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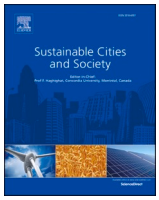

Contrasting the framing of urban climate resilience

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ABSTRACT

Cities worldwide face climate change and other complex challenges and strive to become more resilient to the shocks and stresses that these bring. The notion of urban (climate) resilience has become highly popular in both research and practice. However, the concept is inherently malleable; it can be framed in different ways, emphasising different problems, causes, moral judgements, and solutions. This review explores contrasting ways of framing urban climate resilience and their potential consequences. It identifies four typical framings: Urban Shock-Proofing (short-term & system focus), Resilience Planning (long-term & system focus), Community Disaster Resilience (short-term & community focus), and Resilient Community Development (long-term & community focus). These framings lead to different approaches to urban resilience and climate adaptation in research, science-policy-society interactions, governance, and practical resilience-building. They also offer different synergies with wider sustainability efforts, including the SDGs. Resilience Planning is widely represented in urban climate adaptation research. However, Resilient Community Development, dealing with community self-determination, equity, and deeper long-term socio-political determinants of vulnerability, is currently underdeveloped. Expansion of current scientific and institutional toolboxes is needed to support and build community-based adaptive and transformative capacities. Explicit reflection on framing is important to facilitate collaboration among actors and across disciplinary and departmental siloes.

1. Introduction

Cities worldwide are particularly vulnerable to climate change, due to their geographic locations (e.g. along coasts and rivers), large fraction of hardened surfaces, and large concentration of people and capital at risk (Revi et al., 2014; Koop & Van Leeuwen, 2017; Rosenzweig et al., 2018). They experience increasing sea levels, flood risks, heat, drought, soil subsidence, and the impacts that these have on public safety, health, water and food supply, tourism, and so on. While the nature of these impacts is often relatively clear, the precise magnitude, location (e.g. which neighbourhoods or local sectors?) and timing of these impacts are associated with large uncertainties and unknowns (Dessai & Van der Sluijs, 2007; Capela Lourenço et al., 2014). Moreover, cities face numerous other challenges, including increasing urban populations, migration, housing, social and economic problems, demographic change (e.g. aging), political change, and other environmental and resource concerns and constraints (UN, 2018; Vandecasteele et al., 2019). These challenges 'compete' with climate-related issues for the attention of policymakers, but can also impact local vulnerability to climate change. Consequently, cities are looking for creative approaches to become more climate-proof and sustainable, preferably ones that are holistic (tackle multiple problems), present a positive perspective on the tasks at hand, and can handle uncertainty and complexity.

The notion of urban (climate) resilience seems to have caught the attention in particular, with burgeoning scientific literatures and policy discourses emerging over the past decade (Tyler and Moench, 2012; Bulkeley & Tuts, 2013; Davoudi et al, 2013; Eraydin & Taşan-Kok, 2013; Friend et al., 2014; Meerow et al., 2016; Brown et al., 2018; Sharifi & Yamagata, 2018; Moser et al., 2019). This has been coined as the 'Resilience Renaissance' (Bahadur et al., 2010) or the 'Race to Resilience' (UNFCC, 2021). International organisations and policy agendas present resilience as a key goal, for instance in the UNFCCC COP21 Paris Agreement, Sendai Framework for Disaster Risk Reduction, Habitat III New Urban Agenda, World Bank City Resilience Program, EU Urban Agenda, Sustainable Development Goals and city networks such as ICLEI, C40 Cities, 100 Resilient Cities, and ACCCRN (e.g. OECD, 2014; UN, 2015; (Resilient Cities Network 2021); Rockefeller Foundation, 2021; UNFCC, 2021). These initiatives are "helping cities around the world become more resilient to the physical, social, and economic challenges that are a growing part of the 21st century" (Rockefeller Foundation, 2021). Climate change is often cited as one of the key issues that urban resilience programs aim to tackle (e.g. Fastiggi et al., 2020).

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In the climate adaptation literature, resilience-based adaptation is described as an approach that is particularly suitable for adaptation under high uncertainty (Dessai & Van der Sluijs, 2007; Capela Lourenço et al., 2014; Thissen et al., 2017). Resilience can be applied as a holistic guiding concept to address multiple challenges. For instance, the Resilient Cities Network (2021) defines it as: "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience". Furthermore, even though the impact on policy support is not clear-cut (Meerow & Neuner, 2021), the notion of resilience might have more positive connotations than 'adaptation', 'reducing vulnerability' or 'countering climate-related threats' (Fünfgeld & McEvoy, 2011; Shaw & Maythorne, 2013; McEvoy et al., 2013). As such, it has the potential to be the approach that cities are looking for: positive, uncertainty-proof, and widely applicable.

However, similar to other popular concepts related to sustainable cities (cf. De Jong et al, 2015), resilience can be interpreted in many ways. Policy documents often leave its definition implicit or vague (Hutter & Kuhlicke, 2013; (White and O'Hare, 2014); Wardekker et al., 2020). Moreover, the scientific literature also offers widely diverging definitions and interpretations. On one hand, this intangibility helps resilience function as a boundary object: because it is still open to interpretation, it can draw a wide range of actors and interests to the table (Brand & Jax, 2007; Meerow et al., 2016). On the other hand, it could lead to miscommunication and clashing interpretations between actors when translating the general concept into specific policy actions (Brand & Jax, 2007; McEvoy et al., 2013; Wardekker et al., 2020). Many papers have examined this issue from a theoretical perspective. However, these diverging interpretations also have important practical consequences, and can result in different policies and outcomes (e.g. Sanchez et al., 2018). This review aims to explore these consequences. It uses framing analysis to contrast the different perspectives on urban resilience in the literature and assess their implications for resilience-building, knowledge development and governance. The analysis will focus on urban resilience in the context of climate change specifically.

2. Tensions underlying resilience

2.1. Diverging fields and definitions

The concept of resilience has a long history. Alexander (2013) traces it back to Classical times, where resilio or resilire (Latin; bounce, rebound) was used in relation to shrinking, avoiding, or leaping; and the first scientific use to Francis Bacon in the 1600s. Since then, the concept has spread over many fields of science, ranging from engineering to physics, ecology, management science, operations research, economy, disaster studies, urban studies, geography, sustainability science, health science, law, anthropology, psychology, and sociology (Alexander, 2013; Matyas & Pelling, 2014; Quinlan et al., 2016; Folke, 2016; Meerow et al., 2016; Nunes et al., 2019; Ribeiro & Gonçalves, 2019). Each of these disciplines and topics brings its own norms, methods, assumptions, and other tailoring to the application of resilience (Leichenko, 2011; Alexander, 2013; Quinlan et al., 2016; Ribeiro & Gonçalves, 2019). This has resulted in conceptual and practical divergence.

The literature observes a historical shift in the dominant perspective in resilience-thinking from engineering resilience, to ecological resilience, to socio-ecological resilience (Adger, 2000; Carpenter et al., 2001; Walker et al., 2004; Folke, 2006, 2016; Brand & Jax, 2007; Cote & Nightingale, 2012; Nunes et al., 2019). Engineering resilience involved a mechanical conceptualisation; how fast can something under strain recover its shape and size (quick recovery to equilibrium) (e.g. Pimm, 1984)? Ecological resilience emerged from the work of Holling (1973). It was about the interplay between disturbances (e.g. shocks), conservation, renewal, and multiple equilibria (Holling, 1973, 2001). This paradigm introduced principles such as buffering, homeostasis, and redundancy, which reduce the impact of disturbances. Socio-ecological resilience shifted the focus to the interplay between humans and ecosystems (Adger et al., 2005; Folke et al., 2005; Folke, 2006, 2016; Carpenter et al., 2001; Walker et al., 2004; Cote & Nightingale, 2012). This paradigm added principles such as self-(re)organisation, adaptiveness, and learning.

The application of these paradigms to urban climate resilience, and its subdisciplines and topics, led to a wide variety of more specific definitions (e.g. Leichenko, 2011; Davidson et al., 2016; Meerow et al., 2016; Moser et al., 2019; Nunes et al., 2019). Similarly, the subjective interpretations that have emerged among policymakers and citizens are also wide-ranging (Hutter & Kuhlicke, 2013; Walsh-Dilley & Wolford, 2015; Restemeyer et al., 2018; Fitzgibbons & Mitchell, 2019; Meerow & Neuner, 2021). A key observation from these studies is that resilience is a highly multi-dimensional concept, and that each definition highlights dimensions that authors consider particularly important.

