Studien zur Resilienzforschung

Gérard Hutter · Marco Neubert
Regine Ortlepp *Editors*

Building Resilience to Natural Hazards in the Context of Climate Change

Knowledge Integration, Implementation and Learning

Springer

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Foreword

Throughout human history, a crucial motive in the conception and design of settlements has been the protection of people against natural hazards of diverse kinds. Across continents and cultures this has generated a wealth of solutions and processes of continuous learning, serving their purpose largely well – even if sometimes failing in the case of exceptional events. However, this basic capacity of adaptation has become undermined increasingly through modernization and is now reaching its limits in the context of the global climate crisis. On the one hand, ecological wisdom and the appreciation of local knowledge have been gradually abandoned to favour globally standardized and profit-optimized technological fixes, thereby reinforcing or even creating new climate-related vulnerabilities. On the other hand, evidence of the growing intensity and frequency of extreme events resulting from a changing climate as well as their spatial (co-)incidence in urban areas is amounting. This combination implies potentially disastrous consequences for a steadily urbanizing planet.

It is therefore not surprising that the concept of *resilience* has received growing attention in the context of urban planning and development, acknowledging that the ability to cope with risks and hazards forms a vital goal - as expressed e.g. in the UN Sustainable Development Goal 11. But while the concept as such is now widely shared and promoted, there is still an underlying tension between divergent understandings of “resilience” rooted in different disciplines and communities in research, policy, and practice. While for some the call for resilience essentially demands strengthening the robustness and quick recovery of the material urban fabric, others rather focus on enhancing social processes required to adapt and transform. These perspectives also align with different political and economic interests, considering that the former quickly translates into known measures of urban (eco-)engineering, whereas the latter asks for adopting novel forms of interaction and social learning. Apparently, both orientations are critically important but they are seldom brought into dialogue with each other.

This book takes up this challenge and unpacks notions of resilience in the context of building and planning urban areas. The expression “building resilience” used in the title thus refers to both – resilience as an *attribute* of built environs and as the *outcome* of a social process. Editors and authors draw on a range of in-depth contributions on specific natural hazards in the context of climate change (e.g., river floods, heat stress) as well as goal-driven approaches for developing resilience in local or regional settings in Germany, to underpin their proposition: Building resilience implies an integrated handling of four key aspects: 1) Resilient buildings, 2) knowledge integration, 3) local implementation, and 4) participation and multi-level governance. This may also entail recognizing that certain forms of “resilience” can be undesirable when their increase comes into conflict with other sustainability goals. Therefore, this book offers an instructive read for urban scholars and practitioners alike, inviting to rethink future research and policy agendas aimed at “urban resilience” or “climate resilience”.

Prof. Dr. Marc Wolfram
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Abbreviations[1]

BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (Federal Ministry for Environment, Nature Conservation, and Nuclear Safety)
DAS	Deutsche Anpassungsstrategie an den Klimawandel (German strategy for climate change adaptation)
DIN	Deutsche Industrienorm (German industrial standard)
DLR	Deutsches Zentrum für Luft- und Raumfahrt (DLR Projektträger) (German Aerospace Center (DLR Project management agency))
DWA	Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (German Association for Water, Wastewater and Waste)
EEWärmeG	Erneuerbare-Energien-Wärmegesetz (German renewable energies heat law)
EnEV	Energieeinsparverordnung (German energy saving regulation)
ESS	Ecosystem services (Ökosystemleistungen)
EU	Europäische Union (European Union)
GEG	Gebäudeenergiegesetz (German building energy law)
GRUWAD	Schadenssimulationsmodell für Grundhochwasser (groundwater damage simulation model)

[1] The list considers selected abbreviations that are used in the chapters of this edited volume. Abbreviations that are not listed above and that are nevertheless used in the volume are explained in the individual chapters.

GZG	Gründerzeitgebäude (Wilhelminian-style apartment building)
HOWAD	Hochwasserschadens-Simulationsmodell (flood damage simulation model)
Kh	Kelvin hours
Kh/a	Kelvin hours per year
LAWA	Bund/Länder-Arbeitsgemeinschaft Wasser (German Working Group on water issues)
PCM	Phase Change Materials
SächsNatSchG	Sächsisches Naturschutzgesetz (Nature conservation act of Saxony)
SächsWG	Sächsisches Wassergesetz (Saxon water law)
SMUL	Sächsisches Staatsministerium für Umwelt und Landwirtschaft (Saxon State Ministry of the Environment and Agriculture)
Tmax	Maximum Temperature
UBA	Umweltbundesamt (German Environment Agency)
WHG	Wasserhaushaltsgesetz (German water resources law)

Building Resilience to Natural Hazards in the Context of Climate Change—Introducing the Focus and Agenda of the Edited Volume

1

Gérard Hutter, Marco Neubert, and Regine Ortlepp

1.1 Purpose and Focus of the Volume

The decade from the year 2011 to the year 2020 was the "hottest" in history and the average global temperature by 2020 has risen by 1.2 °C since the start of the industrial era (see IPCC 2018 for more details). With extreme weather events becoming more frequent and prospects of the negative impacts of climate change intensifying, the need to enhance resilience is obvious.

Resilience has become the hope for many that cities and regions as well as whole societies are increasingly capable of dealing with risk and uncertainties related to natural hazards in the context of climate change, especially extreme events and their potentially disastrous consequences. Consequently, the bodies of literatures on resilience, natural hazards, and climate change are continuously growing. There are manifold references to resilience concepts like "urban resilience" (Coaffee and Lee 2016; Coaffee et al. 2018; Elmqvist et al. 2019; Meerow et al. 2016) and "urban disaster resilience" (e.g., Zhang et al. 2020).

This edited volume follows the purpose of making a focused contribution to these growing literatures. We as editors (and authors) and our collaborators want

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to provide a coherent set of conceptual and empirical contributions to the overall theme of the volume "Building resilience to natural hazards in the context of climate change—Knowledge integration, implementation, and learning". Theoretical and methodological arguments remain in the background of argumentation. The following explains further what coherence in our context of research and practice means.

Coherence results from the focus of this edited volume on issues of *climate change adaptation at local and regional level in cases from Germany*. Climate policy and governance are both based on climate change mitigation and adaptation. However, the contributions to this volume are more about the latter than the former. Policies and governance arrangements *above* local and regional level are important background conditions of efforts to build resilience in cities and regions (e.g., IPCC 2018; see Biesbroek and Swart 2019 on the adaptation strategy of the EU; Die Bundesregierung 2020; Vetter et al. 2017). We assume that cities and regions, especially actors in large cities, have significant leeway to establish their "own" specific efforts of building resilience to natural hazards. We understand building resilience as a core element of urban resilience. The expression "building resilience" refers to both (1) social processes of increasing resilience and (2) intended change of the building stock and related blue and green infrastructures (including open spaces and urban greenery) as well as intended change of grey infrastructures.

It has become common to consider the high diversity of understandings of resilience in research and practice.[1] Not surprisingly, readers will *not* find only one specific understanding of resilience in this edited volume. This is so not least because engineers, physical geographers, social scientists, and urban planners have contributed to this volume and resilience is therefore contextualized in diverse "messy histories" (Ansell 2019, p. 3) of research streams on dealing with crisis, catastrophe, risk, and uncertainty.

Coherence results especially from efforts of the contributors to argue about resilience with regard to specific natural hazards, actors involved in dealing with such hazards and their actual and possible consequences for the stock of buildings and infrastructures in cities and regions. Contributions mainly deal with river floods and risk related to heavy rain fall as well as rising temperatures, heat waves and associated droughts in urban areas. Hence, only selected issues of high

[1] Some even state that the resilience word may have only "low scientific status" (Jore 2020); see also Brand and Jax (2007) with regard to resilience as "boundary object" in contrast to resilience as narrowly defined concept of high scientific status that is useful in empirical analysis.

priority of the German strategy for climate change adaptation are addressed in this volume (Die Bundesregierung 2020).

It is interesting to see that one of the most widely mentioned arguments *for* resilience is the positive connotation of the word in the context of uncertainty and crisis (Meerow et al. 2016; Abeling et al. 2018; Die Bundesregierung 2020). In policy contexts and at the interface of policy, practice, and research, resilience in general, climate and building resilience in particular, may serve as a somehow fuzzy or ambiguous reference point for communication among public, private, and intermediary actors. Compared to this, the agenda of the volume is relatively focussed. Contributions deal with issues of knowledge integration, implementation, and learning in cities and regions. The following further elaborates on this agenda.

1.2 Introducing the Agenda

An agenda summarizes the main topics of a communication format and indicates why the selected topics are in the foreground of discussion. It may entail priorities between topics. The agenda of this edited volume encompasses four main topics:

- Building resilience as a core element of urban resilience,
- Knowledge integration,
- Implementation at local level,
- Learning in the context of participation and multi-level governance.

The following briefly comments on each point in turn.

1.2.1 Building Resilience as a Core Element of Urban Resilience

The term “resilience” is used in many research efforts, policy discourses, and practices of climate change adaptation. The term is related to a broad spectrum of phenomena. For instance, psychologists focus on the resilience of individual persons (Masten 2014). Management and organizational scholars highlight the conditions and social processes of organizations in the context of volatile markets and unexpected events (Weick and Sutcliffe 2015). Governance researchers address the resilience of public administrations and governance arrangements (Duit 2016). Economic geographers are interested in resilience as capability and condition of regional growth pathways (Boschma 2015). Researchers that engage in research on Social-Ecological Systems (SES) follow the most encompassing view on processes of resilience in which diversified, but nested systems are related through dynamic processes that generate social-ecological resilience (or not) (Elmqvist et al. 2019; Folke et al. 2010; Deppisch 2017). Scholars interested in the question how cities and regions deal with past crises and catastrophes as well as future risks and uncertainties may prefer the concept of "urban resilience" (e.g., Coaffee and Lee 2016; Coaffee et al. 2018). Some scholars argue that high diversity of resilience understandings has turned the term into something of "poor scientific status" (Jore 2020, p. 15) or—even worse—into something that is "vulnerable" to ideology-driven misuse and over-biased policy-making (e.g., neoliberal policies of allocating responsibility to private actors, for instance, citizens that need to prepare for low-probability events in the context of climate change, Coaffee and Lee 2016; Tierney 2015; see also the contribution of Zimmermann and Lee in this volume).

We assume that the term "resilience" helps, if the multiplicity of possible meanings of the word is taken into due account (Davoudi 2018) and if contributors to the volume consider the historical context[2] of how they understand resilience in their argumentation. We understand building resilience as one core element of urban resilience. "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" (Meerow and Newell 2016, p. 7). Some comments on this understanding are in order (see also Elmqvist et al. 2019): Firstly, urban resilience is framed as an *ability* (or capacity) to deal with disturbance and change. Hence, this definition does not highlight the usage of resilience for ideological and political purposes (e.g., resilience as a "myth", Kuhlicke 2013). Of course, we do not deny that such usage of the term is possible (e.g., Hutter and Lorenz 2018). Secondly, resilience refers to an urban *system*. The term "system" also has multiple meanings, for instance, with regard to a specific system theory (e.g., systems as closed or open systems). In this introduction, "system" simply means that urban resilience emerges from complex processes that relate manifold

[2] With regard to the general problem of "conceptual pluralism", Ansell (2019) speaks of partly overlapping, partly different entailments of one term in the context of "messy histories" of research streams that use the same word in different scientific disciplines, debates, and policy discourses. Conceptual pluralism happens in many research streams and policy discourses (e.g., strategy, governance, and knowledge, to name just a few terms). Ansell (2019) underlines that conceptual pluralism is here to stay, so we have to deal with it without oversimplification of diverse contexts and messy histories.

physical and social elements and multiple spatial and temporal scales—more or less directly coupled. Thirdly, this definition of urban resilience is a broad one, because it refers to the ability to maintain functions, to adapt to future change, and to transform for more resilience in the future (Elmqvist et al. 2019).

The expression "building resilience" refers to both *social processes* and *physical outcomes.* As outcome, building resilience means intended change of the building stock and related blue, green, and grey infrastructures in urban areas. As social process, building resilience refers to process patterns through which urban systems develop more resilience in the future. Building resilience as social process corresponds with strategies for the mid- to long-term (e.g., Comfort et al. 2010; Chelleri et al. 2015). We cannot provide a comprehensive picture of many process patterns that are important for building resilience. We focus on *goal-driven* processes of building resilience ("goal-driven" is similar to "teleological", Van de Ven and Poole 1995): Actors involved in urban systems are (to some extent) dissatisfied with the status quo. They envision improvements and formulate goals. They undertake individual and collective efforts of knowledge integration and implementation, and they seek to learn from experience (including "anticipated experience", for instance, through scenario-based learning). We highlight three process patterns[3]: (1) Knowledge integration, (2) implementation on the level of the local building stock, related infrastructures and open spaces, and (3) learning in the context of participation and multi-level governance.

1.2.2 Knowledge Integration

Tell (2011) distinguishes between three approaches to knowledge integration: Knowledge integration as (1) sharing or transferring knowledge, (2) as use of similar/ related knowledge in a specialized knowledge domain, and (3) as the combination of specialized, but complementary knowledge. In this volume, we emphasize *knowledge integration as the purposeful combination of specialized and complementary knowledge to accomplish specific tasks.* Knowledge integration in this understanding is especially important for building resilience, because

[3]This does not necessarily mean that every contribution to the volume addresses issues with regard to all three process patterns. Usually, there is an emphasis on one selected pattern (e.g., see the contribution by Hutter et al. in this volume on knowledge integration). Sometimes, authors address issues of knowledge integration and implementation (practicability), e.g., see the contributions by Olfert et al. in this volume on sustainability and resilience and of Ortlepp et al. on building heat-resilient neighborhoods).

enhancing the ability to persist, adapt, and transform in the face of disturbances and changes often requires the inclusion of actors from different knowledge domains, with different interests, and different responsibility (e.g., citizens from a specific neighbourhood, spatial planners responsible for this neighbourhood, local politicians as members of the city council, and experts from water and crisis management research and practice). Manifestations of knowledge integration may be found in inter- and transdisciplinary research projects (Hirsch Hadorn et al. 2008). Furthermore, contributions to the resilience literatures often highlight the challenge of overcoming "knowledge silos" based on institutionalized responsibility and accountability, administrative procedures and politics. They point into the direction of enhancing collaboration and knowledge integration to meet the challenge of "urban resilience implementation" (e.g., Coaffee et al. 2018).

Building resilience to natural hazards in the context of climate change is a knowledge-intensive process across multiple social, spatial, and temporal scales. Of course, integrating *all* knowledge (or as much knowledge as possible) in the sense of an intended maximum of sharing and transferring knowledge is *inefficient*. Specialization of knowledge domains on the one hand and knowledge integration on the other need to go "hand in hand", but this does not easily happen in cities and regions. As project examples on climate change adaptation in cities and regions in the Dresden region show (see Neubert & Schinke, Ortlepp and colleagues, as well as Hutter & Olfert in this volume), researchers and practitioners alike may experience difficult times trying to integrate knowledge and to learn how to build resilience over the mid- to long term. Limitations in efforts of knowledge integration have many causes and consequences and the contributions to the volume explore this complexity to some extent (see below).

