zurlini, Petrosillo, Jones, & Zaccarelli, 2012). While leading SES scholars Walker and Salt (2006, p. 121) do not contrast adaptability or adaptive capacity and adaptedness, they do emphasize the importance of maintaining "general" resilience to unforeseen threats in addition to "specified" resilience to known risks.

This tension is also apparent in the urban resilience literature. More than half of the definitions stress generic adaptability, flexibility, or adaptive capacity (Ahern, 2011; Brugmann, 2012; Chelleri, 2012; Coaffee, 2013; Desouza & Flanery, 2013; Godschalk, 2003; Leichenko, 2011; Liao, 2012; Lu & Stead, 2013; Pickett et al., 2004; Romero-Lankao & Gnatz, 2013; Schmitt, Harbo, Diş, & Henriksson, 2013; Tyler & Moench, 2012; Wardekker et al., 2010). One definition explicitly mentions both as being critical (Wamsler et al., 2013), and seven definitions take no clear position (e.g., Alberti et al., 2003; Campanella, 2006). Just one emphasizes adaptations based specifically on disaster risks (Lamond & Proverbs, 2009). Scholars focusing on resilience to climate change align with Brown et al. (2012) in arguing that urban resilience should focus on adaptive capacity rather than specific adaptations.

3.7. Timescale of action

With respect to timescale of action, some definitions view rapidity of recovery as an essential characteristic. Temporal emphasis is often contingent on whether the focus is on rapid-onset disasters or more gradual climactic change (Wardekker et al., 2010). Just 10 definitions mention timescale at all, and these come from the literature on disasters (Asprone & Latora, 2013; Lamond & Proverbs, 2009; Wamsler et al., 2013), climate change (Henstra, 2012; Leichenko, 2011; Tyler & Moench, 2012; Wardekker et al., 2010), and natural hazards (Lhomme et al., 2013; Liao, 2012; Wagner & Breil, 2013). All acknowledge the importance of rapid recovery post-disturbance. As an example,

Table 2
Addressing conceptual tensions in urban resilience.

Conceptual tensions	Our position
Conceptualization of "urban"	Complex, multi-scalar systems composed of socio-ecological and socio-technical networks that encompass governance, material and energy flows, infrastructure and form, and social-economic dynamics.
Notion of equilibrium	Non-equilibrium with a focus or the ability to retain key desirable functions.
Resilience as a positive concept	A contested, normative vision that cities strive to attain.
Pathway to resilience	Different degrees of change may be required; this can be seen as a continuum from persistence to transformation.
Understanding of adaptation	Should not become highly adapted to current conditions at the expense of general adaptive capacity.
Timescale of action	The speed of recovery or transformation after a disturbance is critical.

Wagner and Breil (2013, p. 114) include the capacity to "rapidly move on," noting that "the time required to return to a previous stable state after a disturbance" can be used to measure resilience. But in these definitions, what 'rapid' denotes exactly (e.g., hours, weeks, years) is unclear. In contrast, other definitions make no mention of the speed of recovery. Emphasis in these definitions is placed on returning to a pre-disturbance level (or better) of function and structure, but the time necessary to do so is not specified.

3.8. An integrative definition of urban resilience

Given the inconsistencies in the literature, a definition of urban resilience needs to incorporate these conceptual tensions (or at least take an explicit position on them) and do so in a flexible and inclusive way so as to allow different perspectives and emphases to remain and flourish. With this in mind, we propose urban resilience be defined as the following:

> *Urban resilience refers to 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.*

This definition is carefully worded to articulate a position on each of the six conceptual tensions (Table 2). Urban resilience operates in non-equilibrium, is viewed as a desirable state, recognizes multiple change pathways (persistence, transition, and transformation) and emphasizes the importance of adaptive capacity and timescales. This section elaborates on this definition by parsing its major components, beginning with an explanation of what is meant by the urban system and then addressing the five remaining conceptual tensions in turn.

'Urban systems' are conceptualized as complex, adaptive, emergent ecosystems composed of four subsystems—governance networks, networked material and energy flows, urban infrastructure and form, and socioeconomic dynamics—that themselves are multi-scalar, networked, and often strongly coupled. A simplified schematic of the urban system (Fig. 3) provides the reader with a picture of these systems, drawing on other conceptual diagrams, including the global economy by geographer Dicken (2011), urban metabolism by industrial ecologist Kennedy, Cuddihy, and Engel-yan (2007), urban ecosystems by urban ecologists Alberti et al. (2003), and urban resilience research themes by the Resilience Alliance (2007). For example, the latter identifies the four major subsystems of the urban system as being composed of "governance networks," "metabolic flows," the "built environment," and "social dynamics."