2.2. Critiques of resilience

In reaction to the 'Resilience Renaissance' (Bahadur et al., 2010), critiques have also emerged, particularly in fields such as human geography and political science. One critique was that the lack of agreement on the definition of resilience results in conceptual vagueness (McEvoy et al., 2013; (White and O'Hare, 2014); Pizzo, 2015; Davidson et al., 2016; Moser et al., 2019). If no consensus can be reached on a definition, how can it be meaningfully operationalised, applied, or measured? A second critique, was that many definitions lean heavily on the natural sciences (Cote & Nightingale, 2012; Brown, 2014; Vale, 2014; Weichselgartner & Kelman, 2015; Moser et al., 2019). Even in the 'social-ecological' resilience paradigm, there seems to be limited awareness of issues such as agency, power, equity, social inclusivity, normative aspects and value judgements, trade-offs, and vulnerable groups (Davoudi & Porter, 2012; Forsyth, 2018; Dewulf et al., 2019; Fitzgibbons & Mitchell, 2019; Krüger 2019). For example, who's resilience is improved, who bears the burdens, and who decides? This led some to question whether resilience can be meaningfully applied to complex social issues (Cote & Nightingale, 2012; Brown, 2014; Vale, 2014; (White and O'Hare, 2014); Moser et al., 2019).

Conceptual progress has been made. Most scholars now agree that urban climate resilience should be integrative, place-based, and aware of long-term change (rather than just shocks), cross-scale interactions, and trade-offs (Cote & Nightingale, 2012; Davoudi et al., 2013; Chelleri et al., 2015; Matyas & Pelling, 2014; Davidson et al., 2016; Meerow et al., 2016). Other tensions remain, for instance on whether resilience is normative (a 'good' to be achieved) or simply a neutral system characteristic (Matyas & Pelling, 2014; Walsh-Dilley & Wolford, 2015). Despite this progress, many applications of resilience to cities and climate adaptation seem to (still) emphasise short-term, conservative and 'technology-fix' interpretations of resilience (Davoudi et al., 2013; O'Hare and White, 2013; Wenger, 2017; Meerow & Stults, 2016; Harris et al., 2018; Moser et al., 2019). Others argue that resilience runs the risk of being hijacked by neoliberalism (Joseph, 2013; Walsh-Dilley & Wolford, 2015). This might place the burdens of resilience-building on those most vulnerable to climate change and least able to act (Davoudi, 2018; White & O'Hare, 2014). While these issues are potential pitfalls, they are not necessarily inherent to resilience. Rather, because the concept is malleable, different actors will emphasize different aspects of resilience to fit their existing belief structures and needs.

2.3. Framing

As described in the previous sections, various authors and actors highlight different aspects of urban climate resilience, depending on what they consider important. In other words, they *frame* resilience differently. People have different perceptions of what a 'climate-resilient

urban future' looks like, and different beliefs on what the goals of resilience-building should be and what actions and choices are appropriate to support those goals. Frames are "structures of belief, perception and appreciation" that underlie policy positions (Gamson and Modigliani, 1989; Schön & Rein 1994). Framing means that people "select some aspects of a perceived reality and make them more salient… in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described" (Entman, 1993). Often, this happens subconsciously, in a taken-for-granted way (De Boer et al., 2010). In relation to climate change, framing analyses have been conducted on for example media reporting (e.g. Nisbeth, 2009; Schäfer & O'Neill, 2017), scientific visualisations (e.g. Wardekker & Lorenz, 2019; Van Beek et al., 2020), and science-policy interfaces and decision-making (e.g. De Boer et al., 2010; Grainger et al., 2019). Several papers have also conducted framing analyses on how different adaptation concepts (e.g. resilience, adaptation, vulnerability, disaster prevention) frame climate policy differently (McEvoy et al., 2013; Meerow & Neuner, 2021), or how resilience is framed in specific empirical case studies (Sakai & Dessai, 2015; Restemeyer et al., 2018; Marschütz et al., 2020).

Framing links conceptual and practical aspects. Different framing implies different perceptions of the problems that the city should be made resilient against, and different preferences regarding how urban resilience should be achieved. For example: which types of policy options are preferred and seen as 'valid' or 'sensible', what distributions of burden are 'fair', what governance arrangements are appropriate (e.g. who should be involved in decision-making, and in what way?), and what scientific and policy information and tools for decision-making are 'relevant' to the situation at hand (De Boer et al., 2010; McEvoy et al., 2013; (Wardekker, 2019). This steers the adaptation of cities into resilient cities, from problem detection, to agenda-setting, designing and implementing adaptation pathways, and evaluating resilience-impacts (De Boer et al., 2010; Sakai & Dessai, 2015; Restemeyer et al., 2018). A framing analysis can therefore uncover the potential practical consequences of these perspectives for science, governance, and practice.

3. Methods

This review presents a framing analysis of the literatures on urban climate resilience. The aim is to analyse the different conceptualizations and choices that underly resilience-building and to assess the consequences that those might have for science and policy. Therefore, the paper follows the methodology of an 'integrative review' (Snyder, 2019), which is particularly suitable for conceptual analyses. Integrative reviews assess, critique or synthesise the literature, with the aim of providing a new perspective, framework or classification. Compared to 'systematic reviews', integrative reviews do not aim to cover all available literature or show quantitative patterns or historical trends. Instead, they provide a conceptually-driven analysis of the key ideas and arguments on a broad question.

3.1. Search strategy

The literature search and selection was a step-by-step process (Fig. 1). An initial broad literature search was performed using Scopus, supplemented by Google Scholar (particularly to capture book chapters and key grey literature discussion papers). It aimed at finding reviews and conceptual papers on urban and/or climate resilience, and other papers that discussed conceptualisations of resilience in-depth. It focused on English language papers, published in the period 2010–2020. As discussed above, much of the literature on urban climate resilience emerged and matured during this decade. Four pre-2010 articles were included because they provided details on the historical origins of different resilience concepts or framings. A second, focused literature search was conducted on the identified contrasts (equilibrium/evolutionary, systemic/community). It included more methodological and empirical papers, and used Scopus and Google Scholar searches and snowball sampling. The final corpus included a core set (n=104), and a supplementary set that provided details on potential consequences (n=24).

3.2. Analysis

The corpus was analysed using framing analysis (Entman, 1993; De Boer et al., 2010; Wardekker & Lorenz, 2020), which is similar to taxonomic and componential literature analysis (cf. Onwuegbuzie et al., 2012). Most reviews on urban resilience to date have conducted thematic analyses or syntheses, exploring the definitions, disciplines, or

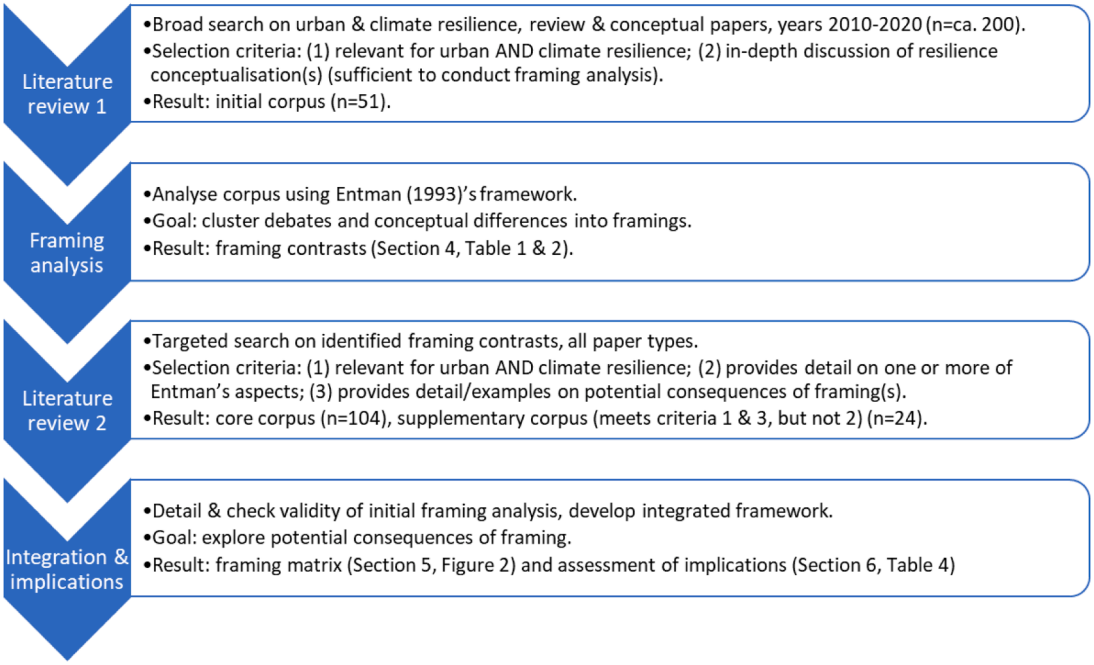

Fig. 1. Literature review and analysis process.