Integrating scientific and professional knowledge that focuses on descriptive and explanative knowledge is an important effort in building resilience. However, knowledge integration also encompasses efforts of integrating "facts" and "values" (e.g., systems knowledge, target knowledge, and transformation knowledge, Hirsch Hadorn et al. 2008). Facts may continuously be the object of update and reconsideration. In contrast, values are often embedded in "messy histories" (Ansell 2019, p. 3) of complex justifications and institutions in society—as the contribution of Thaler on resilience and justice in flood risk management shows (Chap. 3, see also the contribution by Zimmermann and Lee, Chap. 9 in this volume). As editors, we can quite easily contend that issues of justice in building resilience to natural hazards need more in-depth consideration. However, much remains to be accomplished to establish justice as a core element of building resilience to natural hazards in urban areas (Davoudi 2018; Ziervogel et al. 2017). Furthermore, we need practical approaches that show how the complexity of value-related criteria of sustainability and resilience can be considered "on the ground" in urban systems (see the contribution of Olfert and colleagues in this volume).

1.2.3 Implementation at Local Level

Implementation in this volume means, first and foremost, that specific measures to physically and intentionally change the building stock as well as related blue, green, and grey infrastructures have been accomplished in the "real world". We cannot provide a survey of measures that have been realized in a population of cases (Gerringson and Christenson 2017).[4] The contributions to the volume focus on selected cases of implementation and report on these cases in vivid detail (e.g., see contributions by Ortlepp and colleagues as well as Eisenberg and colleagues). They show that incremental changes for building resilience may require intensive communication processes and resource allocations of the actors involved. Furthermore, contributions ask how participatory and communicative instruments can motivate private actors such as residents of flood-prone urban areas to make structural changes in their homes (e.g., Grothmann & Michel).

As mentioned, this volume focuses on conceptual and empirical contributions. Hence, theory-justified explanations of implementation issues are not of high priority. However, the empirical accounts point to some important factors for future studies. Adopting the perspective of collaborative policy making, Ansell and colleagues (2017) distinguish between four typical failures of policy implementation: Design failure, top-down-failure, bottom-up failure, and limits of steering capacity of public actors with regard to private and intermediary agents. The contributions to the volume give manifold insights how to avoid design failure on the local level with regard to specific contents of building resilience. They point to factors that limit public steering capacity (e.g., spatially and socially fragmented property rights of buildings). We address issues of top-down- and bottom-up failure under the topic of learning.

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[4]Some survey information on the "state of work" of implemented measures for climate change adaptation on local level (municipalities in a formal sense) can be found in the „Zweiter Fortschrittsbericht zur Deutschen Anpassungsstrategie an den Klimawandel " (Die Bundesregierung 2020, especially part B.3 on implementation).

1.2.4 Learning in the Context of Participation and Multi-level Governance

Learning is a manifestation of “human agency” (Emirbayer and Mische 1998). Many scholars would probably agree that learning happens, if actors show efforts of reflection and deliberate change in knowledge on relations between the content, processes, and context conditions of action (e.g., Carroll et al. 2003). Different theories and models seek to differentiate between how this happens, the degree of deliberateness of change, various types of knowledge, and so forth (Biggs et al. 2015). Learning can refer to experience in the past and anticipated “experience”. Learning may also mean learning when and why *not to change* knowledge (Weick and Westley 1996).

The edited volume is open with regard to the learning patterns addressed, but tries to focus on *similar occasions for learning*. In the context of climate change adaptation policy in Germany, a significant number of pilot projects and innovative actions have been undertaken at local and regional level (see Die Bundesregierung 2020; see Turnheim et al. 2018 for case studies in European member states). Some pilot projects were justified and established through referring to the notion of resilience. Other projects may have contributed to building resilience without explicitly using the term. In the edited volume, we are interested in both types of pilot projects and innovative actions (see, for instance, the contributions by Neubert & Schinke, Ortlepp and colleagues as well as Hutter & Olfert on pilot projects in the Dresden region).

Learning as a social process is related to the context conditions and contents of building resilience to natural hazards. The contributions to the edited volume address issues of learning at local and regional level. For instance, the contribution by Grothmann and Michel investigates the effectiveness of participation processes for building resilience in four German cities (Bremen, Kempten, Lübeck, Worms), focusing on learning effects regarding knowledge gains, behaviour change and building of social capital. Karsten Zimmermann and Dahae Lee address the dynamics of building resilience at multiple governance levels in the Ruhr region.

Taken together, these contributions show that design choices based on “facts and figures” are not sufficient for building resilience to natural hazards in the context of climate change. Even intended incremental changes do not happen easily and without continuous efforts of actors in urban regions to build resilience in the mid- to long-term. Pathways of transformations to increase the resilience of urban systems entail much higher complexity and much more dynamic relations at multiple social, spatial, and temporal scales (e.g., Birkmann et al. 2016; Elmqvist et al. 2019; Endlicher and Kress 2008; Köhler et al. 2019; Pelling, 2011; Wolfram, 2016). We understand this edited volume as a coherent set of conceptual and empirical contributions that facilitate future studies on pathways to increase adaptive and transformative capacity for building urban resilience and for dealing with the consequences of climate change.

1.3 Overview Over the Contributions to the Volume

We structured the contributions to the volume roughly in accordance with two ideas: Firstly, we followed the trinity of knowledge integration, implementation, and learning. All contributions seek to consider contents, processes, and context conditions of building resilience. However, chapters that address issues of knowledge integration and implementation emphasize contents, whereas chapters that follow a learning orientation highlight processes and context conditions like participation, multi-level governance, and project-based learning. Secondly, contributions are clustered according to the natural hazards that are in the foreground of argumentation. We begin with three chapters that highlight river floods, especially low-probability flood events. Chapters on heat stress and associated droughts as well as on managing the risk of heavy rain fall follow.

Gérard Hutter and colleagues focus on the topic of *"Knowledge integration for building resilience—The example of flood risk maps"*. This conceptual contribution emphasizes knowledge integration as purposeful combination of specialized and complementary knowledge to accomplish a specific task. The example of developing flood risk maps illustrates knowledge integration. Thereby, the authors use the well-known distinction between specified and general resilience. They understand developing flood risk maps as manifestation more of the former than the latter, especially with regard to low-probability flood events. The chapter shows how to combine concepts of (interdisciplinary) knowledge integration and concepts of urban resilience (including secondary effects of floods through increases in groundwater levels in urban areas).

Thomas Thaler provides a conceptual contribution on the topic of *"Justice and resilience in flood risk management: What are the socio-political implications?"*. He argues that flood risk management requires to comprehensively assess how policies may affect individuals and communities, but actual policies and practices often downplay or even increase social inequality. His contribution critically questions the roles of social justice and their political implications for flood risk management with regard to resilience. The chapter considers a broad range of concepts as well as different perspectives on justice (e.g. social, environmental and climate justice). The author urges us to take concepts of justice more seriously when discussing issues of resilience and flood risk management.

Marco Neubert and Reinhard Schinke analyse the topic of *"House lifting to improve resilience in Settlement Areas—an example from the Elbe village Brockwitz (Saxony, Germany)"*. They empirically compare the traditional flood protection measure of dyke construction with the measure of house lifting including land filling for a small-scale area (the Elbe village of Brockwitz/Coswig in Saxony, Germany). The interdisciplinary analysis of the two alternatives considers a complex set of criteria of sustainability and resilience and shows that house lifting has, among others, specific advantages with regard to the consequences of low-probability flood events. The chapter shows how to apply efforts of knowledge integration "on the ground" of building resilience at the local level.

The challenge of integrating criteria of sustainability and resilience is also in the foreground of the chapter provided by Alfred Olfert and colleagues on *"Sustainability and resilience—A practical approach to assessing sustainability of infrastructures in the context of climate change"*. Based on extensive empirical work, they propose a new evaluation tool for in-process sustainability assessment of local infrastructure innovation designed for early stage phases of development. This tool treats resilience as integral part of sustainability. They focus on the resilience of socio-eco-technical infrastructure systems at the local level to external disturbances such as climate change-influenced weather extremes. As a reference for the sustainability check, an operational stability-oriented understanding of resilience ("bounce back") based on "engineering resilience" is adopted. Among others, they argue that the sustainability assessment tool helps to mediate between diverse professional perspectives and, hence, supports, knowledge integration.

Issues of building resilience to heat stress and droughts are addressed in the chapter of Regine Ortlepp and colleagues on *"Heat-resilient neighbourhoods—Testing the implementation on buildings and in open spaces in two sample quarters Dresden and Erfurt"*. The chapter reports on measures that were implemented in two sample quarters in the cities of Dresden and Erfurt. A complex set of measures addresses intended change on the building scale and with regard to green and open spaces. The selection of measures for evaluation and implementation took place on the basis of an inter- and transdisciplinary process to consider both scientific effectiveness analysis and how measures are perceived and accepted by residents. The chapter also reports on measures that were planned to be implemented, but could not be implemented due to various reasons. Like the chapter of Marco Neubert and Reinhard Schinke, the chapter takes us "on the ground" of building resilience to natural hazards in urban areas. The chapter is relevant for issues of knowledge integration and implementation.

Bernd Eisenberg and colleagues report on *"The Impulse Project Stuttgart—Stimulating resilient urban development through blue-green infrastructure"*. They argue that, given increasing temperatures and less summer precipitation due to climate change, the maintenance and management of green spaces is essential and challenging. The chapter describes the development and implementation of a one-on-one model for urban resilience on the building scale. Designed as both a public space with high aesthetic value and an open lab, it also serves as a starting point for a debate about resilient urban development through blue-green infrastructure in Stuttgart and elsewhere. The Impulse Project Stuttgart shows how compact blue-green infrastructure can be successfully implemented in densely populated urban spaces, thereby significantly contributing to the urban microclimate, flood protection during stormwater events, and alleviating the demand for drinking water through its substitution with rainwater and greywater.

Scholars and practitioners alike argue that building resilience involves participation. In this context, Torsten Grothmann and Theresa Michel report empirical findings on *"Participation for building urban climate resilience? Results from four cities in Germany"*. They observe a lack of evaluation studies that empirically validate the many expected positive effects of participatory approaches. The authors develop a new resilience concept differentiating three dimensions: resilience knowledge, action and network. They apply this concept to the evaluation of eight government-led public participation events on adaptation to climate change, particularly to increasing heavy rain events, in four cities in Germany (Bremen, Kempten, Lübeck, Worms). Results of the participant questionnaires indicate that the events were effective in increasing participants' knowledge (particularly knowledge integration), action (supporting rather than triggering action) and networks. But increases were only moderate and could not be achieved for all participants. Hence, Grothmann and Michel conclude that the positive effects of participatory approaches on building resilience should not be overestimated. The chapter also addresses the important issue of assigning and sharing responsibilities for building resilience between public and private actors.

Karsten Zimmermann and Dahae Lee approach the topic of *"Building resilience in the context of multi-level governance—Insights from a living lab in the Ruhr"* from a critical perspective. Like others, they observe that the term "resilience" is used in an inflationary way and recent publications discuss resilience critically. They acknowledge that much of the criticism of the fashionable notion of resilience does make some sense, but they still argue that the resilience word has theoretical and practical value as it points to the capacity to change a city or region. This includes collective learning and multilateral forms of governance and a stronger recognition of city-region governance. However, what is missing in debates is a stronger consideration of the political science literature on governance, decentralization and public policy analysis. They illustrate their argumentation through referring to a case study from the project "Future of the City-Region Ruhr" (Zukunft-Stadt-Region-Ruhr, ZUKUR).

Gérard Hutter and Alfred Olfert provide a conceptual contribution on *"Project-based learning for building urban resilience—Reflecting on project examples of climate change adaptation in the Dresden region"*. They ask how partners in projects on climate change adaptation contribute to building urban resilience, if such resilience is understood as ability of permanent evolutionary urban systems and if projects are understood as temporary designed collective actions. The authors develop the outline of a new typology that considers two dimensions: Learning options may vary with regard to whether learning agents consider whole systems or only sub-units of a system. Opportunities further vary with regard to whether agents aim to increase adaptive capacity or also transformative capacity. They illustrate this learning approach through two project examples on climate change adaptation in the Dresden region (REGKLAM with a duration from 2008 to 2013 and HeatResilientCity (HRC) with a duration from 2017 to 2021).

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References

Abeling, T., Daschkeit, A., Mahrenholz, P., & Schauser, I. (2018). Resilience—A useful approach for climate adaptation? In A. Fekete & F. Fiedrich (Eds.), *Urban disaster resilience and security. Addressing risks in society* (pp. 461–471). Cham: Springer.

Ansell, C. (2019). Coping with conceptual pluralism: Reflections on concept formation. *Public Performance & Management Review*, 1–22

Ansell, C., Sørensen, E., & Torfing, J. (2017). Improving policy implementation through collaborative policymaking. *Policy & Politics, 45*(3), 467–486

Biesbroek, R., & Swart, R. (2019). Adaptation policy at supranational level? Evidence from the European Union. In E. C. H. Keskitalo & B. L. Preston (Eds.), *Research handbook on climate change adaptation policy.* (pp. 194–211) Cheltenham: Edward Elgar.

Biggs, R., Schlüter, M., & Schoon, M. L. (Eds.). (2015). *Principles for building resilience: Sustaining ecosystem services in social-ecological systems.* Cambridge: Cambridge University Press.

Birkmann, J., Wenzel, F., Greiving, S., Garschagen, M., Vallée, D., Nowak, W., Welle, T., Fina, S., Goris, A., Rilling, B., Fiedrich, F., Fekete, A., Cutter, S. L., Düzgün, S., Ley, A., Friedrich, M., Kuhlmann, U., Novák, B., Wieprecht, S., … Mitchel, J. K. (2016). Extreme events, critical infrastructures, human vulnerability and strategic planning: Emerging research issues. *Journal of Extreme Events, 3*(4), 1–25

Boschma, R. (2015). Towards an evolutionary perspective on regional resilience. *Regional Studies, 49*(5), 733–751

Brand, F. S., & Jax, K. (2007). Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. *Ecology and Society, 12*(1), 1–16

Carroll, J. S., Rudolph, J. W., & Hatakenaka, S. (2003). Learning from organizational experience. In M. Easterby-Smith & M. A. Lyles (Eds.), *The Blackwell handbook of organizational learning and knowledge management* (pp. 575–600). Malden: Blackwell.

Chelleri, L., Waters, J. J., Olazabal, M., & Minucci, G. (2015). Resilience trade-offs: Addressing multiple scales and temporal aspects of urban resilience. *Environment & Urbanization, 27*(1), 181–198

Coaffee, J., & Lee, P. (2016). *Urban resilience. Planning for risk, crisis, and uncertainty.* London: Palgrave.

Coaffee, J., Therrien, M.-C., Chelleri, L., Henstra, D., Aldrich, D. P., Mitchell, C. L., Tsenkova, S., & Rigaud, É. (2018). Urban resilience implementation: A policy challenge and research agenda for the 21st century. *Journal of Contingencies and Crisis Management, 26*, 403–410

Comfort, L. K., Boin, A., & Demchak, C. C. (2010). Resilience revisited. An action agenda for managing extreme events. In L. K. Comfort, A. Boin, & C. C. Demchak (Eds.), *Designing resilience. Preparing for extreme events* (pp. 272–284). Pittsburgh: University of Pittsburgh Press.