In this schematic (Fig. 3), governance networks refer to the diverse range of actors and institutions whose decisions shape urban systems. This includes the levels of government (denoted by "states"), nongovernmental organizations (NGOs), and businesses

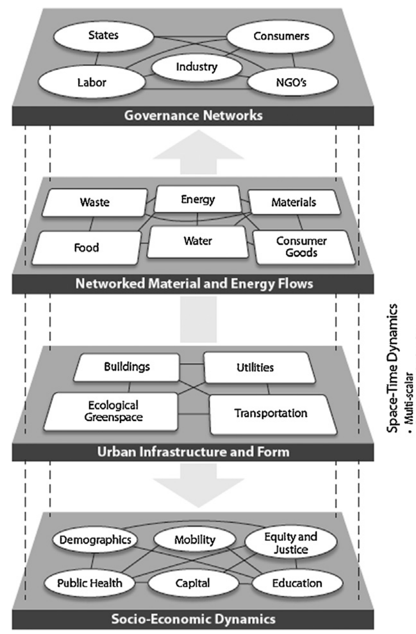

Fig. 3. A simplified conceptual schematic of the urban 'system'. *Note*: Schematic design inspired by Dicken (2011).

(industry). Networked material and energy flows refer to the myriad materials that are produced or consumed in or by an urban system, such as water, energy, food, and waste flows, often collectively referred to as the "urban metabolism" (Kennedy et al., 2007). Urban infrastructure and form encompass the built environment such as buildings, transportation networks, energy, and water grids (utilities), along with urban green space and parks (Wolch, Byrne, & Newell, 2014). Categorizing urban ecological structure and function as such is obviously a simplification of the biological and ecological processes underway in urban areas. Finally, socio-economic dynamics such as monetary capital, demographics, and justice and equity shape the other subsystems and the livelihoods and capacities of urban citizens (Resilience Alliance, 2007).

This schematic emphasizes the interconnections both within and between the four complex and adaptive sub-systems, which interact at multiple spatial and temporal scales. For a comprehensive assessment of urban resilience, these subsystems and their elements need to be considered. To capture system interdependence across spatial and temporal scales, urban systems must be conceptualized as entities embedded in broader "networks" of global resources, commodities, communication, and multilevel governance. These networks are essential to their functioning (Hodson & Marvin, 2010; Seitzinger et al., 2012). As Desouza and Flanery (2013, p. 98) write of resilient cities, "Both physical and social processes can be understood as spatial and temporal interactions across networks, and it is the flow into, out of, and within cities which is of paramount concern for enhancing beneficial operations and suppressing harmful ones. People, activities, institutions, resources, and processes interact in emergent patterns." In essence, Fig. 3 provides a heuristic for thinking through these complex urban structures and dynamics.

The complex and dynamic character of urban systems makes a post-disturbance return to a previous state highly improbable (Barata-Salgueiro & Erkip, 2014; Klein et al., 2003). Climate change and urbanization will likely exacerbate the already unstable nature of cities. Thus, this definition conceptualizes urban resilience as operating in a state of non-equilibrium, whereby resilience reflects a system's capacity to maintain key functions, but not necessarily to return to a prior state. Second, resilience is posited as a normative vision or "agenda" that cities should strive for (Weichselgartner & Kelman, 2014, p. 2). However, as will be discussed in Section 4, defining this vision should be a highly contested, political, and participatory process.

Building resilient urban systems requires different degrees of alteration, thus "transitional," "incremental," or "transformational" changes may all be relevant (Chelleri et al., 2015; Pearson & Pearson, 2014). In the definition, the phrasing "to maintain … desired functions," "to adapt," and "to transform" denotes a continuum of actions, from resistance to change (i.e., persistence) to radical transformation. All are potentially relevant for a particular urban area. Persistence may be desirable for certain components (e.g., a building remaining intact through a storm), while for others incremental transition or transformation may be necessary. Efforts to build resilience should focus on transforming systems that are inequitable (e.g., poverty traps) or hinder individuals or communities from developing adaptive capacity.

Given the uncertainties and risks cities face—from climate change to the instability of financial markets—building resilience hinges on general flexibility and adaptability (denoted by "adaptive capacity" in the definition), rather than becoming highly adapted to specific threats. To borrow an illustration from Chelleri and Olazabal (2012, p. 70), developing an electricity system based entirely on wind might be a positive adaptation to immediate energy and climate concerns, but a more diverse and flexible energy portfolio would enhance adaptability to future changes.