topics of application of resilience in a more general sense. Framing analysis takes a deeper look at these. It is particularly suitable to elicit key contrasts in the visions of what resilience means, and what potential practical implications these might have. However, it does require that the source material discusses the ideas behind their approaches in-depth. This paper used the interpretive approach to framing analysis discussed by Entman (1993). It explores how people make sense of ambiguous and complex situations, and set out a course of action to address a perceived problem (Rein & Laws, 2000; Grainger et al, 2019). The initial corpus was assessed using Entman (1993)'s framework, which disaggregates framing into problem, causal, moral, and solution framing. This helped determine which conceptual differences, debates and definitions in the literature really represent framing, and whether they were contrasting, similar, or dissimilar but complementary. Based on that analysis, they were clustered into framing contrasts (Section 4). These framing contrasts were integrated into a framing matrix (Section 5), which was used to assess and discuss the potential implications of resilience framing (Section 6).

4. Framing analysis of the urban climate resilience literature

4.1. Equilibrium versus evolutionary resilience

The first contrast relates to the shift in the resilience literature from engineering and ecological to social-ecological resilience (Carpenter et al., 2001; Walker et al., 2004; Folke, 2006, 2016; Brand & Jax, 2007; Cote & Nightingale, 2012; Nunes et al., 2019). A distinction can be made between approaches that focus primarily on engaging with short-term shocks and equilibrium (engineering, ecological resilience), and those that focus on engaging with long-term change and evolution (socio--ecological, evolutionary-transformative resilience). See Table 1 for comparison.

4.1.1. Equilibrium resilience

Equilibrium resilience focuses on maintaining the status quo. Many cities and sectors seem to follow this approach (Brown, 2012; Davoudi et al. 2013; Joseph, 2013; (White and O'Hare, 2014); Sakai & Dessai, 2015; Meerow & Stults, 2016; Borie et al., 2019; Chelleri & Baravikova, 2021). *Problem framing*: Disturbances disrupt the functionality, structure and identity of cities (Brown, 2012; Matyas & Pelling, 2013). Climate change impacts can disrupt the normal functioning of a city or region, for instance by temporarily or permanently damaging or hindering human communities, critical functions, facilities, services, resource supply, and infrastructure (Wardekker et al., 2010; Sakai & Dessai, 2015). This approach is commonly applied in fields such as disaster and crisis management, business continuity and operations research, economics, ecology, and engineering (Brown, 2012; Alexander, 2013; Matyas & Pelling, 2014; Quinlan et al., 2016; Davidson et al., 2016). *Causal framing*: The focus is on short-term shocks and acute stressors. In the context of climate change, this includes extreme weather events, such as floods, droughts, and heat waves (e.g. Sakai & Dessai, 2015; Wenger, 2017). Often, the focus is on specific types of disasters, rather than integrated and multi-hazard approaches (Sanchez et al., 2018). *Moral framing*: Equilibrium resilience places value in avoiding catastrophic impacts, preserving what people have built in a city (functions, structures, identity; Brown, 2012; Matyas & Pelling, 2013), and a quick return to 'normalcy' (cf. Pendall et al., 2010; Davoudi et al., 2013). Resilience is important, because it allows the city to accommodate disruptions "gracefully and without catastrophic failure"; people and property fare better and experience fewer deaths, injuries and damage during disasters (Godschalk, 2003). Important factors are persistence, efficiency, predictability, 'provision of certainty', 'bouncing back', and fast recovery time; "quickly getting basic urban functions back online" (e.g. Davoudi et al., 2013; (White and O'Hare, 2014); Sanchez et al., 2018). This involves trade-offs and judgements regarding who and what are prioritised during resilience-building and post-shock recovery: what functions and infrastructure are considered 'critical' (i.e. protected first) and for whom (Wardekker et al., 2010, 2020; Sanchez et al., 2018), and who has access to resources for recovery? *Solution framing*: This framing is heavily influenced by pre-existing notions in the disaster resilience literature, such as the 'prevent-prepare-respond-recover (PPRR) framework' (Wenger, 2019). The resilience principles and policy options envisioned under this framing aim to absorb or limit the impacts of shocks (e.g. buffer capacity, safety margins, stabilizing mechanisms), allow subsystems to fail safely (e.g. redundancy, omnivory), and provide mechanisms for quick recovery (e.g. high flux of resources, flatness of decision-making structures; emergency funds, easily restored infrastructure, insurance mechanisms) (e.g. Godschalk, 2003; Rose, 2007; Norris et al, 2008; Wardekker et al., 2010; Jha et al, 2013; Linkov et al., 2014; Sharifi & Yamagata, 2016).

4.1.2. Evolutionary resilience

Evolutionary resilience assumes that change is inevitable in complex, dynamic systems. It has gained dominance in the literature on urban and climate resilience (Meerow et al., 2016; Nunes et al., 2019; Wardekker et al., 2020), and is emerging in practitioner discourse (Milly et al., 2008; Restemeyer et al., 2018; Chelleri & Baravikova, 2021). *Problem framing*: This framing relates to the interactions between cities and long-term changes, such as climate change, urbanisation, socio-economic change, and demographic change (Wardekker et al., 2010, 2020; (White and O'Hare, 2014); Meerow & Stults, 2016; Sanchez et al., 2018; Nunes et al., 2019). These are 'post-normal' problems (cf. Funtowicz & Ravetz, 1993), characterised by uncertainty, ignorance and surprise, value disputes and complex interactions across issues and

Table 1
Contrasting equilibrium and evolutionary framing of urban climate resilience.

Framing: What's the:	Equilibrium resilience	Evolutionary resilience
Example definitions	• "encompasses the idea that towns and cities should be able to recover quickly from major and minor disasters" (Lamond & Proverbs, 2009). • "the ability of a city or urban city to withstand a wide array of shocks and stresses" (Leichenko, 2011). • "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" (Henstra, 2012).	• "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 et al., 2004). • "Evolutionary resilience challenges the whole idea of equilibrium and advocates that the very nature of systems may change over time with or without an external disturbance" (Davoudi & Porter, 2012). • "resilience is often framed positively – more holistic and integrated management approaches aimed at 'adaptation' and building 'adaptive capacity' seem to be key to 'governing the unknown'" (Restemeyer et al., 2018).
Problem	Disturbances bring system out of equilibrium, 'normalcy' is disrupted.	'Stationarity is dead', urban context is continuously changing.
Causes	Short-term shocks.	Long-term changes, trends and pressures.
Moral judgements	Focus: prevent catastrophe and protect what we've built. Trade-offs in: access, priority for recovery.	Focus: stimulate innovation, learn to live with uncertainty & change. Trade-offs in: who pays for flexibility, who/what is 'replaced'?
Remedies	Counteract shocks, mobilize resources, quick recovery.	Build flexibility and adaptability, learning capacity, monitor trends.