Davoudi, S. (2018). Just Resilience. *City & Community, 17*(1), 3–7

Deppisch, S. (Ed.). (2017). *Urban regions now & tomorrow. Between vulnerability, resilience and transformation.* Wiesbaden: Springer.

Die Bundesregierung. (2020). *Zweiter Fortschrittsbericht zur Deutschen Anpassungsstrategie an den Klimawandel.* o. A.

Duit, A. (2016). Resilience thinking: Lessons for public administration. *Public Administration, 94*(2), 364–380

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., & Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability, 2*(4), 267–273

Emirbayer, M., & Mische, A. (1998). What is agency? *American Journal of Sociology, 103*(4), 962–1023

Endlicher, W., & Kress, A. (2008). Wir müssen unsere Städte neue erfinden. *Anpassungsstrategien für Stadtregionen. Informationen Zur Raumentwicklung, 6*(7), 437–445

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society, 15*(4), 1–9

Gerring, J., & Christenson, D. (2017). *Applied social science methodology. An introductory guide*. Cambridge: Cambridge University Press.

Hirsch Hadorn, G., Biber-Klemm, S., Grossenbacher-Mansuy, W., Hoffmann-Riem, H., Joye, D., Pohl, C., Wiesmann, U., & Zemp, E. (2008). The emergence of transdisciplinarity as a form of research. In G. Hirsch Hadorn, H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, U. Wiesmann, & E. Zemp (Eds.), *Handbook of transdisciplinary research* (pp. 19–39). Wiesbaden: Springer.

Hutter, G., & Lorenz, D. F. (2018). Social resilience. In S. Fuchs & T. Thaler (Eds.), *Vulnerability and resilience to natural hazards.* (pp. 190–213) Cambridge: Cambridge University Press.

IPCC. (2018). Summary for Policymakers. In Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J. B. R., Chen, Y., Zhou, X., Gomis, M. I., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (Eds.), *Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (pp. 1–32). Geneva: World Meteorological Organization.

Jore, S. H. (2020). Is resilience a good concept in terrorism research? A conceptual adequacy analysis of terrorism resilience. *Studies in Conflict & Terrorism*, 1–20

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation & Societal Transitions, 31*, 1–32

Kuhlicke, C. (2013). Resilience: a capacity and a myth: Findings from an in-depth case study in disaster management research. *Natural Hazards, 67*, 61–76

Masten, A. S. (2014). Global perspectives on resilience in children and youth. *Child Development, 85*(1), 6–20

Meerow, S., & Newell, J. P. (2016). Urban resilience for whom, what, when, where, and why? *Urban Geography*, 1–21

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning, 147*, 38–49

Pelling, M. (2011). *Adaptation to climate change. From resilience to transformation.* London: Routledge.

Tell, F. (2011). Knowledge integration and innovation: A survey of the field. In C. Berggren, A. Bergek, L. Bengtsson, M. Hobday, & J. Söderlund (Eds.), *Knowledge integration and innovation. Critical challenges facing international technology-based firms* (pp. 20–38). Oxford: Oxford University Press.

Tierney, K. (2015). Resilience and the neoliberal project: Discourses, critiques, practices—And Katrina. *American Behavioral Scientist, 59*(10), 1327–1342

Turnheim, B., Kivimaa, P., & Berkhout, F. (Eds.). (2018). *Innovating climate governance. Moving beyond experiments*. Cambridge: Cambridge University Press.

Van de Ven, A. H., & Poole, M. S. (1995). Explaining development and change in organizations. *Academy of Management Review, 20*(3), 510–540

Vetter, A., Chrischilles, E., Eisenack, K., Kind, C., Mahrenholz, P., & Pechan, A. (2017). Anpassung an den Klimawandel als neues Politikfeld. In G. P. Brasseur, D. Jacob, & S. Schuck-Zöller (Eds.), *Klimawandel in Deutschland.* (pp. 325–334) Berlin: Springer.

Weick, K. E., & Sutcliffe, K. M. (2015). *Managing the unexpected. Sustained performance in a complex world*. Hoboken: Wiley.

Weick, K. E., & Westley, F. (1996). Organizational learning: Affirming an oxymoron. In S. R. Clegg, C. Hardy, & W. R. Nord (Eds.), *Handbook of organizational studies.* (pp. 440–458) London: SAGE.

Wolfram, M. (2016). Conceptualizing urban transformative capacity: A framework for research and policy. *Cities, 51*, 121–130

Zhang, Q., Hu, J., Song, X., Li, Z., Yang, K., & Sha, Y. (2020). How does social learning facilitate urban disaster resilience? *A Systematic Review. Environmental Hazards, 19*(1), 107–129

Ziervogel, G., Pelling, M., Cartwright, A., Chu, E., Deshpande, T., Harris, L., Hyams, K., Kaunda, J., Klaus, B., Michael, K., Pasquini, L., Pharoah, R., Rodina, L., Scott, D., & Zweig, P. (2017). Inserting rights and justice into urban resilience: A focus on everyday risk. *Environment & Urbanization, 29*(1), 123–138

2 Knowledge Integration for Building Resilience—the Example of Flood Risk Maps

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2.1 Introduction

Surprisingly little systematic attention has been devoted to thinking about knowledge integration for building resilience in cities and regions. Researchers and practitioners alike have been more concerned about the diversity of meanings of the term "resilience" (e.g., engineering, ecological, and evolutionary resilience), its manifold potential manifestations (from the resilience of children to socio-ecological resilience of whole urban systems), and its complex and perhaps also ambiguous relations to other guiding ideas like sustainability, vulnerability, and

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climate change adaptation (e.g., Brand & Jax, 2007, Bruijne et al. 2010; Coaffee & Lee, 2016; Meerow & Newell, 2016; Abeling et al. 2018; Davoudi, 2018; Fuchs & Thaler, 2018; Hein & Schubert, 2020).

Many scholars and practitioners would probably agree that building resilience to natural hazards in the context of climate change in urban regions is a knowledge-intensive process and also a process characterized by manifold types and forms of knowledge. For instance, if individual persons, small groups of people interested in enhancing resilience to natural hazards, organizations responsible for specific tasks to deal with natural hazards and their consequences, as well as networks of organizations are relevant for building resilience, how then is knowledge integrated across these different *scales of social action*? If innovative solutions are important to build resilience (e.g., in the context of extreme flood events), how then are different *types of knowledge* combined to create such solutions (e.g., expert knowledge on flood hazards and damage potentials, political knowledge, and local knowledge about the behaviour of residents and business organizations)? Furthermore, knowledge may refer to diverse *temporal and spatial scales*. For instance, knowledge about the past and the next years to come is different to knowledge that refers to climate change and its consequences up to the year 2100 with regard to issues of validity and salience for present action.

Knowledge integration is at the heart of building resilience to natural hazards and this topic deserves more attention in research and practice. Up to now, it is not uncommon that efforts of knowledge integration are mainly *implicit* in contributions to resilience research and practice. In this chapter, we want to be explicit about the relations of knowledge integration and building resilience, especially in the sense that knowledge integration can be understood as a "means" (or "tool", "instrument") to the "end" of resilience building ("aim").

Unfortunately, we cannot yet provide neither deep qualitative empirical findings nor "hard" evidence in terms of quantitative findings on the topic (Gerring & Christenson, 2017). Therefore, this chapter addresses knowledge integration for building resilience on a *conceptual* level. It proposes a specific understanding of knowledge integration (Tell, 2011), illustrates this understanding, and then shows that knowledge integration has at least two important conceptual relations to building resilience: the commitment to both specific and general resilience (Folke et al. 2010) at a *micro level of social action* (e.g., Weick & Sutcliffe, 2015) and enhancing knowledge integration in *urban systems* characterized by complex social, spatial, and temporal scales (urban resilience, Meerow et al. 2016). This conceptualization of knowledge integration for building resilience, we argue, is especially appropriate to consider natural hazards in the context of climate change adaptation characterized by uncertainty and surprise (e.g., Schneider, 1998).

The chapter is structured as follows: Firstly, we focus on knowledge integration as purposeful combination of specialized and complementary knowledge to accomplish specific tasks. Secondly, we illustrate this focus through referring to examples of flood risk maps in urban regions. Thirdly, we explain how actors relevant for building resilience in cities and regions may balance efforts of specific and general resilience without overestimating the relevance of one or the other. Fourthly, efforts of building resilience to natural hazard are placed in the context of urban systems (urban resilience). Fifthly, we conclude through looking out on future research and practice.

2.2 Three Approaches to Knowledge Integration

It is common to distinguish between knowledge, information, and data (e.g., Al-Laham, 2003 in management research, Willke, 2001 in sociology, Zimmermann, 2010 in urban planning research). Two characteristics are crucial to understand knowledge: Firstly, knowledge emerges through the combination of information and data over time and through *synthesizing* the latter on a relatively high level of abstraction. Secondly, knowledge is embedded in the experience of actors and experience is context-specific, but actors seek to draw some general lessons from experience (March, 2010; March et al. 1991). Knowledge is commonly understood as the content of learning (Carroll et al. 2003), learning being a process that is characterized by knowledge *change* (see the chapter by Hutter & Olfert in this volume).

Even if knowledge is the content of learning, it may *refer* to the contents, processes, and context conditions of experience. There are many classifications and typologies of knowledge (e.g., explicit and tacit/implicit knowledge; know-what, know-how, know-who, know-when, and so forth; knowledge about the past, present, and future, Al-Laham, 2003; organizational knowledge as epistemology of possession and organizational knowing as epistemology of practice, Cook & Brown, 1999). Furthermore, there is a high diversity of knowledge domains and related forms of knowledge (e.g., expert knowledge, political knowledge, local knowledge, Zimmermann, 2010). Scholars involved in transdisciplinary research distinguish between systems knowledge, target knowledge, and transformation knowledge (e.g., Hirsch Hadorn et al. 2008, 31). How the term “knowledge” is understood and used depends on the conceptual framework and, of course, on the topic chosen (Weick, 1995).

If there is high diversity of knowledge types and forms, how then is it possible to accomplish the task of knowledge integration? Following Tell (2011), we distinguish between three approaches to knowledge integration[1]:

- *Sharing and transferring knowledge:* In principle, sharing may have two meanings that is possessing the same knowledge on the one hand and dividing knowledge into parts and distributing it to different people on the other (Weick, 1995). We only refer to the first meaning in this chapter. When at least two actors A and B share the same "body" of knowledge, this can be interpreted as redundancy in social action: actor A knows what actor B knows. Knowledge transfer is the process through which actors realize knowledge sharing. The main concern of transfer is matching message and medium (Van de Ven, 2007). *After* knowledge transfer, A knows what B already knew. Grant (1996) points out that it is inefficient, if actors share *all* knowledge.
- *Using similar/related knowledge:* The second approach is characterized by adopting a body of similar or related knowledge domains to accomplish a specific task. The term "integration" does not primarily refer to relations between the domains of knowledge involved, but to the common task and context of application. Efforts of integration are necessary and possible, because the accomplishment of a specific task requires the application of *already* similar or related knowledge types and forms. (Perhaps this second approach to knowledge integration should be labelled as integrated knowledge application.)
- *Purposeful combination of specialized and complementary knowledge to accomplish specific tasks:* In this approach, actors combine highly different and hitherto unrelated knowledge by purpose and in regard of a specific task. For instance, A and B possess significantly different and unrelated, but potentially complementary knowledge. After knowledge integration, *new* knowledge emerges that is useful to accomplish a specific task that could not be accomplished with only the existing related or similar knowledge. Hence, knowledge integration in this third approach implies some *degree of synthesis* of pre-existing knowledge and some degree of innovation in knowledge development. Tell (2011) as well as Van de Ven and Zahra (2017) point out that knowledge

[1]The term „integration" is used in many scientific disciplines and knowledge domains (e.g., social and systemic integration in sociology, technical integration in engineering, integration as inclusion of marginalized social groups into society, socio-cultural integration of "foreigners"). In this paper, integration only refers to the integration of knowledge based on the synthesis of information and data over time in the context of social action. This understanding of knowledge integration can be enhanced through elaborating on theories of social action and order (see Joas & Knöbl 2013 for an overview).

integration as combination is only possible if the involved actors also share some knowledge.

In this chapter, knowledge integration primarily refers to *the purposeful combination of specialized and complementary knowledge to accomplish specific tasks.* Knowledge sharing and transfer as well as knowledge application are also important for building resilience. However, we assume that knowledge integration through combination is more "critical" for building resilience in many urban regions. Furthermore, knowledge integration implies, as mentioned, some degree of knowledge sharing. Knowledge integration as purposeful combination is the most complex approach to knowledge integration and this approach needs some illustration.

2.3 An illustrative example: Developing Flood risk Maps

A flood risk map is a visual representation of geographical areas in river catchments that depicts the degree of anticipated damage due to a flood hazard of a certain probability. Anticipation of damage refers to the calculated negative consequences to values of receptors in inundated areas due to flooding measured by its various parameters (e.g., water extension and depth, flow velocity). Developing a flood risk map is often a knowledge-intensive process in which different types of knowledge need consideration and integration (e.g., engineering knowledge on flood depth-damage functions, cartographic knowledge on the visual representation of geographical areas, knowledge on administrative boundaries). Developing flood risk maps is an apt example to illustrate building resilience in urban regions:

- *Flood risk maps, especially of low-probability events, are important for building resilience:* Flood risk maps gained prominence in the context of establishing the European directive "on the assessment and management of flood risks" (EC 2007). European member states are obliged, among others, to develop flood risk maps as a basis for the formulation and implementation of aims and measures to reduce flood risk in river catchments. Disastrous events, like the Elbe river flood in August in the year 2002 in Dresden, triggered policy making for establishing the European directive. The directive requires to also consider low-probability events and their adverse consequences in flood-prone areas (EC 2007, Article 6). Dealing with low-probability and extreme events is an important topic in resilience research and practice (e.g., Comfort et al. 2010).

- *Flood risk maps may facilitate cooperation for building resilience:* Various development options may lead to flood risk maps. Sometimes, risk maps are developed in practice; sometimes, they are the result of (project-based) cooperation between scientists and practitioners. Flood risk maps are, as *tangible* tools, not only the result of cooperation, they may also facilitate effective processes of working together, if project partners use maps as common reference point for result-oriented communication, trust-building, and building mutual understanding (Ansell & Gash, 2008).

Elaborating flood risk maps may contribute to building resilience. The following shows that such map-making may also count as manifestation of knowledge integration.

2.3.1 Knowledge Sharing

Knowledge integration is especially challenging in joint projects of scientists and practitioners. Scientists and practitioners follow different "logics" in terms of perceptions, interpretations, interests, and actions (Van de Ven, 2007). Gläser and colleagues (2004) characterize joint projects of scientists and practitioners as "heterogeneous cooperation". Heterogeneity between actors encompasses differences in knowledge, languages, preferences, perceptions, interpretations, interests, practices, and institutional constraints (e.g., Gläser et al. 2004, pp. 7–17). There is high variety in constellations of scientists and practitioners as partners of joint projects. In some projects, scientists and practitioners may be embedded in very different institutional context conditions (e.g., publication pressures for scientists, whereas practitioners face political constraints), but they both adopt mainly an engineering perspective on flood risk management. In other projects, there is high variety on both sides, science and practice (e.g., social scientists and engineering researchers on the one hand and local officials responsible for water management, social issues, and urban planning on the other).