A critical feature of a resilient city is the speed of action and recovery. It is obviously preferable to rapidly reestablish critical functions following a disturbance than to experience long delays. The speed in which telecommunication and energy systems recover post-disaster, for example, directly affects the degree, breadth, and duration of impacts experienced. This definition does not necessarily posit, however, that a return to a pre-disaster state of operations is always desirable. As cities regularly operate in a state of non-equilibrium, speed of recovery encompasses both a rapid return to a pre-disaster state and a rapid evolution to a new state of operations.

4. Conclusion

We are experiencing a "resilience renaissance" (Bahadur, Ibrahim, & Tanner, 2010). In particular, there is a growing emphasis on enhancing the resilience of cities in the face of unprecedented urbanization and climate change. A diverse group of academics and practitioners have adopted the term urban resilience. As demonstrated by literature review and bibliometric analysis, however, definitions of urban resilience are contradictory and beset by six conceptual tensions. To foster resilience in urban settings and to encourage collaboration among and between researchers and stakeholders, this paper has introduced a new definition of urban resilience. This definition balances the need to clarify theoretical inconsistencies while retaining requisite flexibility.

Although the primary purpose has been to review the literature on urban resilience and to provide an inclusive definition for it, we conclude this paper by offering two final points. First, building on the work of Brand and Jax (2007) and others, urban resilience serves an important function as a boundary object, and this can be facilitated by the proposed definition and conceptual schematic of the urban system (Fig. 3). The meaning of a boundary object is "malleable," allowing it to be adapted by diverse disciplines and stakeholders (Brand & Jax, 2007, p. 1). This is especially important for work on cities, which are complex systems and therefore require the expertise of multiple disciplines and stakeholders. As Vale (2014, p. 198) argues, "The biggest upside to resilience is the opportunity to turn its flexibility to full advantage by taking seriously the actual interconnections among various domains that have embraced the same terminology." Other scholars have previously identified the potential for resilience to function in this way (Beichler, Hasibovic, Davidse, & Deppisch, 2014; Brand & Jax, 2007; Coaffee, 2008).

Second, enacting urban resilience is inevitably a contested process in which diverse stakeholders are involved and their motivations, power dynamics, and trade-offs play out across spatial and temporal scales. Therefore, *resilience for whom, what, when, where, and why* needs to be carefully considered. These 'five Ws of urban resilience' extend work by scholars who stress the importance of asking resilience 'for whom and of what to what?' (Brown, 2013; Carpenter et al., 2001; Elmqvist, 2014; Vale, 2014). Fig. 4 provides an initial list of such questions to be contemplated in the process of understanding resilience in specific urban areas.

To conclude, briefly consider the 5 Ws in relation to the definition proposed. In this definition, resilience is recognized as a desirable state, but who determines what is 'desirable' and for whom? Urban resilience is shaped by who defines the agenda, whose resilience is being prioritized, and who benefits or loses as a result. We have argued in favor of building general adaptive capacity over adapting to specific threats, but priority areas, sectors, and hazards will undoubtedly differ from city to city. Contextual factors also shape the temporal and spatial scales at which urban resilience is applied (Chelleri et al., 2015). Thinking through 'resilience for when' entails deciding whether the focus is on short-term disruptions (i.e., storms) or long-term stressors (i.e., climate change) and translating the phrases "rapidly return" or "quickly transform" in the definition to a particular setting. Similarly, 'resilience for where' refers to the challenge of delineating spatial boundaries for an urban system with a complex set of often global networks, and how shifts in one location or at one scale impact those at others. Finally, why is resilience being promoted

Questions to Consider		
Who?		Who determines what is desirable for an urban system?
		Whose resilience is prioritized?
		Who is included (and excluded) from the urban system?
What?	T	What perturbations should the urban system be resilient to?
	R	What networks and sectors are included in the urban system?
	A	Is the focus on generic or specific resilience?
When?	D	Is the focus on rapid-onset disturbances or slow-onset changes?
	E	Is the focus on short-term resilience or long-term resilience?
	O	Is the focus on the resilience of present or future generations?
Where?	F	Where are the spatial boundaries of the urban system?
	F	Is the resilience of some areas prioritized over others?
	S	Does building resilience in some areas affect resilience elsewhere?
Why?	?	What is the goal of building urban resilience?
		What are the underlying motivations for building urban resilience?
		Is the focus on process or outcome?

Fig. 4. Fundamental questions related to urban resilience.

and what are the underlying motivations for doing so? There are no right or easy answers to these questions, but grappling with them collectively through an inclusive and open discourse is fundamental if we hope to forge cities that are indeed resilient.

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