time- and spatial scales (Wardekker et al., 2010, 2020; Davoudi et al., 2013; (White and O'Hare, 2014); Restemeyer et al., 2018; Sanchez et al., 2018). This framing builds on the social-ecological (Carpenter et al., 2001; Walker et al., 2004; Folke, 2006, 2016) and evolutionary-transformative interpretations of resilience (Davoudi & Porter, 2012; Davoudi et al., 2013). *Causal framing*: The focus is on long-term climate change, slow trends in 'shock regimes', and chronic pressures, such as sea level rise, changes in precipitation or river discharge, and changes in climate vulnerability (Wardekker et al., 2010; Meerow & Stults, 2016; Wenger, 2017; Restemeyer et al., 2018). Climate-related problems and vulnerabilities are multi-causal. Consequently, this framing asserts that they should be assessed in an integrated way. *Moral framing*: The moral starting point seems to be that resilience should be "progressive and dynamic, challenging existing practices, and aspiring for a new normality" (White and O'Hare, 2014). It is about "building capacity for envisaging and embracing transformation through creativity and imagination" (Davoudi et al, 2013). Therefore it is about accepting interdependencies, uncertainty, ignorance and surprise, change, and promoting diversity, reflexivity and innovation (Wardekker et al., 2010, 2020; Biggs et al., 2012; Davoudi et al., 2013; (White and O'Hare, 2014); Sakai & Dessai, 2015; Restemeyer et al., 2018; Sanchez et al., 2018; Nunes et al., 2019). This implies choices and trade-offs such as: what aspects of the city are deemed essential and should be preserved; who and what are replaced; and who bears the costs and who benefits from flexibility (Keessen et al., 2013; Sanchez et al., 2018; Wardekker et al., 2020)? *Solution framing*: Evolutionary resilience focuses on long-term adaptability, proactive foresight, preparedness and transformation, while remaining mindful of shocks (cf. Linkov et al., 2014; Sharifi & Yamagata, 2016; Wardekker et al., 2020). Principles and options in this framing focus on building flexibility (e.g. multi-functional spaces and buildings), active learning (e.g. urban experimentation, science-policy collaboration), building adaptive and transformative capacity, long-term monitoring, foresight, and future-oriented design (Nelson et al., 2007; (Wardekker et al., 2020); Biggs et al., 2012; Eraydin & Taşan-Kok, 2013; Sharifi & Yamagata, 2016). This can involve a shift in emphasis from structural to non-structural and functional interventions (Vanderlinden et al., 2015; Elmqvist et al., 2019).

4.2. System versus community resilience

The second contrast relates to the discussion of whether a 'natural science' concept such as resilience can be meaningfully applied to complex social issues. Much of the modern resilience literature developed from system dynamics and ecology (e.g. Holling, 1973, 2001). For urban climate resilience, cities have also been envisioned as complex adaptive systems (e.g. Meerow et al., 2016; Olazabal, 2017; Wardekker et al., 2020). However, as Alexander (2013) explored, resilience not a purely natural science concept. A rich literature developed separately on resilience in psychology, sociology and anthropology. A distinct perspective on urban climate resilience, with solid social science roots, developed around the notion of 'community resilience' (Wardekker, 2019). See Table 2 for comparison.

4.2.1. System resilience

System resilience focuses on the 'urban system' and the "ability of the city to maintain the functions that support the well-being of its citizens" (Da Silva et al., 2012). *Problem framing*: The problem perspective in this framing is that climate-related disturbances can hamper the functioning of the urban system, and therefore threaten the provision of these critical services. It focuses on exploring problems through functionality, structure and networks (cf. Cote & Nightingale, 2012), and understanding the system as a whole, including its dynamics, interrelations and feedbacks (cf. Da Silva et al., 2012; Fiksel, 2006). Consequently, it tends to have a large scale, top-down perspective. This framing is evident in much of the engineering, ecological, and social-ecological resilience literature (cf. Matyas & Pelling, 2014; Davidson et al., 2016). Numerous climate-related applications can be found in (water) engineering, socio-ecological systems, urban studies, economics, architecture, infrastructure, and disaster risk management (Alexander, 2013; Matyas & Pelling, 2014; (Davidson et al., 2016)Fastiggi et al, 2020; Wardekker et al., 2020). It conceptualizes cities as systems with subsystems, components, and flows of resources (water, energy, money, goods, people) that together provide goods and services (e.g. Wardekker et al., 2010; Da Silva et al., 2012; Meerow et al, 2016). *Causal framing*: Climate-related events or changes might disrupt the structure, processes, and dynamics of the urban system, for example when floods damage buildings, infrastructures and social and economic activities and resource flows are halted. *Moral framing*: The moral starting point might be embedded in the attention to complexity and

Table 2
Contrasting system and community framing of urban climate resilience.

Framing: What's the:	System resilience	Community resilience
Example definitions	• "the ability of a system to absorb changes and disturbances in the environment and to maintain system functionality" (Furuta, 2015) • "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 et al., 2004) • "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." (Meerow et al., 2016).	• "a process linking a network of adaptive capacities (resources with dynamic attributes) to adaptation after a disturbance or adversity… Community resilience emerges from four primary sets of adaptive capacities—economic development, social capital, information and communication, and community competence" (Norris et al. 2008). • "the ongoing and developing capacity of the community to account for its vulnerabilities and develop capabilities that aid that community in (1) preventing, withstanding, and mitigating the stress of a health incident; (2) recovering in a way that restores the community to a state of self-sufficiency and at least the same level of health and social functioning after a health incident; and (3) using knowledge from a past response to strengthen the community's ability to withstand the next health incident" (Chandra et al., 2011). • "considers the interaction between adaptive capacity and agency on one hand, and community characteristics (such as leadership, values and beliefs, knowledge, skills and learning, networks, engaged governance, community infrastructure, diverse and innovative economy) that influence agency and self-organization on the other" (Berkes & Ross, 2013).
Problem	Threats to functioning of urban system.	Threats to community wellness & social cohesion.
Causes	Disruption of resource flows and activities.	Overwhelm of community's capacities to act.
Moral judgements	Focus: seek to understand complexity, what's analysable. Trade-offs in: prioritisation of subsystems, spatial scales, and time scales, issues.	Focus: human element, bottom-up action, self-determination. Trade-offs in: participation, equity, vulnerable groups.
Remedies	Engineer ways to deal with this, enhance buffers, feedback & forecasting systems.	Improve social support networks, skills & education, enhance resource access.

interconnectedness. This frame seeks to "understand the dynamic, cross-scale interactions of coupled human-environment systems" (Matyas & Pelling, 2014). Da Silva et al. (2012), arguing for a systems approach to resilience, explain that traditional risk analyses "fail to recognize uncertainty of climate data or the complexity of cities". The issue of interlinkages between systems, spatial and temporal scales, and disturbances appears to be a major concern (e.g. Brown, 2012; Da Silva et al., 2012; Matyas & Pelling, 2014; Davidson et al., 2016; Fiksel, 2006; Fastiggi et al, 2020). Interventions can have side-effects and cross-scale and cross-system effects that aren't immediately obvious: "absent a full understanding of the system implications, there is a risk of unintended consequences" (Fiksel, 2006). Decisionmakers make normative choices while setting priorities for different subsystems, neighbourhoods, geographic scales, and timescales, and in dealing with trade-offs regarding these (cf. Chelleri et al., 2015; (Grainger et al., 2019). Improving resilience for one neighbourhood or sector might reduce that of another. *Solution framing*: Resilience is improved using typical system dynamic principles such as buffering, redundancy, omnivory, organisational flatness, homeostasis, high flux, interconnectivity, compartimentalisation, feedback systems, forecasting and foresight, and early warning systems (e.g. Watt & Craig, 1986; Wardekker et al., 2010, 2020; Eraydin & Taşan-Kok 2013; Shutters et al., 2015; Biggs et al., 2012; Martin & Sunley, 2015; Sharifi & Yamagata, 2016).