For the purpose of illustration of knowledge sharing while developing flood risk maps, we want to introduce two project examples in which some authors of this chapter were involved:

- The IOER led the project VERIS-Elbe[2] (project duration from 2005 until 2008). VERIS-Elbe mainly focused on *scientific* challenges of flood risk management with regard to extreme floods events and large river catchments. Statements on target groups in practice are mainly generic (Schanze et al. 2015). Partners from practice participated to some extent in the process of project implementation. However, the book publication for summarizing the main project findings mainly refers to individual persons from science and *not* from practice (Schanze et al. 2015).
- This is different in MULTISURE[3] (project duration from 2006 until 2010). Officials belonging to the local administration of the City of Dresden were involved in the project. They played an active role to steer the project into the direction of their own interests. MULTISURE was relatively specific with regard to how local actors in the City of Dresden could use project results (Sommer et al. 2012).

Hence, the thrust of the two projects, partner constellations and target groups are consistent. Partner constellations between the two project examples VERIS-Elbe and MULTISURE differed substantially, but project partners within and across projects shared important knowledge on flood risk management.[4] Both projects were based on the understanding of flood risk as the probability of negative consequences ("damage") due to the inundation of receptors in flood-prone areas. This understanding framed common knowledge on how to define such contested terms like "hazard" and "vulnerability" as well as "risk" and "risk management". Project partners referred to publications and official documents that are widely acknowledged in both science and practice (e.g., the EU directive on flood risk management, official documents of the LAWA). Based on this common knowledge, project partners implemented VERIS-Elbe and MULTISURE

[2]The project title VERIS-Elbe stands for "Changes and management of risks of extreme flood events in large river basins—the example of the Elbe River" (Neubert et al. 2016; Schanze et al. 2015).

[3]The project title MULTISURE stands for "Development of multi-sequential mitigation strategies for urbanized areas prone to high groundwater level" (Schinke et al. 2012; Sommer et al. 2012).

[4]Some individual persons participated in both projects VERIS-Elbe and MULTISURE. Hence, it is plausible to propose that *overlap in project partner constellations* also contributes to knowledge integration. However, in this paper, we abstract from such social relations. They could be investigated further in future network-oriented research on building resilience to natural hazards (e.g., Hutter 2014).

through adopting a comprehensive flood risk modelling methodology encompassing, for instance, coupled rainfall-runoff models, models for predicting water depths, and flood damage simulation models. This leads us to the purpose of the two selected project examples and the specific task of combining specialized and complementary knowledge.

2.3.2 Purposeful Combination of Specialized and Complementary Knowledge

Flood events and multi-level governance processes led to changes in how flood risk is managed in European Member States. In summary terms, this change is described as change from "conventional flood protection" to "flood risk management" (e.g., Klijn et al. 2008, 309). Projects were established to demonstrate that the latter is not only possible in theory, but also in practice (empirical projects included, e.g., the project FLOOD*site* funded by the EC, Klijn et al. 2008). VERIS-Elbe and MULTISURE followed this purpose for specific areas. VERIS Elbe focused on causes of changes of flood risk and options for reducing the risk of extreme flood events in large river catchments. The project team chose the basin of the river Elbe as a case study area with emphasis on its German part (Schanze et al. 2015). To consider the complex causal chain that leads to floods and their consequences for receptors, the project team combined different scientific models (e.g., a rainfall-runoff model for the transnational Elbe river basin, a one-dimensional hydrodynamic numerical model for predicting water depths, a nested two-dimensional hydrodynamic-numerical model for selected river sections, and a so-called "Modifiable Digital Terrain Model (DTM)") for simulating dike relocations.

The VERIS-Elbe team focused on developing a model for flood damage simulation (a model named HOWAD,[5] Neubert et al. 2016). Knowledge integration as purposeful combination manifests itself especially in the project effort to *thrive for a balance between* (1) being *too general* (e.g., because of average damage values adopted to specific areas based on economic statistics) and (2) being *too case-specific* (e.g., due to detailed damage analysis adopted to only a small number of cases of buildings). The aim of developing a new model for the simulation of flood damages was justified through the intention of combining synthetic depth-damage functions regarding the flood vulnerability of residential buildings ("engineering

[5]The name HOWAD of the model stands for "Hochwasserschadenssimulationsmodell", which can be translated as "Flood damage simulation model".

analysis”) *with* generalizing functions to whole areas of the river basin based on concepts and methods of urban development, physical geography, geoinformation, and cartography (“spatial analysis”).

The project team applied a complex site-specific typology of *residential* buildings to the whole area under investigation. The typology of buildings combined two dimensions: structure type and period of construction. It covered seven structure types and seven construction periods that served as indicators of complex building features. Damages were operationalized as refurbishment costs based on expert knowledge about measures for site-specific building types. The detailed analysis of individual buildings *as representatives* of building types led to *building type-specific synthetic depth-damage functions.* Spatial analysis assigned individual buildings in the “real world” to building types based on methods like, for instance, “on-screen digitizing”. This procedure applied, as mentioned, to residential buildings. HOWAD considered other general types of buildings (e.g., commercial and public buildings) through expert judgements.

HOWAD was (and is) able to integrate information and data given in a GIS-compatible digital data format in the same geographic coordinate system. It was possible to establish a link between the buildings in the area under investigation and their synthetic depth-damage functions (for residential building types) or relative damage functions (for non-residential buildings and land-use types). HOWAD visualized model results as maps overlaid on topographic data or aerial imagery. The project team made risk maps for specific sub-areas of the German Elbe river. The team simulated damage of flooding with regard to multiple return periods. It compared—out of a total of 50 events—a relatively frequent flood event (like an event with a return period of 50 years) with an extreme flood event operationalized as an event with a return period of 300 years (Neubert et al. 2016). The VERIS-Elbe team concluded that the results of the whole flood risk modelling methodology are rather sensitive to the spatial downscaling of the underlying climate projections (Schanze et al. 2015). It also concluded that the *new* damage simulation model HOWAD is relatively robust and of high spatial resolution compared to the existing methods of calculating damage potentials due to flooding (Neubert et al. 2016).

In sum, flood risk maps, like the ones made in the VERIS-Elbe project, are the result of a knowledge-intensive process that also encompasses efforts of knowledge integration. The project and map examples illustrate that knowledge integration requires some common knowledge among the people involved. Without common knowledge, project partners are too much strangers to each other to develop new innovative solutions for building resilience to natural hazards through trust-based cooperation and result-oriented communication. Based on knowledge sharing, complex processes of knowledge integration may flourish between project partners. The example of the project VERIS-Elbe illustrates that flood risk maps are, in this case, mainly the result of *inter-disciplinary* knowledge integration. This is consistent with the mainly scientific overall purpose of the project. Project partners thrived to integrate knowledge from engineering and urban development research as well as physical geography and cartography. Looking at the flood risk maps (e.g., Neubert et al. 2016), we see the result of knowledge integration in the sense of combining specialized and complementary knowledge, but quite "naturally" we see only little of the efforts of actually accomplishing the *social process* of map making.

2.3.3 Using similar/related Knowledge

Researchers and practitioners alike often focus on surface water floods (e.g., river floods), because these are associated with primary effects like casualties and high economic losses due to damage to buildings and settlements. However, significant flood damage may also be due to secondary effects of surface water floods, because of rising groundwater levels, especially in the basements of buildings (Schinke et al. 2012). Flood damage specifically due to rising groundwater levels may remain underestimated, because it is difficult to assess, especially for the whole building stock of flood-prone areas. Therefore, project partners of MULTISURE decided to develop a damage simulation model called GRUWAD[6] (a variation on the name HOWAD of VERIS-Elbe).

Like HOWAD, GRUWAD combines concepts, methods and data from engineering science, urban development research, physical geography and cartography to calculate and simulate flood damage due to groundwater inundation of buildings (Schinke et al. 2012). The GRUWAD-module "Urban structure" has high resemblance with the spatial analysis and the building typology used for damage simulation in HOWAD. Similarities exist also with regard to the overall procedure to generate building type-specific synthetic depth-damage functions due to groundwater inundation of buildings. The procedure of GRUWAD provides enough leeway to consider specific challenges of damage caused by groundwater inundation (e.g., basement/footprint ratio and of foundation depth to determine which and how many residential and non-residential building types need investigation for the generation of depth-damage functions).

[6]The name GRUWAD of the model stands for "Grundwasserschadenssimulationsmodell", which can be translated as "Groundwater damage simulation model".

The module “Calculation” integrates the parameter “minimal depth to groundwater” from the module “Groundwater dynamics”, all geo-data on the building stock with the designation of the building types from the module “Urban structure” as well as the depth-damage functions from the module “Vulnerability of buildings due to groundwater inundation”. As a result, calculation leads to a GIS data-set encompassing the potential subterranean building damage caused by groundwater inundation for different inundation scenarios. It is possible to aggregate damage values calculated in GRUWAD to statistical units like building blocks, urban districts or other topologies (e.g., grid cells or damage clusters) and to visualize model results through risk maps (Schinke et al. 2012).

MULTISURE started after the project VERIS-Elbe. Project partners shared some knowledge within and across projects. Concepts, methods, types of data and calculation procedures of HOWAD and GRUWAD show similarities. GRUWAD expands the range of application of HOWAD to issues of flood damage of buildings due to groundwater level rise as secondary effect of surface water floods. Hence, GRUWAD illustrates the approach to knowledge integration as using similar or related knowledge.

2.4 Justifying knowledge Integration as Means to Build Resilience

Knowledge integration is neither “one thing”. There are different approaches like knowledge sharing, using similar/related knowledge, and the purposeful combination of specialized knowledge. Nor is integration always a “good thing”. It is inefficient to share all knowledge. Efforts of combining specialized knowledge may fail, because knowledge is not complementary. Knowledge integration often requires recurring cycles of co-operation and trust-building between the people involved. Trust is quickly “destroyed”, but emerges only over time.

Given such complexities and limitations, we nevertheless argue that knowledge integration is a potential means towards the end of building resilience to natural hazards in the context of climate change. To show this on a conceptual level of argumentation, we clarify, firstly, in general terms what it means to understand knowledge as a means (tool, instrument) for the end (aim, goal, purpose) of building resilience. Secondly, we specify the meaning of resilience as ability of actors to manage disturbance and surprise. Both are important in the context of natural hazards and climate change, because these context conditions increasingly lead to limits of knowledge and the unexpected. Thirdly, we argue that the distinction between specific and general resilience is crucial in pro- and reactive approaches to resilience.

2.4.1 Means and their Justification through Ends

The categories “end” and “means” are commonly used in some scientific disciplines and policy fields (e.g., policy design research, Howlett, 2019, climate change adaptation policy, e.g., Vetter et al. 2017). It is crucial to distinguish between ends and means with regard to time and temporality: Means are used in the present to realize desired effects in the future. Means are deployed to realize ends *and* ends justify that resources for specific means are used. Thus, there are two very different approaches to relate ends and means (there is abundant social science literature on this topic, e.g., Howlett, 2019; Luhmann, 1968; March, 1994; Weick, 2001; Wiechmann, 2008):

- *Searching for and choosing alternatives to implement a given end:* Deterministic one-to-one relations between ends and means are of little relevance for social action in the “real world”. There are often alternative means to realize a given end and actors decide about means on the basis of multiple criteria (see the contribution by Neubert & Schinke in this volume on how to decide between the alternative of dyke construction and the alternative of lifting residential buildings to accomplish the given design level). This approach is characterized by starting with an end and then searching for alternatives to realize this end. Multi-criteria-analysis shows which alternative to choose.
- *Justifying a given means through statements about ends:* Idealistic notions of ends-means-rationality often mainly refer to searching for alternatives to realize a given end. However, actors do not (and cannot) *always* follow this rationality. Given bounded rationality, uncertainty, and change in context conditions, they start with specific means (e.g., knowledge integration) and then search for justification to demonstrate the relevance and (net) benefits of such means. From the viewpoint of the first approach, this kind of ends-means-rationality is somehow questionable, because it seems that decisions about means are not justified through systematic and “fair” comparison with alternatives, but only by searching for the best justification to legitimize a given decision about means.

In this chapter, we adopt mainly the second approach to the rationality of ends-means-relations. This does not mean that the first approach is less relevant or useful, but only that, before looking for alternatives to knowledge integration to the end of building resilience, it seems appropriate to specify in which ways such integration contributes to resilience.

2.4.2 Building Resilience as Pro- and Reactive Management of Disturbance and Surprise

Considering building resilience through knowledge integration obviously refers to human agency and intentionality (Coaffee & Lee, 2016; Emirbayer & Mische, 1998). Actors intend to increase resilience in the future. In daily life, resilience is broadly understood as being able to deal with adversity in its manifold manifestations in a way better than compared to a state of suffering from adversity due to a lack in resilience. Scientific disciplines and related research streams seek to develop a more precise understanding of what it means to consider resilience as ability and aim of human agency. In principle, there are many options to justify knowledge integration as means to building resilience, depending on the diverse scientific literatures of resilience (e.g., Coaffee & Lee, 2016; Fuchs & Thaler, 2018). We propose that resilience is the *ability of an actor to proactively adapt to and recover from disturbance and surprise* (similar to the definition of social resilience suggested by Hutter & Lorenz, 2018, p. 191).

In a complex, uncertain, and turbulent world, some disturbance of action is inevitable and increasingly "the new normal" (see Farazmand, 2009 on "surprise management" and Ansell et al. 2017 on "Governance in turbulent times"). There are different kinds of disturbance. Some disturbances are well-known in kind in advance ("usual"). Still, *when* they happen and exactly *how* they happen may unsettle the lives of the affected actors. Other disturbances are less known ("unusual") or even outside the range of experiences and expectations of an actor.

In a similar vein, in his seminal book on "Searching for safety", Wildavsky (1988, p. 93) distinguishes between "quantitative (expected) surprise" and "qualitative (unexpected) surprise". The former is known in kind, but not in its specific manifestation when it occurs; the latter is impossible to expect in qualitative and, therefore also, in quantitative terms. Otherwise, by definition, such manifestation of surprise would be classified as "expected surprise". Wildavsky (1988, p. 93) highlights unexpected surprise as "true" surprise.

Knowledge integration for building resilience needs to consider both usual and unusual disturbance as well expected and unexpected surprise. To elaborate on this, we, firstly, focus on conditions for disturbance and the unexpected. Secondly, we define in more depth resilience as the ability of an actor to pro- and reactively manage disturbance and surprise. Thirdly, we argue that being more specific on knowledge integration as a means for building resilience leads us to the distinction between specific and general resilience (in the next sub-section).

The terms "disturbance" and "surprise" highlight different conditions for building resilience. The term "disturbance" is more action-oriented, whereas the term "surprise" points to cognition about the future. If there is disturbance, something that *could have been undisturbed* is present. In the social sciences, disturbance is often related to institutionalized action. Institutions are not only regulative arrangements for solving conflicts between self-interested actors, but also normative and cognitive-cultural aspects of social action (Scott, 2014). Actors do not invent "reality" from day to day. They expect some parts of social life to stay (at least) similar to as they were in the past (Emirbayer & Mische, 1998). Actors adopt (more or less explicitly) value premises, normative expectations, classifications, and "scripts" to act. There are many manifestations of disturbed action (e.g., disturbed routines of daily life, organizational routines, and social practices).