4.2.2. *Community resilience*

Community resilience takes a people-centric approach. It explores how communities navigate disturbances and adversity, through the interplay of local capacities, resources, and adaptation (Norris et al., 2008; Berkes & Ross, 2013). It involves many qualitative aspects: "it is possible for a city to be reconstructed, even heroically, without fully recovering… [cities] are also thick concatenations of social and cultural matter, and it is often this that endows a place with its defining essence and identity" (Campanella, 2006). *Problem framing*: Problems emerge when community wellness and social cohesion are disrupted, for example through impacts on daily life, quality of life, urban identity, or social bonds. Compared to system resilience, this framing is often more small scale and bottom-up. Climate-related applications involve impacts on natural disasters, crises, health, and global development (Ronan & Johnston, 2005; Chandra et al., 2011, 2013; Berkes & Ross, 2013; Goldstein & Brooks, 2013; Thornley et al., 2015). *Causal framing*: Community resilience emerges from the capacities and resources of local actors (individuals and groups) to cope successfully with risk exposure and trauma (Alexander, 2013; Matyas & Pelling, 2014; Davidson et al., 2016). Problems emerge where these capacities are overwhelmed: absent, insufficient or depleted due to existing stresses. In disasters, communities often cannot rely fully on authorities and official systems, who's responses take time to mobilize and may be insufficient, and will need to leverage capacities to self-organise as 'first responders' (e.g. Norris et al., 2008; Chandra et al., 2011, 2013). Furthermore, communities can utilize these capacities to exercise agency and self-determination, coming together to further shared goals (Berkes & Ross, 2013; Tanner et al., 2015). *Moral framing*: This framing values the human elements, individual and communal strengths, and leveraging capacities and resources for common goals, self-reliance, and self-determination (Brown, 2012; Berkes & Ross, 2013; Matyas & Pelling, 2014; Davidson et al., 2016). Doing so, communities can "thrive in an environment characterized by change, uncertainty, unpredictability and surprise" (Magis, 2010). It is important to improve the 'capabilities' of individuals to meet their needs, for instance, be nourished, mobile, sheltered, and socially connected (Doorn et al., 2019). Adaptive aspects are also important; several authors note that simple recovery could reproduce or worsen existing inequalities (Leach, 2008; Bahadur & Tanner, 2014; Doorn et al., 2019). Community resilience involves both individual and collective aspects, which can lead to trade-offs. Communities are not homogenous; 'focusing on the average' could hide individual differences, minority voices, and vulnerable groups, reinforcing problems regarding distributive justice and social inclusiveness (Cote & Nightingale, 2012; Forsyth, 2018; Doorn et al., 2019). *Solution framing*: Typical options for community resilience involve improving education, skills, leadership, agency, access, diversity, engagement, self-sufficiency, social ties, social equity, partnership, social capital, cultural capital and values (Ronan & Johnston, 2005; Norris & Stevens 2007; Campanella, 2006; Norris et al., 2008; Twigg, 2009; Chandra et al., 2011, 2013; IFRC, 2011; Berkes & Ross, 2013; Thornley et al., 2015; Aldrich, 2017).

5. Integration: combining the contrasts

The two framing contrasts, Equilibrium/Evolutionary and System/Community, are complementary. For example, a specific resilience study or policy plan might have both an equilibrium-oriented and a system-oriented perspective. This is also apparent in the corpus: see Table 3 and Supplementary Materials S1. Among the 56 papers that write from specific framings, combinations all four combinations can be observed. Evolutionary-system resilience is most well-represented (25), and evolutionary-community the least (3). While integrative reviews aren't designed for quantitative analyses (percentages shouldn't be interpreted as representative for the full literature), these difference are noteworthy. The high representation of evolutionary-system could be due to the focal topic of climate change, but the reason for the low number of evolutionary-community papers is unclear.

The two framing contrasts can be integrated into a matrix. See Fig. 2. This matrix can be used as analytical lens; to show key differences in how literatures and policy actors engage with urban climate resilience, and to assess the implications.

Firstly, *Urban Shock-Proofing* (short-term equilibrium, systems) shows a classic perspective, related closely to the 'engineering resilience' definition and its notions of equilibrium and bouncing back (Folke et al., 2005). Examples are most common in literatures such as disaster risk reduction, disaster engineering, external safety, system stability & reliability, operations research, and economic resilience (e.g. Watt & Craig, 1986; Rose, 2007; Henstra, 2012; Martin & Sunley, 2015; Matyas & Pelling, 2014; Furuta, 2015; Shutters et al., 2015; Davidson et al., 2016).

Secondly, *Resilience Planning* (long-term evolution, systems) emphasises change and flexibility. While the previous framing might include some post-shock incremental adaptations, this framing focuses explicitly on pre-emptive long-term planning and inbuilt adaptability and transformability. It is highly prevalent in the urban social-ecological systems, climate change adaptation, and urban planning literatures, applied to for instance water management, nature and green space, health, tourism, and urban design (e.g. Wardekker et al., 2010, 2020; Da Silva et al., 2012; Davoudi & Porter, 2012; Davoudi et al., 2013; Eraydin & Taşan-Kok 2013; (White and O'Hare, 2014); Vanderlinden et al., 2015; Fiksel, 2006; Meerow et al., 2016; Wenger, 2017; Sanchez et al.,

Table 3
Framing of urban climate resilience in the core corpus (n=104). Of these, 48 discuss resilience more generally because of the focus of this study (initial corpus consisted of reviews and conceptual papers, which often discussed multiple definitions & perspectives). The remaining 56 could be assessed using the combined framing contrasts.

Framing in core corpus	Number of papers
Papers with broader focus:	
General conceptual discussions	19
Relevant to Equilibrium / Evolutionary contrast	16
Relevant to System / Community contrast	13
Papers with specific framing:	
Systems AND Equilibrium	12
Systems AND Evolutionary	25
Community AND Equilibrium	16
Community AND Evolutionary	3

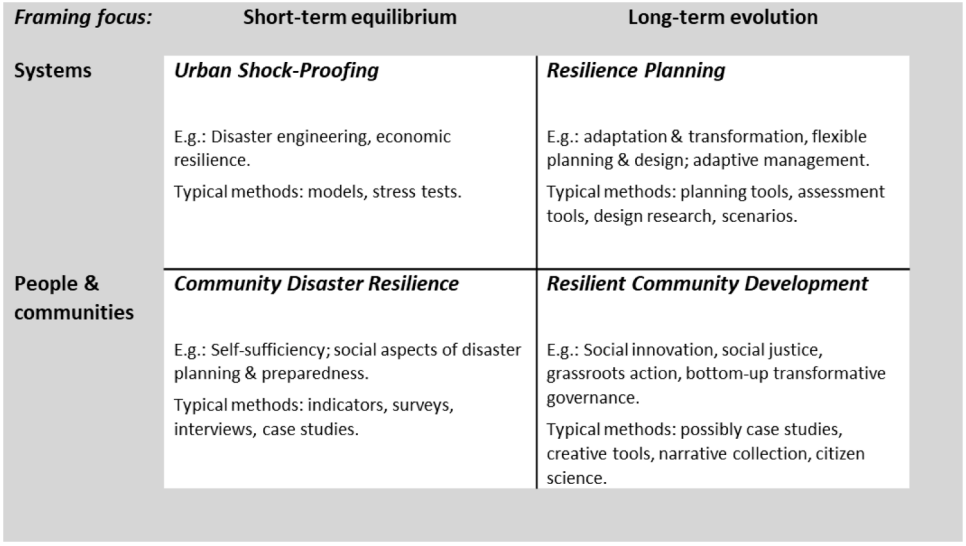

Fig. 2. Cross-comparison of urban resilience framings and their typical applications and analytical methods.

2018).

Thirdly, *Community Disaster Resilience* (short-term equilibrium, people & communities) takes a people-oriented approach to disasters. Like Urban Shock-Proofing, this framing also developed in the disaster management literature, but from a social science background. It emphasises bottom-up preparedness, vulnerabilities, and community and individual coping capacities. It is well-represented in social disaster preparedness, global development, household economics & livelihoods, and climate vulnerability research (e.g. Ronan & Johnston, 2005; Campanella, 2006; Norris et al., 2008; Chandra et al., 2011, 2013;

Table 4
Potential implications of resilience framing for urban climate adaptation.