The term "surprise" focuses attention on the cognitive-cultural representations of future action and on the fact that expectations do not necessarily become "true", when the future unfolds in the present. When an actor experiences surprise, there are—by definition (Hutter, 2017)—two relevant approaches to explaining the unexpected (Weick & Sutcliffe, 2001, 2015): (1) explanation through referring to the external context conditions of action (e.g., change in socio-economic conditions, action of other actors, hence, strategic interaction) and (2) explanation through the more or less appropriate expectations of an actor as internal context conditions. Weick and Sutcliffe (2001, 2015) argue that resilience requires that actors resist the temptation to attribute success mainly to internal conditions and failure to external circumstances. Actors interested in building resilience consider the full range of options: internal conditions as causes of success and failure (e.g., appropriate and inappropriate expectations) and external conditions of success and failure (e.g., good luck and bad luck).

Against this background, we understand resilience as the ability of an actor to proactively adapt to and to recover from disturbance and surprise, *especially unusual disturbance and unexpected surprise.* This understanding is inspired by the work of Weick and Sutcliffe (2001, 2015) on managing the unexpected, but highlights resilience as *both pro- and reactive ability.* Weick and Sutcliffe (2015) understand resilience mainly as a reactive ability of actors, especially of teams and organizations:

"Notice that in the reactive world of the unexpected, the ability to make sense of an emerging pattern is just as important as is anticipation and planning. And the ability to cope with the unexpected requires a different mind-set than to anticipate its occurrence. The mind-set for anticipation is one that favors precise identification of possible difficulties so that specific remedies can be designed. A commitment to resilience is quite different. Resilience is a combination of keeping errors small, of improvising work-arounds that keep the system functioning, and of absorbing change while persisting." (Weick & Sutcliffe, 2015, p. 97).

We agree that the "proof of resilience" is in present action in the face of *actual* disturbance and surprise. However, the *intention of building resilience* necessarily involves anticipatory efforts of actors and this also holds for efforts that seek to adopt the management lessons proposed by Weick and Sutcliffe (2001, 2015).

2.4.3 Building Specified and General Resilience

Given the fuzziness as well as the many possible meanings of the term resilience, it is not surprising that some scholars seek to develop a specific concept that is suitable in scientific efforts of also testing hypotheses derived from resilience thinking (Brand & Jax, 2007). However, Folke and colleagues (2010) point to the *danger* that actors interested in resilience and demonstrating the usefulness of the notion become *too interested in narrowing down resilience to a concept as specified as possible.* They underline that building resilience does not only encompass dealing with the specified and expected, but also with the truly novel and hitherto unimaginable, hence, unusual disturbance and "true" surprise. They distinguish between specified and general resilience.

Folke and colleagues define (2010, p. 3) specified resilience as "…resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks." Referring to Carpenter and colleagues (2001), they characterize specified resilience as effort to determine resilience of what, to what. In contrast: "General resilience…is about coping with uncertainty in all ways" (Folke et al. 2010, p. 5). Folke and colleagues (2010, p. 3) define general resilience as the "resilience of any and all parts of a system to all kinds of shocks, including novel ones."

The distinction between specified and general resilience is crucial to understand how efforts of knowledge integration for managing disturbance and surprise can be understood conceptually in flood risk management. Flood risk maps (like the ones developed in the projects VERIS-Elbe and MULTISURE, see above) are apt examples to adopt a concept of specified resilience. For instance, flood risk maps are specific on the geographical areas inundated in the context of a flood event of a certain probability. Flood risk maps specify how damage potentials of receptors in inundated areas are calculated. It is the point of developing flood risk maps in accordance to the directive of the EU on assessing and managing flood risk (EC 2007) to make also the extreme and relatively unlikely available in anticipatory efforts of flood risk management. Flood risk assessment (including map making) with regard to flood events of different probabilities is then the basis for developing specific aims and measures for flood risk reduction.

In Article 2 of the directive, floods are defined as "temporary covering by water of land not normally covered by water." (EC 2007, Article 2). Hence, a flood event can be interpreted as a (temporary) disturbance of how land is used in normal times. Referring to different probabilities, it is possible, for instance, to specify what "usual" and "unusual" mean (e.g., defining an unusual disturbance as a flood event with a low probability or as an extreme flood scenario, EC 2007, Article 6). This clarification points into the direction that flood risk management in line with the directive corresponds to building *specified* resilience. Thereby, it is useful to remember that specification is *not* the same as specialization. Flood risk maps are, in the cases of the maps developed in VERIS-Elbe and MULTISURE, specific results of knowledge integration through combining specialized and complementary knowledge.

From the viewpoint of resilience thinking, it is crucial how the relevant actors in anticipatory management efforts interpret specified disturbances as well as expected surprise and how they decide about responses to such events and anticipated experiences (Folke et al. 2010, see also March et al. 1991; Weick & Sutcliffe, 2001, 2015). Do actors derive a *"false sense of safety" from the consideration of only one specific extreme flood scenario?* Or do they interpret knowledge integration for specified resilience as one component of a comprehensive approach to building resilience in the context of natural hazards and climate change?

A comprehensive concept for building resilience to natural hazards may encompass diverse tools, resources, methods, and governance arrangements, as well as approaches to cognitive-cultural change of the relevant actors (e.g., Cunha et al. 2006, 2012; Farazmand, 2009; Hutter, 2017; McDaniel et al. 2003; Mendonça et al. 2009; Weick & Sutcliffe, 2001, 2015). Up to now, research contributions to building general resilience have mainly been developed for managing business organizations (Cunha et al. 2012) or technology-driven "High-Reliability Organizations (HRO)" (Weick & Sutcliffe, 2015). An appropriate concept for flood risk management still has to be found (Hutter, 2016, 2017; Merz et al. 2015).

The set of requirements to develop a comprehensive approach for building resilience in flood risk management is diverse. We highlight one requirement:

Knowledge integration for building general resilience needs systematic comparison with alternatives of dealing with uncertainty in all ways. Two alternatives are especially noteworthy: (1) generalized *resources* (e.g., money, power, social capital), and (2) *insurance* as instrument to handle expected and unexpected surprise. Comparison with money as generalized resource may be especially illuminating, because—however an uncertain future unfolds—money will probably play a role in it. This will be different in case of knowledge integration, not least because of its complexity and limitations (see above). Future research should explore the relatively limited range of contents and context conditions in which knowledge integration for building general resilience plays a role.

In sum, if specific resilience efforts dominate, flood risk managers may have the illusion that they can calculate an uncertain future and that it is sufficient to consider disturbance and expected surprise. If general resilience dominates, management efforts follow an idea of resilience that is too unspecific to be consequential for present collective action. Thus, building specified and general resilience are both important for dealing with disturbance and surprise. Efforts of specific resilience are not always in harmony with efforts to deal with uncertainty in all ways. Flood risk managers may need to set priorities. They can do so in different ways (Poole & Van de Ven 1989): Firstly, they may separate the two *over time* (e.g., phase one: focus on specific resilience, phase two: adding general resilience). Secondly, they place a *stable priority* on specific resilience, but also consider general resilience, perhaps in the background of management efforts. Thirdly, they may strive for a *new synthesis* of flood risk management in which both specific and general resilience are components of equal weight. We suggest that the concept of urban resilience (Meerow et al. 2016) has the potential to provide such a new synthesis for building resilience in flood risk management.

2.5 Knowledge Integration and Urban Resilience

Building specific and general resilience are both important for dealing with natural hazards like floods in the context of climate change. However, practitioners responsible for specific tasks and researchers working on selected topics of flood risk management may prefer the former to the latter. Specification of resilience issues is necessary for publications and practitioners of flood risk management like to stay within the formal boundaries of their management tasks. Collaboration of researchers and practitioners then may be an opportunity to address the issues of building general resilience for developing a contribution to a comprehensive approach for dealing with uncertainties of natural hazards, but collaboration also benefits from working on (specific interim and final) results (Ansell & Gash, 2008; Hutter, 2016 see also Hutter & Olfert on project-based learning in this volume).

Against this background, we suggest that especially the ambition of building general[7] resilience leads to the challenge of taking a broader and systemic view on how actors in urban regions deal with natural hazards in the context of climate change. The concept of urban resilience enhances such a systemic view (e.g., Coaffee & Lee, 2016; Meerow et al. 2016). Meerow and Newell (2016, p. 7) define urban resilience 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."

The term "system" is crucial here. Like resilience, the term "system" may be understood in different ways, for instance, with regard to a specific system theory (e.g., theories of closed, open, and autopoietic systems). In this chapter, system simply means that urban resilience emerges from complex processes that relate to manifold social, ecological, and technical elements and multiple spatial and temporal scales—*more or less directly coupled* (see, for instance, Tödtling & Trippl, 2005, on "fragmented metropolitan regions", see also Zimmermann & Lee in this volume).

The second half of the definition refers to efforts in urban systems of coping, adaptation, and transformation. In reality, these efforts are not always in harmony; *tensions* between coping, adaptation, and transformation need to be considered (Folke et al. 2010, see also the literature on regional resilience that considers tensions between adaptation and adaptability, Boschma, 2015, p. 735). Actors in urban regions that emphasize coping in the sense of coping with a specific event related to a natural hazard and its consequences ("emergency management") and that are interested in returning to a similar state as before the emergency as quickly as possible may have difficulties taking general resilience seriously (e.g., using the resilience word mainly as buzz word).

[7] Building specific resilience and urban resilience are also closely connected. For instance, it would be possible to trace how specific solutions found in flood risk management diffuse in other parts of urban systems (e.g., river flood risk maps are inputs to managing the risk of heavy rain and then the risk of further natural hazards like rising temperaturs and heat waves, see further contributions in this edited volume). However, in this short sub-section, we largely abstract from connections between specific and urban resilience.

Folke and colleagues (2010, p. 5) argue that building general resilience is especially related to transformation of urban systems and the transformative capacity of the actors involved (Wolfram, 2016). However, the relations between *general* resilience and *urban* resilience to natural hazards are, up to now, undertheorized and only little conceptualized, not to speak of qualitative or quantitative empirical research. The state of art is more elaborated with regard to specific resilience (see the diverse contributions in this volume). We hope that contributions to building a comprehensive approach for urban resilience that pays due attention to the relations between knowledge integration as well as specific and general resilience flourish in the future.

2.6 Conclusion and Outlook

This chapter followed a conceptual purpose. We conceptualized knowledge integration as purposeful combination of specialized and complementary knowledge based on knowledge sharing between often heterogeneous actors and illustrated this understanding through referring to examples of flood risk maps in line with requirements of the directive of the EU on assessing and managing flood risk (EC 2007). We further conceptualized knowledge integration as means to the end of building resilience, especially in urban regions, and distinguished between specific and general resilience to natural hazards in the context of climate change.

Specific and general resilience are both crucial for building resilience in this context. The former enables actors to be specific in their assessment and management approaches while embracing uncertainties as well as possible disturbances and surprises related to natural hazards. Actors can work out the specific consequences and implications of resilience for collective action. General resilience reminds them that unusual disturbance and unexpected surprise are *always* possible even in the case of intensive management efforts to consider specific low-probability events like extreme floods. Thereby, it is probably unlikely that flood risk managers in urban regions will develop capabilities like managers of the so-called "High-Reliability Organizations (HRO)" to manage disturbance and surprise *mainly* in an unfolding (emerging) present through high "sensitivity to operations" (Weick & Sutcliffe, 2001, 2015). Especially general resilience needs elaboration based on the *specific* contents and context conditions of flood risk management in urban regions and this points into the direction of resilience efforts that are more concerned about anticipation and long-term planning than Weick and Sutcliffe (2001, 2015) are willing to contend.

To advance research and practice about knowledge integration for building resilience, a systemic and network-oriented view on resilience efforts in urban systems is required. The concept of urban resilience (as proposed, for instance, by Meerow et al. 2016 or Coaffee & Lee, 2016) emphasizes that actors are embedded in complex and dynamic relations with socio-technical and socio-ecological networks on multiple spatial and temporal scales. Embeddedness in networks is crucial to understand if, and if yes, how actors involved in resilience efforts are able to not only adapt to an uncertain future, but also are able to transform urban systems for more resilience in the future. Pathways towards more specific and general resilience may differ between urban regions and the role of knowledge integration is likely to be also more context-specific than, for instance, the role of generalized resources like money and social resources. Therefore, we need more multi-level and dynamic analysis that considers (1) different approaches to knowledge integration, (2) specific and general resilience[8] as well as (3) relations to the multiple social, temporal, and spatial scales in urban systems and (4) different pathways to incremental or transformative change.

References

Abeling, T., Daschkeit, A., Mahrenholz, P., & Schauser, I. (2018). Resilience—A useful approach for climate adaptation? In A. Fekete & F. Fiedrich (Eds.), *Urban disaster resilience and security. Addressing risks in society* (pp. 461–471). Cham: Springer.

Al-Laham, A. (2003). *Organisationales Wissensmanagement. Eine strategische Perspektive.* München: Vahlen.

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory, 18,* 543–571

Ansell, C., Trondal, J., & Ogard, M. (Eds.). (2017). *Governance in turbulent times*. Oxford: Oxford University Press.

Boschma, R. (2015). Towards an evolutionary perspective on regional resilience. *Regional Studies, 49*(5), 733–751

Brand, F. S., & Jax, K. (2007). Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. *Ecology and Society, 12*(1), 1–16

[8] Thorén (2020) argues against using the concept of "general resilience". However, this conceptual issue is not yet solved, because, firstly, his argumentation remains rather general and needs to be applied to specific problems of building resilience. Secondly, from a conceptual viewpoint, the distinction between specified and general resilience is more important than focusing on general resilience (March et al. 1991; Weick & Sutcliffe 2015). However, we agree that this distinction needs to be specified with regard to the identity and issues of persistence of the actors and urban systems that are in the foreground of argumentation.

Bruijne, M. d., Boin, A., & Eeten, M. v. (2010). Resilience. Exploring the concept and its meanings. In L. K. Comfort, A. Boin, & C. C. Demchak (Eds.), *Designing resilience. Preparing for extreme events* (pp. 13–32). Pittsburgh: University of Pittsburgh Press.

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems, 4*, 765–781

Carroll, J. S., Rudolph, J. W., & Hatakenaka, S. (2003). Learning from organizational experience. In M. Easterby-Smith & M. A. Lyles (Eds.), *The Blackwell handbook of organizational learning and knowledge management.* (pp. 575–600) Blackwell.

Coaffee, J., & Lee, P. (2016). *Urban resilience. Planning for risk, crisis, and uncertainty.* London: Palgrave.

Comfort, L. K., Boin, A., & Demchak, C. C. (2010). Resilience revisited. An action agenda for managing extreme events. In L. K. Comfort, A. Boin & C. C. Demchak (Eds.), *Designing resilience. Preparing for extreme events* (pp. 272–284). Pittsburgh: University of Pittsburgh Press.