Framing: *Aspect:*	Urban Shock-Proofing	Resilience Planning	Community Disaster Resilience	Resilient Community Development
Focus	Systems & Short-term equilibrium.	Systems & Long-term evolution.	Communities & Short-term equilibrium.	Communities & Long-term evolution.
Resilience & adaptation science	Mono-disciplinary, quantitative. Focus on structural aspects, single system at one or more scales. Narrow but detailed methods (system specific).	Interdisciplinary, quantitative & qualitative. Focus on complex systems (multi-system, -impact, -scale). Primary interest often city scale. Large, diverse methodological toolbox.	Mono- & interdisciplinary, quantitative & qualitative. Focus on community scale. Bottom-up, social science, situated knowledge. Large methodological toolbox.	Interdisciplinary, likely qualitative. Focus on extended communities (distributed in time & space; diasporas). Bottom-up, social science & humanities, creative methods. Currently underdeveloped toolbox.
Science-policy-society tools	Early warning systems, 'city dashboards', forecasting tools, stress tests	Urban experiments, scenario & visioning tools, adaptive management, design competitions.	Indicator studies & maps, communication & education programs, community workshops.	Social engagement tools, inspirational tools, citizen science, participatory arts & humanities.
Governance	Centralised, decentralised & public-private governance. Classic big actors. Bureau-/ technocratic.	Interactive & decentralised governance. More room for small actors, citizens, creatives. Participatory.	Self-governance. Citizens, local NGOs, schools & educators, charities. Community-led.	Interactive & self-governance. Local NGOs, citizens, creatives, other community actors.
Practical focus on impacts	Floods (rivers, rain, storms), droughts (fresh water supply & scarcity).	Sea level rise, change in weather patterns, ecological change, snow & permafrost, soil subsidence.	Floods, heat waves, health impacts, water & food scarcity.	All impacts, but related to deeper socio-political causes (e.g. inequality), social sustainability, and shifts in vulnerability.
Practical focus on adaptation	Critical infrastructure interventions (redundancy, buffer capacity, early warning).	Spatial planning (long-term robustness & flexibility), climate- & future-proof urban design, adaptive management, local knowledge networks.	Community capacity-building, improving access to resources, improving social connectedness, communication.	Improving community self-determination. Stimulate local initiatives for knowledge-building, decision-making & adaptation action.
Example resilience principles	Redundancy, omnivory, buffering, flatness, high flux, homeostasis (Watt & Craig, 1986).	Anticipation & foresight, preparedness & planning, homeostasis, robustness & buffering, diversity, redundancy, flatness, high flux, learning, flexibility (Wardekker et al., 2020).	Wellness, access, education, engagement, self-sufficiency, partnership, quality, efficiency (Chandra et al., 2013).	Community resources, resource development, resource engagement, active agents, collective action, strategic action, equity, impact (Magis, 2010)
Links with SDGs	6, 7, 9, 11, 13	2, 6, 7, 9, 11, 12, 13, 14, 15, 17	2, 3, 4, 6, 11, 13	1, 2, 3, 4, 5, 6, 8, 10, 11, 13, (14, 15), 16, 17
Typical strengths	Easy integration with existing disciplinary research & domain-based ('siloed') policy practice.	Integrated approach. High reflexivity. Challenges status quo. Accounts for feedbacks, non-intuitive & non-linear processes.	Bottom-up, situated approach. Accounts for social aspects (e.g. agency, equity, cohesion, education).	Bottom-up, situated approach. Accounts for social & humanities aspects (e.g. culture, history). Enables community self-determination.
Typical pitfalls	Tends to ignore slow change & sudden collapse (surprise, tipping-points), assumes status quo is acceptable, risks technocratic approach.	Tends to ignore aspects that can't be expressed in 'system language' (or applies unsuitable tools), difficulty in dealing with social aspects.	Risk of uncritically shifting responsibility from powerful actors to communities.	Risk of biasing participation to those that can afford to think about the future.

Cutter et al., 2010; Brown, 2012; Matyas & Pelling, 2014; Tanner et al., 2015; Thornley et al., 2015; Davidson et al., 2016; Imperiale & Vanclay, 2021).

Fourthly, *Resilient Community Development* (long-term evolution, people & communities) focuses on bottom-up capacity development and community empowerment to deal with long-term change processes. It currently seems underdeveloped in the urban resilience literature. While there is much work on adaptive capacity (Gallopín, 2006; Gupta et al., 2010; Engle, 2011), this deals with larger scales and developed alongside the social-ecological systems literature. There are few resilience papers that combine bottom-up community-based approaches with an explicit focus on change and transformation, with some exceptions (e.g. Smit & Wandel, 2006; Magis, 2010; (Marschütz et al., 2020).

6. Assessment and discussion: potential implications for research, practice and governance of urban climate resilience

Framing describes how people make sense of and manage complex issues, using different notions on what mechanisms lead to resilience, what information is relevant, and who should be 'in the driver's seat'. This has practical consequences for science, science-policy-society interactions, practice and governance. This section will assess these implications using the framework developed in Section 5. Table 4 presents an overview of the results.

6.1. Implications for resilience science for urban climate adaptation

Urban climate resilience is studied from a variety of scientific disciplines, each with its own theoretical and methodological bases. Different framings match well with specific ways of developing knowledge (De Boer et al., 2010).

Urban Shock-Proofing steers the analytical focus towards the dynamics of short-term, high-impact events. This lends itself well to in-depth structural analysis of systems that are highly vulnerable or where disruptions would have large consequences, such as public (critical) infrastructure, services or economic systems. Using models and stress tests, applied in a mono-disciplinary setting, one might suggest options to strengthen resilience or reduce vulnerabilities in a specific system. This allows for easy integration into existing science and practice (e.g. Matyas & Pelling, 2014). However, this approach is also the most criticized in the literature (Section 2.2). It tends to ignore slowly changing variables and social, non-structural, multi-system and interdisciplinary aspects, narrows down the analytical tools that can be applied, and may increase vulnerability to sudden collapse (Brown, 2012; Joseph, 2013; Matyas & Pelling, 2014; White & O'Hare, 2013; Dewulf et al., 2019). A key challenge for this framing is to increase its awareness of the social context of systems, interdisciplinary aspects, and long-term change.

Resilience Planning intersects with a wide range of scientific literatures. It steers the focus towards analysing the interplay between long-term changes and transformations. It is the most well-represented framing in the corpus (25 of 56 papers with specific framing; Table 3). This framing has an advanced multi- and interdisciplinary methodological toolkit, with a wide range of detailed qualitative and quantitative approaches. These include planning guidelines, assessment methods, sets of 'resilience principles', scenario methods, and simulation models (Quinlan et al., 2016; Wardekker et al., 2020). Resilience Planning stimulates reflexivity regarding uncertainty, complexity and deeper causes of risk and vulnerability and involves integrated and flexible analyses (Wardekker et al., 2010; Sanchez et al., 2018; Nunes et al., 2019). It is particularly suited to analyse coupled systems, feedbacks, cross-scale effects, and non-intuitive and non-linear processes (e.g. Matyas & Pelling, 2014). In principle, this involves multiple time and spatial scales, (sub-)systems and climate change impacts. In practice, this can be complicated, requiring considerable resources, and simplified analyses might be conducted (Wardekker et al., 2020). Often, the primary interest is at the city scale. This framing does risk ignoring aspects that cannot be easily expressed in system-analytical terms. It might also tempt researchers to analyse these using tools that aren't suitable for this purpose. For example, Cote & Nightingale (2012) note that attempts to analyse social resilience using ecological system dynamics principles hide questions of power and equity; these do not lend themselves well to modelling. This potentially creates a mismatch between analytical and social-political realities. Challenges include to better embed social science and humanities expertise in research methods and practices, and combine quantitative and qualitative aspects of resilience.

Community Disaster Resilience focuses explicitly on the messy social situations in cities. It often involves on-the-ground research (e.g. case studies, interviews) or indicator studies that represent different aspects of the situation. Occasionally, these are presented in the form of maps (Cutter et al., 2010; Cariolet et al., 2019). This lends itself well to research that is highly situated (rooted in the local situation), focused on daily challenges and strengths of local communities and residents, and can actively engage with social science aspects of resilience, such as agency, equity and power (cf. Cote & Nightingale, 2012). However, some aspects of community resilience are difficult to represent using indicators. For instance, education levels and livelihoods might be quantified easily, but this is more challenging for community engagement, good communication, or leadership (cf. Norris et al., 2008; Chandra et al., 2013). Consequently, qualitative aspects of this knowledge might be more difficult to generalize or use in decision-making, while quantitative indicator studies could overlook important aspects. This framing places the analytical lens at the community level. This makes it relevant to citizens. However, many impacts and decision-making processes play at other levels (household, city, region). This could lead to undesirable aggregation of impacts (might overlook vulnerable subgroups) or a mismatch between the analytical level and the level where adaptation might be most effective. Challenges include building reflexivity to long-term change, scale issues, balancing quantitative and qualitative aspects, and the potential systemic origin of vulnerabilities.

Resilient Community Development is currently underdeveloped (3 of 56 papers). Research in this framing could focus on how communities might shape and transform their environment for the future; on their capacities for building and maintaining long-term, bottom-up transformative climate adaptation. Like Community Disaster Resilience, this focuses on the community scale. However, as communities are mutable on long time scales, research would likely involve extended communities: exploring on how communities and their resilience evolve over time and space, and interlink with histories, development, migration, culture, and identities, and the role of diasporas and extended networks. It is challenging to engage communities in long-term thinking, because many have pressing short-term concerns (Baztan et al., 2020). However, filling this gap could build a scientific basis for climate adaptation efforts that stimulate the self-determination of communities. This might involve bottom-up visioning and creative methods, community-based narrative research (Baztan et al., 2020; Krauß & Bremer, 2020; Marschütz et al., 2020), grassroots citizen science (Wildschut & Zijp, 2020), social justice approaches (Ziervogel et al., 2017), and similar social sciences and humanities methods. Perhaps, research on governance capacities could be translated to community capacities, for example from sustainable development (Magis, 2010; Berkes & Ross, 2013) and transformative governance (Hölscher et al., 2019; Revi et al, 2020). A major challenge for this framing will be to develop a toolbox that enables communities to think about their futures, is comprehensive (e.g., not only about livelihoods), and remains mindful of everyday and present-day concerns.

Urban climate resilience inherently transcends disciplinary siloes. For all framings, strengthening interdisciplinarity is important. They can learn from each other and shed light on potential blind spots. However, there is a risk of forming disciplinary 'islands', which study the topic from their distinct perspective, without much successful interaction. For

instance, while the disasters literature and climate adaptation literature deal with similar issues, they remain mostly separated, because of their different histories, norms, knowledge bases, and time and spatial scales (Birkmann & Von Teichman, 2010; Solecki et al., 2011; Pilli-Sihvola & Väätäinen-Chimpuku, 2016). In the context of this paper, disasters literature focuses primarily short-term shocks (Urban Shock-Proofing, Community Disaster Resilience) and climate adaptation literature on long-term pressures and changes (Resilience Planning particularly). This may play a role in their continued separation. To make use of such dissimilar but interconnected information sources, resilience assessments will need to integrate different types of information. Such approaches have been developed, but they are often complex and time-consuming (Quinlan et al., 2016; Wardekker, et al., 2020). More research is needed on how to combine scientific knowledge developed with different frames in mind.

6.2. Implications for science-policy-society interactions

Different framings provide 'natural matches' with different information needs, science-policy interactions and decision-support tools (De Boer et al., 2010). For *Urban Shock-Proofing*, science-policy-society interactions might be mostly expert-driven, depending largely on advanced quantitative methods and engineering or economics expertise. The focus would be on analysing, testing, forecasting and monitoring the resilience of various urban systems, involving for instance 'city dashboards', early warning systems, damage and adaptation option cost estimation tools, and stress tests. For *Resilience Planning*, current practices in urban climate adaptation often involve science-policy interaction driven by policymakers and experts, with input from other local actors. Typical tools include visioning and scenarios (Wardekker et al., 2010; Matyas & Pelling, 2014), design competitions (Šakić Trogrlić et al., 2018), and urban experiments to develop and field-test novel ideas (Castán Broto & Bulkeley, 2013). For *Community Disaster Resilience*, efforts might be aimed at identifying current vulnerabilities, strengths and opportunities in communities. This can lead to mixed science-policy-society interactions. The experience of neighbourhood managers, community actors and residents would provide key information, so this framing could benefit from bottom-up interactions, driven by local residents' needs. Tools might include resident surveys, indicator-based maps, community workshops and analyses focused on livelihoods, demographics, social ties, and community health. This knowledge might also be actively spread into the community, through communication and education programs that help improve community resilience and stimulate access to information, resources, and connections. For *Resilient Community Development*, the challenge is to develop the local capacities for critical reflexivity, reflexive policymaking, learning and self-organisation, including better interactions, co-development and co-design with citizens (Weichselgartner & Kelman, 2015). This suggests mixed science-policy-society interactions, driven by local residents, actors and policymakers. While the toolkit is underdeveloped, novel tools could focus on supporting citizen-led adaptation initiatives (Mees et al., 2019), local citizen science (Wildschut, 2017) and community-based humanities (e.g. narrative and arts-based methods; Baztan et al., 2020; Marschütz et al., 2020). These would aim at stimulating creativity, engagement, inspiration, and long-term capacity development.

A more general challenge related to science-policy-society interactions, is that climate change knowledge and policy are increasingly developed interactively, at multiple levels. This involves co-production of knowledge with policymakers, societal actors and citizens, combination of different knowledge types and systems (e.g. scientific, applied/practical, indigenous/traditional), and city-to-city learning initiatives in city networks (Elmqvist et al., 2019; Feagan et al., 2019; Ilgen et al, 2019; Ribeiro & Gonçalves, 2019; Haupt et al., 2020; Lemos et al., 2020). Such efforts will involve actors with multiple frames of urban resilience and are inherently highly political processes. Consequently, science-policy-society interactions will require negotiation and active reflection on the framing, disciplinary toolboxes and blind spots among the actors involved.

6.3. Implications for practice

Framing influences which problems are perceived as salient and what solutions as appropriate. Resilience is a 'holistic perspective', but resources are always limited. Urban governments and actors will prioritise those aspects that they see as particularly important to their city or interests. *Urban Shock-Proofing* emphasises high-consequence events that can be modelled at the level of specific urban systems. These include impacts from extreme weather events, such as floods (from rivers, heavy precipitation, storm surge) and droughts (fresh water supply/scarcity). It could also include heat waves (impacts on electricity supply, health systems), but these also involve many social aspects that aren't typically addressed well in this framing. An example is London, who's resilience-plans emphasise absorbing shocks, recovery processes and systems engineering (Davoudi et al., 2013; Pelling et al., 2016; Restemeyer et al., 2018; Wardekker, 2018; Greater London Authority, 2020). Adaptation efforts focus heavily on 'critical infrastructures' and safeguarding key functions and services. This includes flood defences, water supply, transportation (roads, rail, shipping), electricity, and ICT systems. Resilience is improved by building redundancies, buffer capacity, early warning systems, and similar structural capacities. *Resilience Planning* instead emphasises long-term changes. These might include changes in the pattern (frequency, duration, magnitude) of extreme weather events. These can have long-term impacts on flood safety, water supply and food provision. Resilience Planning is also concerned with gradual impacts, such as sea level rise, soil subsidence, ocean acidification, and changes in temperature, cover and permafrost, and ecology. An example is Rotterdam, who's current adaptation and resilience-building emphasises long-term change and scenario planning, flexible use and planning of public spaces, and proactively designing for the future (Restemeyer et al., 2018; Wardekker, 2018; Wardekker et al., 2020). Adaptation efforts might focus on spatial planning, urban design, and improving flexibility, societal learning, anticipation, and adaptive management. This could involve urban green spaces, multifunctionality (e.g. in use of space, buildings), climate-sensitive neighbourhood design, and intentionally building local knowledge networks and expertise. In Rotterdam, a policy paradigm shift was observed from seeing 'water as threat' (Urban Shock-Proofing) to 'water as opportunity' (Wardekker et al., 2020). *Community Disaster Resilience* focuses on shock events that require communities to cope or intervene themselves, for example because government responses might take a while. This includes floods, storms, and events that aren't easily solved through engineering alone, such as heat waves and other health-related impacts (e.g. vector-, water- and food-borne diseases, pests). Other relevant impacts include water and food scarcity, especially in cities that don't have centralized supply systems. An example is New York City, in its recovery after Hurricane Sandy. The city has a long tradition of community-focused work, and its overall adaptation approach emphasises aspects such as communication, education, and urban identity (NYC, 2015; Graham et al., 2016; Wardekker, 2018). However, New York's 'Build Back Better' approach also includes much engineering that aligns with Urban Shock-Proofing. Adaptation efforts would focus on increasing communities' coping capacities, through education, improving social connectiveness and participation, local leadership (individuals, neighbourhood level NGOs), and improving access to resources (funds, physical materials, space, information). *Resilient Community Development* would focus attention on impacts that determine the long-term liveability, quality of life, and cohesion in communities. Depending on the local situation, this could be a wide range of climate change impacts. Community-based initiatives tend to be holistic, combining climate with other environmental, social and economic sustainability issues (Smit and Wandel, 2006)Marschütz et al., 2020). While this frame is forward-looking, communities might

stress aspects that are already problematic and are directly experienced by residents (Smit and Wandel, 2006); Marschütz et al., 2020; also Ziervogel et al., 2017). This framing would likely pay particular attention to deeper socio-political causes of climate-related impacts, such as (shifting) climate vulnerabilities, equity, poverty, education, inclusivity, and representation in decision-making. For instance, Marschütz et al (2020) explore how to better embed residents' perspectives into neighbourhood climate adaptation. Magis (2010) discusses community resilience in the context of social sustainability, the 'ability to thrive', and collective agency. Rotterdam's future resilience goals have started to include such characteristics (Municipality of Rotterdam, 2016, 2019; Wardekker et al., 2020).