Cook, S. D. N., & Brown, J. S. (1999). Bridging epistemologies. The generative dance between organizational knowledge and organizational knowing. *Organization Science* 10(4), 381–400

Cunha, M. P., Clegg, St. R., & Kamoche, K. (2006). Surprises in management and organization: Concept, sources and a typology. *British Journal of Management* 17, 317–329

Cunha, M. P., Clegg, St., & Rego, A. (2012). Surprising organization. In T. S. Pitsis, A. Simpson, & E. Dehlin (Eds.), *Handbook of organizational and managerial Innovation.* (pp. 295–316)Cheltenham/Northampton: Edward Elgar.

Davoudi, S. (2018). *Just Resilience. City & Community, 17*(1), 3–7

Emirbayer, M., & Mische, A. (1998). What is agency? *American Journal of Sociology, 103*(4), 962–1023

European Parliament and European Council (EC) (2007). Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (Text with EEA Relevance). *Official Journal of the European Union.*

Farazmand, A. (2009). Hurricane Katrina, the crisis of leadership, and chaos management: Time for trying the 'surprise management theory in action.' *Public Organization Review, 9*(4), 399–412

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society, 15*(4), 1–9

Fuchs, S., & Thaler, T. (Eds.). (2018). *Vulnerability and resilience to natural hazards.* Cambridge: Cambridge University Press.

Gerring, J., & Christenson, D. (2017). *Applied social science methodology. An introductory guide.* Cambridge: Cambridge University Press.

Gläser, J., Meister, M., Schulz-Schaeffer, I., & Strübing, J. (2004). Einleitung: Heterogene Kooperation. In J. Strübing, I. Schulz-Schaeffer, M. Meister, & J. Gläser (Eds.), *Kooperation im Niemandsland. Neue Perspektiven auf Zusammenarbeit in Wissenschaft und Technik* (pp. 7–24). Opladen: Leske + Budrich.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal, 17*, 109–122

Hein, C., & Schubert, D. (2020). Resilience, disaster, and rebuilding in modern port cities. *Journal of Urban History*, 1–15

Hirsch Hadorn, G., Biber-Klemm, S., Grossenbacher-Mansuy, W., Hoffmann-Riem, H., Joye, D., Pohl, C., Wiesmann, U., & Zemp, E. (2008). The emergence of transdisciplinarity as a form of research. In G. Hirsch Hadorn, H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, U. Wiesmann, & E. Zemp (Eds.), *Handbook of transdisciplinary research* (pp. 19–39). Wiesbaden: Springer.

Howlett, M. (2019). *Designing public policies. Principles and instruments.* London/New York: Routledge.

Hutter, G. (2014). Goal-oriented networks and capacity building for natural hazards—Examples in the Dresden region. *Natural Hazards and Earth System Sciences, 14*(1), 81–94

Hutter, G. (2016). Collaborative governance and rare floods in urban regions—Dealing with uncertainty and surprise. *Environmental Science & Policy, 55*(Part 2), 302–308

Hutter, G. (2017). Dealing with surprise in urban regions—Some ideas and examples for planners. In S. Deppisch (Ed.), *Urban regions now & tomorrow. Between vulnerability, resilience and transformation* (pp. 145–164). Wiesbaden: Springer.

Hutter, G., & Lorenz, D. F. (2018). Social resilience. In S. Fuchs & T. Thaler (Eds.), *Vulnerability and resilience to natural hazards.* (pp. 190–213). Cambridge: Cambridge University Press.

Joas, H., & Knöbl, W. (2013). *Sozialtheorie. Zwanzig einführende Vorlesungen.* Frankfurt a.M.: Suhrkamp.

Klijn, F., Samuels, P., & Van Os, A. (2008). Towards flood risk management in the EU: State of affairs with examples from various European countries. *International Journal of River Basin Management, 6*(4), 307–321

Luhmann, N. (1968). *Zweckbegriff und Systemrationalität.* Frankfurt a.M.: Suhrkamp.

March, J. G. (1994). *A primer on decision making. How decisions happen.* New York: The Free Press.

March, J. G. (2010). *The ambiguities of experience.* Ithaca/London: Cornell University Press.

March, J. G., Sproull, L. S., & Tamuz, M. (1991). Learning from samples of one or fewer. *Organization Science, 2*, 1–13

McDaniel, R. R., Jr., Jordan, M. E., & Fleeman, B. F. (2003). Surprise, surprise, surprise! A complexity science view of the unexpected. *Health Care Management Review, 28*(3), 266–278

Meerow, S., & Newell, J. P. (2016). Urban resilience for whom, what, when, where, and why? *Urban Geography*, 1–21

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning, 147*, 38–49

Mendonça, S., Cunha, M. P., Ruff, F., & Kaivo-oja, J. (2009). Venturing into the wilderness: Preparing for wild cards in the civil aircraft and asset-management industries. *Long Range Planning, 42*(1), 23–41

Merz, B., Vorogushyn, S., Lall, U., Viglione, A., & Blöschl, G. (2015). Charting unknown waters—On the role of surprise in flood risk assessment and management. *Water Resources Research, 51*, 1–18

Neubert, M., Naumann, T., Hennersdorf, J., & Nikolowski, J. (2016). The geographic information system-based flood damage simulation model HOWAD. *Journal of Flood Risk Management, 9*(1), 36–49

Poole, M. S., & Van de Ven, A. H. (1989). Using paradox to build management and organization theories. *Academy of Management Review, 14*(4), 562–578

Schanze, J., Schwarze, R., Horlacher, H.-B., & Deilmann, C. (Eds.). (2015). *Veränderung und Management der Risiken extremer Hochwasserereignisse in großen Flussgebieten—Am Beispiel der Elbe.* Stuttgart: Schweizerbart.

Schinke, R., Neubert, M., Hennersdorf, J., Stodolny, U., Sommer, T., & Naumann, T. (2012). Damage estimation of subterranean building constructions due to groundwater inundation—GIS based synthetic model approach named GRUWAD. *Natural Hazards and Earth System Sciences, 12*(9), 2865–2877

Schneider, St. H., Turner II, B. L., & Garriga, H. M. (1998). Imaginable surprise in global change science. *Journal of Risk Research, 1*(2), 165-185.

Scott, W. R. (2014). *Institutions and organizations. Ideas and interests.* Thousand Oaks: SAGE.

Sommer, Th., Deilmann, C., Kreibich, H., Grunenwerg, H., Bothmer, D., & Ulrich, K. (Eds.). (2012). *Unterirdische Schadenspotentiale durch Grundhochwasser in urbanen Lebensräumen.* Dresden: DGFZ.

Tell, F. (2011). Knowledge integration and innovation: A survey of the field. In C. Berggren, A. Bergek, L. Bengtsson, M. Hobday, & J. Söderlund (Eds.), *Knowledge integration and innovation. Critical challenges facing international technology-based firms* (pp. 20–38). Oxford: Oxford University Press.

Thorén, H. (2020). Against general resilience. In M. A. Burayidi, A. Allen, J. Twigg, & C. Wamsler (Eds.), *The Routledge handbook of urban resilience.* (pp. 26–34) London/New York: Routledge.

Tödtling, F., & Trippl, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy, 34*, 1203–1219

Van de Ven, A. H. (2007). *Engaged scholarship. A guide for organizational and social research.* Oxford: Oxford University Press.

Van de Ven, A. H., & Zahra, S. A. (2017). Boundary spanning, boundary objects, and innovation. In F. Tell, C. Berggren, S. Brusoni, & A. H. Van de Ven (Eds.), *Managing knowledge integration across boundaries.* (pp. 241–254) Oxford: Oxford University Press.

Vetter, A., Chrischilles, E., Eisenack, K., Kind, C., Mahrenholz, P., & Pechan, A. (2017). Anpassung an den Klimawandel als neues Politikfeld. In G. P. Brasseur, D. Jacob, & S. Schuck-Zöller (Eds.), *Klimawandel in Deutschland.* (pp. 325–334). Berlin/Heidelberg: Springer.

Weick, K. E. (1995). *Sensemaking in organizations.* London: SAGE.

Weick, K. E. (2001). *Making sense of the organization.* Oxford/Malden: Blackwell.

Weick, K. E., & Sutcliffe, K. M. (2001). *Managing the unexpected. Assuring high performance in an age of complexity*. San Francisco: Jossey-Bass.

Weick, K. E., & Sutcliffe, K. M. (2015). *Managing the unexpected. Sustained performance in a complex world*. Hoboken/New Jersey: Wiley.

Wiechmann, Th. (2008). *Planung und Adaptation. Strategieentwicklung in Regionen, Organisationen und Netzwerken.* Dortmund: Rohn.

Wildavsky, A. (1988). *Searching for safety.* New Brunswick/London: Transaction.

Willke, H. (2001). *Systemisches Wissensmanagement*. Stuttgart: Lucius & Lucius.
Wolfram, M. (2016). Conceptualizing urban transformative capacity: A framework for research and policy. *Cities, 51*, 121–130
Zimmermann, K. (2010). Der veränderte Stellenwert von Wissen in der Planung: Ein Beitrag zu einem wissensbasierten Verständnis von Planung. *Raumforschung & Raumordnung, 68*(2), 115–125

3 Justice and Resilience in Flood Risk Management: What Are the Socio-Political Implications?

Thomas Thaler

3.1 Introduction

The concept of flood resilience has become a central paradigm in current flood risk management strategies around the globe. In particular, various international and national documents encourage authorities to develop and implement community or individual resilience to various threats and risks (Doorn et al. 2019; Kim et al. 2018). The UN Hyogo Framework for Action 2005–2015, the UN Sendai Framework for Disaster Risk Reduction 2015–2030 or US based initiatives such as 100Resilience city initiated by the Rockefeller Foundation, represent resilience as the key goal and ideal for different communities (Béné et al. 2018; Doorn et al. 2019; Spaans and Waterhout 2017; UN 2005, 2015).

Scholars have often linked the term 'resilience' to an engineering understanding (Doorn et al. 2019), such as in Crawford Stanley Holling's seminal paper. In 1973, Holling introduced resilience in the understanding of ecosystems in contexts where a system might change (= reborn) or revert back to the previous status (Holling 1973). Resilience is seen as "a process that links a network of adaptive capacities (resources with dynamic attributes) to adaptation after a disturbance or adversity" (Norris et al. 2008, p. 127). Resilience aims to minimize the vulnerability of a flood event based on the community and individual adaptive and coping capacity, as well as lessening the time of return to 'normal' (Agudelo-Vera et al. 2012; Emrich and Tobin 2018; Liao 2012). More recently, scholars have linked

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the concept of resilience to the concept of bouncing forward (including social learning) or the ability to bounce forward (Grinberger and Felsenstein 2014; Manyena et al. 2011), ending the debate around built-forward-better (Kelman et al. 2016).

Nevertheless, the main understanding and goal of resilience for large numbers of policy makers has been to increase community resilience in terms of to return as fast as possible to the previous (or "normal") pre-disaster stage with all its consequences that initially led to the disaster (Mika and Kelman 2020). In disaster risk reduction, the focus has been on efficiency and robustness measures at regional, community or individual household levels (Doorn et al. 2019). Resilience often overlooks the pre-disaster situation, including distributional and procedural aspects of justice within a community. To realize community resilience, aspects of justice must be addressed by both scholars and policy-makers (Kasperson and Kasperson 2001; Lebel et al. 2009; Doorn et al. 2019). The practical implications of resilience is that already existing inequalities within a community are not addressed. For example, the unequal distribution of the burdens of flood risk and social vulnerability cannot be changed following an event. A key problem is the social exclusion of individuals in the policy making and decision-making processes, which is rarely considered in the wake of an event (Wisner et al. 2004; Collins et al. 2018; Sayers et al. 2018; Thaler et al. 2018a, 2020; Thaler and Fuchs 2020).

The question of justice is widespread and differently understood by scientists, policy makers, stakeholders and citizens. There exist a wide range of different theoretical conceptual understandings of justice and how to reach it as a goal. The chapter focuses on three main themes within the current debate on justice, mainly (i) social justice, (ii) environmental justice and (iii) climate justice. This does not imply that social, environmental and climate justice has only one theoretical concept and understanding. Social justice, for example, includes various philosophical schools that tackle how to understand, analyse, and reach social justice. Having said that, this chapter presents some theoretical concepts and their understanding and how to reach resilience as political and societal goal. Therefore, the current chapter concentrates far more on conceptual than empirical research regarding the link between justice and resilience in the example of flood risk management at the community level. It concludes with a possible outline of a research agenda within this field.

3.2 Social Justice—Environmental Justice—Climate Justice: Different, but the Same

Generally, flood hazard and risk management are often unequally distributed in societies. In some regions, it is more likely that deprived communities (who are more likely vulnerable to flood risks) are living in floodplain areas (Chakraborty et al. 2019; Collins et al. 2018; Maldonado et al. 2016). In addition, these groups are usually less well connected within their national political systems and decision-making processes to ensure their interests and needs are met (Thaler and Levin-Keitel 2016; Thaler and Priest 2014). Deprived communities also often receive less support (such as financial resources) from the public administration (Emrich et al. 2020; Munoz and Tate 2016). Scholars have referred to these unequal policies as discrimination perpetrated by many public administrations (Bolin et al. 2005; Maldonado et al. 2016). Consequently, flood risk management policies often encourage or increase social and spatial inequalities that enhance flood risks (Chakraborty et al. 2014; Thaler et al. 2018b).

3.2.1 Social Justice and Resilience

Social justice focuses on the relationship between individuals or groups within a society. The question is how fair and just are the wealth, possibilities and privileges distributed, as well as means to engage in the political process (Patterson et al. 2018; Thaler and Hartmann 2016). Discussion of social justice and how to reach social justice goals was already happening in antiquity with Plato (Plato 2006). The concept of justice itself has a broad understanding and interpretation (Elster 1992; Mill 2006; Kaufmann et al. 2018; Thaler et al. 2018b, 2020; Bennett et al. 2019). At its most basic conception, social justice concerns questions of fairness in the allocation of resources, capital and wealth among different members of a given society (Thaler and Hartmann 2016). There are many different models of social justice dictating different interpretations of fair resource allocation and distribution, such as neoclassic economic approaches that strongly focus on fair distribution and allocation through their atomic views of society. These approaches often harness some faith in methodological individualism and general market equilibrium (Varian 1975). Honneth (2001) defines social justice as a link between ‘how, and in what way, individuals recognize one another reciprocally’ (ibid, p. 45). The rules of distribution (material and cultural) are mirrors of a society and its institutions; ‘rules of distribution cannot simply be derived from the relations of production, but are rather to be seen as the institutional expression of a sociocultural dispositive that determines in what esteem particular activities are held at a specific point in time' (ibid, p. 54). However, conflicts over distribution are only understandable as 'symbolic struggles over the legitimacy of the sociocultural dispositive' (ibid, p. 54). To achieve fair distribution, the political discussion and especially that surrounding institutions (formal and informal) require change. In the discussion of justice and flood protection, the actual allocation of flood protection measures is significant (Mancilla and Campbell 2012; Neal et al. 2014), but so is the way in which this allocation is achieved. Social justice is more than distributional effects of costs or risks (Zwarteveen and Boelens 2014). It also relates to the procedural process by which a certain distribution is selected (Johnson et al. 2007; Walker and Burningham 2011).

In summary, there have been many different theoretical conceptual frameworks developed over the centuries to consider social justice (such as utilitarian, egalitarian, libertarian, prioritarian (or needs-based), merit-based, or rights-based), which foresee different policy directions and support to reach the goal of resilience. Some theoretical concepts include a strong focus on the support of the most vulnerable groups within our society in terms of capacity building by the government to reach resilience in these groups. Other concepts foresee a strong individualistic approach, which states that each household is self-responsible to be resilient against flood hazards. Therefore, implementation of resilience or activities by the government to reach such resilience depends on different philosophical schools:

- First, in the case of a *utilitarian* policy, the distribution of resources is based on the goal to achieve the "greatest" happiness within a given society. The definition of "greatest" happiness in flood risk management involves understanding the cost–benefit logic; higher benefit = more happiness (Johnson et al. 2007). Investments and activities of individuals, businesses or communities only occur when the cost–benefit ratio is positive or favors the highest outcome in cases that would improve resilience. In pursuing resilience, every activity requires a cost–benefit analysis. Moreover, actions to reach resilience will be implemented in high-income communities, as their physical vulnerability (core impact factor in cost–benefit analysis) is higher in comparison with deprived communities. On the other hand, deprived communities may be provided with sandbags (as a low cost investment) or even no protection at all.
- A second policy approach (*egalitarian* policy) foresees the distribution of resources, such as the aim to increase individual or community resilience based

on an "equal distribution" principle within the catchment or community. Consequently, high risk areas reach the same level of resilience as low risk areas as the actions are equally distributed (Ciullo et al. 2020).

- Another interpretation of social justice (mainly *libertarian* policy) advocates for the distribution of resources based on an individualistic perspective (Thaler et al. 2018b). In such a conception, each person (or household) is responsible for managing and organizing itself. Consequently, a libertarian flood risk management system would foresee privatization of public tasks in flood risk management, expecting to provide information on hazards. This would allow each person to individually (and freely) decide if they would choose to live on a floodplain.
- In contrast, a *prioritarian* justice policy concentrates on identifying the 'most' vulnerable groups in a society. Here, the focus lies on households who need support from the public administration to increase their resilience. In particular, deprived communities are typically located in more hazard-prone areas. These communities usually face strong challenges to recovering in the case of a flood event, as these highly vulnerable groups are more at risk of physical and psychological impacts, as well as unemployment, not to mention financial difficulties restoring or rebuilding their homes (Deeming et al. 2011; Elliott and Pais 2006; Emrich et al. 2020; Medd et al. 2015).
- A similar direction includes *merit-based* justice. A merit-based policy would distribute support from a public administration according to who actually deserves it based on their inputs and efforts. People who are engaging in flood risk management would receive more aid from the public administration in reaching the goal of resilience. However, actually deprived communities show low participation in flood risk management policy because they tend to lack individual resources (time, social networks, cultural capital, needs) (Thaler and Levin-Keitel 2016). Consequently, deprived communities, i.e. those who need the most help/are the most vulnerable, would not receive support from the public administration.
- Finally, a rights-based approach would focus on human-rights. *Rights-based* approaches foresee to encourage a strong capacity building based on the ideals of the capabilities approach (Nussbaum 1998). In this case, the distribution of resources should ensure basic human rights and pre-existing rights of First Nations communities into the decision-making process (Bennett et al. 2019). A central aim is to provide strong capabilities within the communities to reach the goal. A rights-based approach to justice also means that resilience would respect indigenous knowledge and expertise and their definitions of resilience. In line with this understanding, resilience must include traditional

knowledge from First Nations communities rather than relying exclusively on a Eurocentric understanding of resilience (Amin 2010).

The question of who takes the responsibility to reach the goal of resilience (such as government vs. individual household) highly depends on which direction of justice is implemented in a country. Following a radical libertarian understanding, for example, would mean that policy makers concentrate on providing information about the hazards and risks of floods, but not on financial support to implement resilient measures. Other policy strategies, such as utilitarianism, show the danger of focusing most activities on high income communities, wherein low-income communities might get relocated by public administration owing to the cost–benefit ratio being too low or negative (Siders 2019).

3.2.2 Environmental Justice and Resilience

The environmental justice strand strongly follows the 1980s debate on environmental injustice in the United States of America, explaining the disproportionate exposure of individuals according to socio-economic status (Bullard 2000; Harrison 2014; Schlosberg 2007; Walker 2012). Environmental justice strongly focuses on assessing the unequal distribution of exposed householders in terms of hazard-areas, such as floodplains, high risk of air pollution, or poor water quality. This involves asking questions pertaining to who is living in these areas and where water is contaminated, therefore identifying how to diffuse pollutions, for example, insecticides and herbicides, domestic waste, chemical waste, and heavy metals caused by industry or mines and so forth (Boelens et al. 2018). Most of the studies in environmental justice are often focusing on the question of technological hazards, like unequal distribution of air pollution, cancer and social vulnerability (Collins et al. 2015; Dobbie and Green 2015; Grineski et al. 2015; Walker 2012). In past years, a new direction within the current environmental justice debate has involved considering social and spatial inequities involved in flood risk (Chakraborty et al. 2014, 2019; Collins et al. 2018; Liao et al. 2019; Montgomery and Chakraborty 2015; Walker and Burningham 2011).

Environmental justice often uses “traditional” socio-economic variables to explain the spatial and social inequalities pertaining to flood risk. Nevertheless, the literature often identifies socio-economic injustice in addition to cultural injustices. Cultural injustice is reflected in discrimination based on nationality, ‘race’, sexuality, gender or/and ethnicity (Fraser 1995). Fraser sees main cultural injustices in the cultural domination of one or more groups with the result of not recognizing and disrespecting minor groups. Unequal material distribution reflects the income and property ownership of each individual citizen. Unequal economic distribution involves barriers to accessing the labor market, education system, health care etc., but also natural injustice like living in floodplain areas based on socio-economic inequality. Fraser defined social fairness as a combination of economic and cultural justice, noting that, 'People who are subject to both cultural injustice and economic injustice need both recognition and redistribution' (ibid, p. 74).

Assessing the vulnerability (to support them in terms of reaching resilience) of residents is not simply a matter of socio-demographic attributes. The variable age, for example, is no more than a rough indicator for underlying economic and social dynamics. There are further questions like how much pension the person receives, how much savings they have, whether they live alone in a building in need of renovations, whether the person is physically frail, whether they have nearby family members to serve as helping hands, or whether they have experiences from past hazard events (Davis and Bellers 1995; Dibben and Chester 1999). By shifting the perspective from plain socio-economic status to specifics of living situations, it becomes clear that affected households are widely diverse in how strongly they are threatened by flood risk and which resources they can mobilize. Acknowledging diversity among affected households implies that some are better off while others are worse off.

For example, the Vietnamese population in New Orleans weathered Hurricane Katrina in 2005 fairly well despite being highly vulnerable in terms of poverty and housing conditions, largely owing to their close-knit network among families and neighbors that enabled them to cope with the disaster's impacts (Leong et al. 2007). In a similar example in Austria, elderly people with savings recovered better from the St. Lorenzen mudflow event in 2012 than young families who were indebted from building their homes (Weber 2015). This understanding also comprises decisions on how to support people in reaching resilience. Assessing environmental justice is far more complex because one must integrate variables and concepts of vulnerability, coping and adaptive behavior to support individuals or communities. Of course, individuals might need and request different (individualistic) support.

Environmental justice need to assess socio-spatial inequalities within communities. The aim is to understand and explain why low-income families often live in floodplain areas and what the consequences would be in case of a flood event. Here, the research encourages authorities to improve resilience of marginalized groups by changing the actual power distribution. Environmental justice strongly stresses the need to overcome the unequal distribution of power and resources (Allen et al. 2017). Researchers have stressed that decision-makers must recognize communities and include them in the decision-making process to ensure their interests and needs are addressed through a fair distribution of investments and burdens. This includes changing the current political debates to tackling how to overcome environmental racism, as well as overcoming inequalities in other fields, such as income, gender, or sexuality (Fraser 1995).

3.2.3 Climate Justice and Resilience

In past years, there has been a stronger focus on the intergenerational aspects of justice, mainly in the case of climate change. The climate justice debate has mirrored the unequal distribution of climate change impacts (Schlosberg and Collins 2014; Schlosberg et al. 2017). Recent climate observations clearly show an increasing risk of extreme weather events related to climate change. Flood events or heat waves and extreme temperatures are likely to occur more frequently in the future (IPCC 2018). For example, structurally dense urban areas with high amounts of sealed surfaces and low shares of green and blue areas are more vulnerable (Markolf et al. 2019). Climate justice often follows a strong principle of equality, where the main aim is to include intra- and inter-generational equality in the process of sharing risk-burdens (Schuppert 2011).

For example, an approach towards realizing the vision of a city resilient towards climate change involves implementing urban ecological infrastructure like parks, pocket parks or parklets, green roofs, green facades, alleys in streets, de-sealing of impermeable surfaces, percolation troughs and water bodies. Nevertheless, the goal of climate justice often neglects a number of questions pertaining to social equality (Kabisch et al. 2016; Perkins et al. 2004), even leading to non-intended side effects and trade-offs, such as gentrification processes (Checker 2011; Meishar 2018; Rigolon and Németh 2019). As climate justice, for example, can improve living conditions in targeted urban areas, dynamics of residential self-selection and shifts in real estate pricing can lead to uneven access to the benefits, i.e. privileging people who are already resistant or recover easily because of their wealth. This may undermine ongoing political efforts for social diversity and equity, perhaps leading to displacement of less affluent residents when marginalized families have to relocate to affordable residential spaces (Astmarsson et al. 2013; Rigolon and Németh 2018). Refurbishing entire urban quarters may advance residential segregation by pushing out the less affluent and the less outspoken (Pareja-Eastaway and Winston 2017). Such action may also push people to move to a built environment where they can easily uphold their existing preferences and financial possibilities regarding mobility, leisure activities, and cultural context (Cao et al. 2009). When transforming the urban fabric to reach climate justice, from the outset it is paramount to address the necessity to integrate the needs of marginalized groups while ensuring that the negative impacts of a warmer climate are reduced (Iwaniec et al. 2019; Patterson et al. 2018).

3.3 Conclusion

This chapter discusses a wide variety of notions and concepts of justice in the current literatures. The chapter presents different perspectives (such as social, environmental or climate justice), but also a wide range of different theoretical-philosophical understanding, at the same time displaying debates on what justice might be and how to reach it. Nevertheless, policy makers around the world follow justice principles with strong implications for the concept of resilience (Johnson et al. 2007; Thaler and Hartmann 2016). The political implications vary highly in terms of who receives support, resources or information from public administrations. In addition, policy goals and strategies with the aim to increase resilience in low-income communities might include negative trade-offs (like gentrification processes)—this has been evident with the implementation of "Nature-based Solutions (NbS)" in urban areas.

In future research, there exist several aspects that need to be addressed. First, there is a need for better conceptual connections in the field of flood risk management, justice, and resilience. As a first step, scholars must assess the aspect of justice in theoretical discourses in flood risk management (Kuhlicke et al. 2020). Second, there is a need to have a stronger focus on the question of empirical research. The different theoretical streams in justice require reflection surrounding how we might collect data and analyze them. Finally, there is a need to address justice in all fields of resilience activities in flood risk management. There are diverse traditions regarding how to reach resilience, but these actions need to be seen through a lens of justice to address the needs and interests of the community in general.

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References

Agudelo-Vera, C., Leduc, W., Mels, A., & Rijnaarts, H. (2012). Harvesting urban resources towards more resilient cities. *Resources, Conservation and Recycling, 64*, 3–12

Allen, A., Griffin, L., & Johnson, C. (Eds.). (2017). *Environmental justice and urban resilience in the global South.* London: Palgrave Macmillan.

Amin, S. (2010). *Eurocentrism.* (2nd ed.). New York: Monthly Review Press.

Astmarsson, B., Jensen, P. A., & Maslesa, E. (2013). Sustainable renovation of residential buildings and the landlord/tenant dilemma. *Energy Policy, 63*, 355–362

Béné, C., Mehta, L., McGranahan, G., Cannon, T., Gupte, J., & Tanner, T. (2018). Resilience as a policy narrative: Potentials and limits in the context of urban planning. *Climate and Development, 10*(2), 116–133

Bennett, N. J., Blythe, J., Cisneros-Montemayor, A. M., Singh, G. G., & Sumaila, U. R. (2019). Just transformations to sustainability. *Sustainability, 11*(14), 3881

Boelens, R., Perreault, T., & Vos, J. (Eds.). (2018). *Water justice.* Cambridge: Cambridge University Press.

Bolin, B., Grineski, S. E., & Collins, T. W. (2005). The geography of despair: Environmental racism the the making of South Phoenix, Arizona, USA. *Human Ecology Review, 12*(2), 156–168

Bullard, R. (2000). *Dumping in Dixie: Race, class, and environmental quality.* (3rd ed.). Boulder: Westview Press.

Cao, X., Mokhtarian, P. L., & Handy, S. L. (2009). Examining the impacts of residential self-selection on travel behaviour: A focus on empirical findings. *Transport Reviews, 29*(3), 359–395

Chakraborty, J., Collins, T. W., & Grineski, S. E. (2019). Exploring the environmental justice implications of hurricane Harvey flooding in Greater Houston, Texas. *American Journal of Public Health, 2*, 244–250

Chakraborty, J., Collins, T. W., Montgomery, M. C., & Grineski, S. E. (2014). Social and spatial inequities in exposure to flood risk in Miami, Florida. *Natural Hazards Review, 15*(3), 04014006

Checker, M. (2011). Wiped out by the "greenwave": Environmental gentrification and the paradoxical politics of urban sustainability. *City & Society, 23*(2), 210–229

Ciullo, A., Kwakkel, J. H., De Bruijn, K. M., Doorn, N., & Klijn, F. (2020). Efficient or fair? Operationalizing ethical principles in flood risk management: A case study on the Dutch-German Rhine. *Risk Analysis, 40*(9), 1844–1862

Collins, T. W., Grineski, S. E., & Chakraborty, J. (2015). Household-level disparities in cancer risks from vehicular air pollution in Miami. *Environmental Research Letters, 10*, 095008

Collins, T. W., Grineski, S. E., & Chakraborty, J. (2018). Environmental injustice and flood risk: A conceptual model and case comparison of metropolitan Miami and Houston, USA. *Regional Environmental Change, 18*(2), 311–323

Davis, I., & Bellers, R. (1995). *The context of community vulnerability assessment (CVA) and summary of workshop issues*. Paper presented at The Assessment of Community Vulnerability in Hazard Prone Areas, Workshop, London 31 March, Committee of UN IDNDR.

Deeming, H., Whittle, R., & Medd, W. (2011). *Recommendations for changes in UK National Recovery Guidance (NRG) and associated guidance, from the perspective of Lancaster University's Hull Flood Studies*. Lancaster: Lancaster University.