6.4. Implications for governance

Institutions and social structures are organised to address different kinds of decision-making problems (Thompson & Tuden, 1959; Thompson, 2003; De Boer et al., 2010). Framing therefore has consequences for the governance approaches, institutions, adaptation strategies, and the power relations that emerge in building urban climate resilience (Leach, 2008; De Boer et al., 2010). *Urban Shock-Proofing* emphasises emergency management and infrastructural engineering. This lends itself well to top-down governance: it requires fast, controlled and directive action and only actors that have access to substantial information (models, data, technical know-how) and finances can play a meaningful role. This matches with centralized, decentralised or public-private governance arrangements (cf. Driessen et al., 2012), involving classic governmental and corporate actors. *Resilience Planning* has actors reflect on the interactions of many systems, developments and visions and interests for the future. This would require involvement of a wide range of partners. Likely, this leads to an interactive governance arrangement involving governmental actors, large and small companies, NGOs, residents, and creatives. However, the future-oriented, large scale perspective may mean that decentralised governments will need to spearhead these processes and implement them into urban planning and design. Governance approaches might vary per stage of resilience-building. The initial visioning may require informal, collaborative approaches (jointly seeking inspiration), whereas the final urban planning and implementation could require democratic-representative approaches (weighing options & trade-offs, seeking compromises) (cf. De Boer et al., 2010). *Community Disaster Resilience* emphasises local, community-based resilience-building. This would suggest more bottom-up, participatory governance arrangements, such as self-governance (Driessen et al., 2012), which place more power and responsibility on community actors and residents. Interactive governance could also be an option, particularly if a more active role is required of powerful actors, such as the government. Governance under this framing could stimulate citizen participation (e.g. Mees et al., 2019) and involve local NGOs, schools, citizen collectives and individual residents (e.g. Ronan & Johnston, 2005). It is important to be aware of community heterogeneity and inequalities in developing governance within this framing (Cote & Nightingale, 2012; Forsyth, 2018). *Resilient Community Development* would seem to benefit from bottom-up governance, similar to Community Disaster Resilience. However, combination of long-term and strategic aspects, and need to address short-term day-to-day challenges in vulnerable communities, can make this challenging. Therefore, it might involve interactive governance, or a combination between interactive and self-governance. Local leaders and intermediaries play key roles in engaging communities on long-term resilience (Baztan et al., 2020; Marschütz et al., 2020).

Urban actors and city departments will employ different, multiple or unclear framings in governing adaptation and resilience-building. Many cities have developed dedicated 'Resilience Offices' to steer resilience-building. These could coordinate how resilience is framed in urban climate adaptation. However, experiences in adaptation practice reveal that there are clear tensions between central coordination, bottom-up engagement, and weaving adaptation into the disparate realities and rules of different city departments (e.g. Fastiggi et al., 2020). Consequently, it is important not to simply impose a specific perspective on resilience from a top-down office, but to actively disaggregate and negotiate the meaning of resilience among the actors involved. This is necessary to avoid confusion, but also allows for useful and important reflection (Leach, 2008; Bahadur & Tanner, 2014; (Davidson et al., 2016); Walsh-Dilley & Wolford, 2015; Harris et al., 2018; Dewulf et al., 2019). Negotiated approaches to urban climate resilience will be essential to develop transparent adaptation governance: to spot where framings complement each other or have blind spots, and where actors' core values meaningfully diverge.

6.5. Implications for broader efforts to build sustainable cities and societies

Framings of resilience also impact policy integration and other comprehensive policy agendas, such as sustainability. Resilience is a holistic concept and could synergise with environmental, social and economic sustainability. However, specific framings could provide a better match with some sustainability challenges than with others. These can be explored by comparing framings with the Sustainable Development Goals (SDGs). See Table 4. The SDGs involve a variety of natural, social, short- and long-term challenges (e.g. Kelman, 2017; Skirbekk, 2020). Six goals explicitly mention resilience-building. Only three mention climate change explicitly (Kelman, 2017). Some could link with all frames: SDG11 (cities & communities), SDG13 (climate action), and likely also SDG6 (clean water & sanitation). Sirbekk (2020) notes that many SDGs deal with human needs. These connect with both community-oriented framings. Those aspects that focus on short-term coping capacity link with Community Disaster Resilience. Many, however, discuss structural socio-political determinants of climate vulnerability, such as inequalities, poverty, and lack of education, which resonate particularly well with the underdeveloped Resilient Community Development framing. Infrastructural SDGs match with Urban Shock-Proofing and sometimes Resilience Planning. SDG14 (life below water) and SDG15 (terrestrial ecosystems) resonate with Resilience Planning. They might also link Resilient Community Planning, especially in communities that are resource-driven (e.g. farming, fishing, foraging) or have vulnerable populations that are directly dependent on the local ecosystems. The SDGs and other sustainability efforts have many potential tensions and synergies, depending on how they are implemented. As cities develop both Resilience Strategies and sustainability efforts, framing may impact the extent to which they can enhance each other.

7. Conclusion

Urban resilience has become a highly popular concept in climate adaptation science and policy. This has been described as the 'Resilience Renaissance' or the 'Race for Resilience'. However, there are diverging notions of what resilience means. Different framings of urban climate resilience emphasise different problems, causes, policy options, and moral aspects.

This paper explored two key framing contrasts regarding urban resilience. The first is whether the focus is primarily on maintaining and recovering short-term equilibrium, or on facilitating long-term evolution and transformation. The second is whether the focus is primarily on systems, viewing the city in terms of components and flows, or on people and communities, viewing the city in terms of bottom-up capacities. Combining these contrasts, four specific resilience framings were identified: Urban Shock-Proofing (systems & short-term), Resilience Planning (systems & long-term), Community Disaster Resilience (communities & short-term), and Resilient Community Development (communities & long-term). Each leads to different views on the key resilience principles and mechanisms, appropriate adaptation options,

what knowledge and tools are relevant, and who should be 'in the driver's seat' when building and governing urban climate resilience. This divergence allows each framing to deal well with specific challenges, but also involves pitfalls and blind spots.

These framings show up in different scientific literatures and policy practices related to urban climate resilience. Resilience Planning was the most common framing in the corpus on urban climate resilience that was analysed in this paper. It was based in literatures on socio-ecological systems, climate change adaptation, and urban planning and design. The Resilient Community Development framing, however, seems to have received little attention. This framing deals with building communities' bottom-up capacity for self-determination and engaging with long-term change, which would seem highly important for designing comprehensive climate resilience policies. An expansion of the current scientific and institutional toolboxes is needed to support communities in developing these adaptive and transformative capacities.

Resilience framings have important consequences for research, science-policy-society interactions, practice and governance. Urban Shock-Proofing takes a mono-disciplinary approach at the level of specific systems. It leads to fairly top-down governance and a focus on critical infrastructures and extreme weather events. Resilience Planning takes an interdisciplinary, multi-system/multi-scale approach, often at city level, with particular interest in longer-term climatic changes. This leads to interactive-decentralised governance, and a focus on strategic spatial planning, climate-proof design, and knowledge-building. Community Disaster Resilience presents a distinctly social science approach to resilience, at the community level, with an interest in impacts that require community action in addition to government intervention. This leads to more bottom-up, self-governance, and a focus on improving communities' coping capacities. Resilient Community Development takes a long-term view on communities using social science and humanities, at the level of extended communities, and with an interest in the deeper socio-political causes of climate vulnerability. It leads to interactive and self-governance, and a focus on self-determination, collective action and equity. The framings also offer different opportunities for synergy with wider (urban) sustainability efforts. Resilience Planning and Resilient Community Development offer particularly broad options to link with the Sustainable Development Goals. The former with SDGs on natural and human systems (oceans, land, energy, clean water, etc.), the latter with those on human needs and socio-political determinants of vulnerability (education, equality, health, hunger, poverty, etc.).

Research on urban climate resilience often aims to be interdisciplinary and transdisciplinary. Similarly, many cities have started to set up 'Resilience Offices', urban laboratories, and similar interdisciplinary teams to bridge between actors and fields. Such collaborations will need to bridge between diverging frames of resilience as well. The framework presented in this paper can help scan for such differences in framing and initiate reflection on how different actors approach and might complement each other in building urban climate resilience.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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