Dibben, C., & Chester, D. K. (1999). Human vulnerability in volcanic environments: The case of Furnas, Sao Miguel, Azores. *Journal of Volcanology and Geothermal Research, 92*, 133–150

Dobbie, B., & Green, D. (2015). Australians are not equally protected from industrial air pollution. *Environmental Research Letters, 10*, 055001

Doorn, N., Gardoni, P., & Murphy, C. (2019). A multidisciplinary definition and evaluation of resilience: The role of social justice in defining resilience. *Sustainable and Resilient Infrastructure, 4*(3), 112–123

Elliott, J. R., & Pais, J. (2006). Race, class, and hurricane Katrina: social differences in human responses to disaster. *Social Science Research, 35*(2), 295–321

Elster, J. (1992). *Local justice: how institutions allocate scarce goods and necessary burdens*. New York: Russell Sage Foundation.

Emrich, C. T., & Tobin, G. A. (2018). Resilience: An introduction. In S. Fuchs & T. Thaler (Eds.), *Vulnerability and resilience to natural hazards*. (pp. 124–144). Cambridge: Cambridge University Press.

Emrich, C. T., Tate, E., Larson, S. E., & Zhou, Y. (2020). Measuring social equity in flood recovery funding. *Environmental Hazards, 19*(3), 228–250

Fraser, N. (1995). Recognition or redistribution? A critical reading of Iris Young's Justice and the politics of difference. *The Journal of Political Philosophy, 3*(2), 166–180

Grinberger, A. Y., & Felsenstein, D. (2014). Bouncing back or bouncing forward? Simulating urban resilience. *Proceedings of the Institution of Civil Engineers –Urban Design and Planning 167*(3), 115–124.

Grineski, S. E., Collins, T. W., & de Lourdes Romo Aguilar, M. (2015). Environmental injustice along the US–Mexico border: Residential proximity to industrial parks in Tijuana, Mexico. *Environmental Research Letters, 10*, 095012

Harrison, J. L. (2014). Neoliberal environmental justice: Mainstream ideas of justice in political conflict over agricultural pesticides in the United States. *Environmental Politics, 23*, 650–669

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4*, 1–23

Honneth, A. (2001). Recognition: Invisibility: On the epistemology of 'recognition.' *The Aristotelian Society Supplementary, 75*(1), 111–126

IPCC (2018). Special report on global warming of 1.5 °C. https://www.ipcc.ch/sr15/. Accessed: 20. Nov. 2020.

Iwaniec, D. M., Cook, E. M., Barbosa, O., & Grimm, N. B. (2019). The framing of urban sustainability transformations. *Sustainability, 11*, 573

Johnson, C., Penning-Rowsell, E. C., & Parker, D. (2007). Natural and imposed injustices: The challenges in implementing 'fair' flood risk management policy in England. *The Geographical Journal, 173*(4), 374–390

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, J., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology & Society, 21*, 39

Kasperson, R. E., & Kasperson, J.X. (2001). *Climate change, vulnerability, and social justice.* Stockholm: Stockholm Environment Institute.

Kaufmann, M., Priest, S. J., & Leroy, P. (2018). The undebated issue of justice: silent discourses in Dutch flood risk management. *Regional Environmental Change, 18*(2), 325–337

Kelman, I., Gaillard, J. C., Lewis, J., & Mercer, J. (2016). Learning from the history of disaster vulnerability and resilience research and practice for climate change. *Natural Hazards, 82*, 129–143

Kim, H., Marcouiller, D. W., & Woosnam, K. M. (2018). Rescaling social dynamics in climate change: The implications of cumulative exposure, climate justice, and community resilience. *Geoforum, 96*, 129–140

Kuhlicke, C., Seebauer, S., Hudson, P., Begg, C., Bubeck, P., Dittmer, C., Grothmann, T., Heidenreich, A., Kreibich, H., Lorenz, D. F., Masson, T., Reiter, J., Thaler, T., Thieken, A. H., & Bamberg, S. (2020). The behavioral turn in flood risk management, its assumptions and potential implications. *WIREs Water, 7*(3), e1418

Lebel, L., Foran, T., Garden, P., & Manuta, J. (2009). Adaptation to climate change and social justice: Challenges for flood and disaster management in Thailand. In F. Ludwig, P. Kabat, H. van Schaik, & M. van der Valk (Eds.), *Climate change adaptation in the water sector.* (pp. 125–141). Milton Park: Routledge.

Leong, K. J., Airriess, C. A., Li, W., Chia-Chen Chen, A. C., & Keith, V. M. (2007). Resilient history and the rebuilding of a community: The Vietnamese American community in New Orleans East. *The Journal of American History, 94*(3), 770–779

Liao, K.-H. (2012). A theory on urban resilience to floods—A basis for alternative planning practices. *Ecology & Society, 17*(4), 48

Liao, K.-H., Hui Chan, J. K., & Huang, Y.-L. (2019). Environmental justice and flood prevention: The moral cost of floodwater redistribution. *Landscape and Urban Planning, 189*, 36–45

Maldonado, A., Collins, T. W., & Grineski, S. E. (2016). Hispanic immigrants' vulnerabilities to flood and hurricane hazards in two United States metropolitan areas. *Geographical Review, 106*(1), 109–135

Mancilla, A., & Campbell, T. (Eds.). (2012). *Theories of justice.* Milton Park: Routledge.

Manyena, S. B., O'Brien, G., O'Keefe, P., & Rose, J. (2011). Editorial. Disaster resilience: A bounce back or bounce forward ability? *Local Environment 16*(6), 1–8.

Markolf, S. A., Hoehne, C., Fraser, A., Chester, M. V., & Underwood, B. S. (2019). Transportation resilience to climate change and extreme weather events—Beyond risk and robustness. *Transport Policy, 74*, 174–186

Medd, W., Deeming, H., Walker, G., Whittle, R., Mort, M., Twigger-Ross, C., Walker, M., Watson, N., & Kashefi, E. (2015). The flood recovery gap: A real-time study of local recovery following the floods of June 2007 in Hull, North East England. *Journal of Flood Risk Management, 8*(4), 315–328

Meishar, N. (2018). The social aftermaths of landscape architecture: Urban parks and green gentrification. *Landscape Metropolis, 5*(2), 3303
Mika, K., & Kelman, I. (2020). Shealing: Post-disaster slow healing and later recovery. *Area, 52*, 646–653.
Mill, J. S. (2006). *Utilitarianism/Der Utilitarismus*. Leipzig: Reclam, Philipp, jun. GmbH, Verlag.
Montgomery, M. C., & Chakraborty, J. (2015). Assessing the environmental justice consequences of flood risk: A case study in Miami, Florida. *Environmental Research Letters, 10*, 095010
Munoz, C. E., & Tate, E. (2016). Unequal recovery? Federal resource distribution after a Midwest flood disaster. *International Journal of Environmental Research and Public Health, 13*(5), 507
Neal, M., Lukasiewicz, A., & Syme, G. J. (2014). Why justice matters in water governance: Some ideas for a 'water justice framework'. *Water Policy, 16*(S2), 1–18
Norris, F. H., Stevens, S. P., Pfefferbauam, B., Wyche, K. F., & Pfefferbaum, R. L. (2008). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology, 41*(1–2), 127–150
Nussbaum, M. (1998). Capabilities and human rights. *Fordham Law Review, 66*(2), 273
Pareja-Eastaway, M., & Winston, N. (2017). *Sustainable communities and urban housing: A comparative European perspective*. London: Routlege & CRC Press.
Patterson, J. J., Thaler, T., Hoffmann, M., Hughes, S., Oels, A., Chu, E., Mert, A., Huitema, D., Burch, S., & Jordan, A. (2018). Political feasibility of 1.5° C societal transformations: The role of social justice. *Current Opinion in Environmental Sustainability, 31*, 1–9
Perkins, H. A., Heynen, N., & Wilson, J. (2004). Inequitable access to urban reforestation: the impact of urban political economy on housing tenure and urban forests. *Cities, 21*, 291–299
Plato (2006). *Republic*. Translated and with an introduction by R. E. Allen. New Haven: Yale University Press.
Rigolon, A., & Németh, J. (2018). What shapes uneven access to urban amenities? Thick injustice and the legacy of racial discrimination in Denver's park. *Journal of Planning Education and Research* 1–14.
Rigolon, A., & Németh, J. (2019). Toward a socioecological model of gentrification: How people, place, and policy shape neighborhood change. *Journal of Urban Affairs, 41*(7), 887–909
Sayers, P., Penning-Rowsell, E. C., & Horritt, M. (2018). Flood vulnerability, risk, and social disadvantage: Current and future patterns in the UK. *Regional Environmental Change, 18*(2), 339–352
Schlosberg, D. (2007). *Defining environmental justice: Theories, movements, and nature*. Oxford: Oxford University Press.
Schlosberg, D., & Collins, L. (2014). From environmental to climate justice: Climate change and the discourse of environmental justice. *WIREs Climate Change, 5*(3), 359–374
Schlosberg, D., Collins, L., & Niemeyer, S. (2017). Adaptation policy and community discourse: Risk, vulnerability, and just transformation. *Environmental Politics, 26*(3), 1–25
Schuppert, F. (2011). Climate change mitigation and intergenerational justice. *Environmental Politics 20*(3), 303.321.

Siders, A. R. (2019). Social justice implications of US managed retreat buyout programs. *Climatic Change, 152*, 239–257
Spaans, M., & Waterhout, B. (2017). Building up resilience in cities worldwide—Rotterdam as participant in the 100 Resilient Cities Programme. *Cities, 61*, 109–116
Thaler, T., & Hartmann, T. (2016). Justice and flood risk management: Reflecting on different approaches to distribute and allocate flood risk management in Europe. *Natural Hazards, 83*(1), 129–147
Thaler, T., & Priest, S. (2014). Partnership funding in flood risk management: New localism debate and policy in England. *Area, 46*(4), 418–425
Thaler, T., & Fuchs, S. (2020). Financial recovery schemes in Austria: How planned relocation is used as an answer to future flood events. *Environmental Hazards, 19*(3), 268–284
Thaler, T., & Levin-Keitel, M. (2016). Multi-level stakeholder engagement in flood risk management—A question of roles and power: Lessons from England. *Environmental Science & Policy, 55*, 292–301
Thaler, T., Doorn, N., & Hartmann, T. (2020). Justice of compensation for spatial flood risk management–comparing the flexible Austrian and the structured Dutch approach. *Die Erde, 151*(2–3), 104–115
Thaler, T., Fuchs, S., Priest, S., & Doorn, N. (2018). Social justice in the context of adaptation to climate change—Reflecting on different policy approaches to distribute and allocate flood risk management. *Regional Environmental Change, 18*(2), 305–309
Thaler, T., Zischg, A., Keiler, M., & Fuchs, S. (2018). Allocation of risk and benefits—Distributional justices in mountain hazard management. *Regional Environmental Change, 18*(2), 353–365
UN. (2005). *Hyogo framework for action.* Geneva: United Nations.
UN. (2015). *Sendai framework for disaster risk reduction 2015–2030.* Geneva: United Nations.
Varian, H. R. (1975). Distributive justice, welfare economics, and the theory of fairness. *Philosophy and Public Affairs, 4*(3), 223–247
Walker, G. (2012). *Environmental Justice. Concepts, evidence and politics.* Milton Park, Abingdon, Oxon: Routledge.
Walker, G., & Burningham, K. (2011). Flood risk, vulnerability and environmental justice: Evidence and evaluation of inequality in a UK context. *Critical Social Policy, 31*(2), 216–240
Weber, K. (2015). Landschaftsplanerische Betrachtung des Umgangs mit Naturgefahren aus genderspezifischer Perspektive - am Fallbeispiel des Murenabganges in St. Lorenzen im Paltental 2012. Master thesis. Vienna: University of Natural Resources and Life Sciences.
Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk. Natural hazards, people's vulnerability and disasters.* Milton Park: Routledge.
Zwarteveen, M. Z., & Boelens, R. (2014). Defining, researching and struggling for water justice: Some conceptual building blocks for research and action. *Water International, 39*(2), 143–158

4

House Lifting to Improve Flood Resilience in Settlement Areas—an Example of the Elbe Village Brockwitz (Saxony, Germany)

Marco Neubert and Reinhard Schinke

4.1 Introduction

4.1.1 From Flood Risk Management to Resilience and Sustainability

Floods are among the most frequent and consequential natural events worldwide. At the same time, trends show an increase in flood-prone assets and thus flood damage. Concepts, strategies, methods and measures are therefore continuously being developed and refined in order to be better prepared for such events and to be able to mitigate or prevent flood damage. In the past, the main focus was on protection against flood hazards. However, it became apparent that absolute protection is not achievable. An important milestone in flood management reflects the European Floods Directive (2007/60/EC), which illustrates the ongoing shift of traditional flood protection to risk-based approaches (Hartmann and Jüpner 2017). Frequently, decisions in flood risk management are based on risk analyses that relate in particular to direct damage and consequences. Typically, indirect and non-monetary effects are not considered (De Bruijn 2020).

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These limitations characterize one decisive fact for further developments improving the management of floods and other natural hazards. This is in line with current changes and the increasing importance of resilience approaches (cf. Schinke et al. 2016). With focus on urban resilience, the concept geared to integrative and sustainable approaches, considering relevant functions of urban systems and their interactions (Albano et al. 2015; Serre et al. 2012, 2016). In consequence, both research and legislation started to have a more holistic view on all elements of the flood risk management cycle to improve existing solutions and to develop new options reducing current and future flood risks. It also includes environmental, societal and economic perspectives and thus aim for more sustainable solutions (Connelly et al. 2015; De Moel et al. 2015; Serre et al. 2016; Vojinović 2015).

The concept of resilience is gaining more and more attention, despite the fact that the term and concept are characterized by a certain vagueness (Hartmann and Jüpner 2020, see Hutter et al. in this volume, Chap. 1). The idea of resilience is directed towards integrated solutions for environmental issues in an increasingly complex environment that take into account other aspects besides economic consequences (Disse et al. 2020). In this context, the assessment and application of measures should be flexible and integrative, considering the dynamics of the processes—but also robust solutions. With regard to flood risk management, the application of the resilience concept is first fundamentally used to mitigate the negative impact of extreme events (ibid.), but this is linked to improve concepts of measures. Resilience supports on the one hand "bouncing back" (lat. "resilio") to a previous system state, which determines the stability of a system. On the other hand, the concept of resilience focuses on adaptation, which improves the sustainability of the system (ibid.).

Against this background, this paper focuses on the topic of urban resilience (Meerow and Newell 2016), more specifically the resilience of buildings. Since the study is also covering natural instead of solely built-up areas, it is also addressing landscape resilience. Schmidt (2020) defines landscape resilience as the adaptability and self-renewal capacity of a landscape and thus the ability to maintain, regenerate and increase its own fundamental landscape qualities (functions, services, etc.) despite disturbances, crises or ongoing changes. Applied to this study, the construction of a dike would lead to the almost complete loss of the natural landscape resilience of the Elbe floodplain in the case study area as this artificial technical structure would massively impair the natural landscape. In addition, the appearance of the landscape would also be degraded by human intervention. At the same time, the study also considers (to a large extent) aspects of sustainability for assessing the impacts.

Knowledge integration is important as well for the transdisciplinary approach of the study presented. We refer to it as the purposeful combination of specialized and complementary knowledge to accomplish specific tasks (Tell 2011). The research reported here required the involvement of manifold actors of different scientific domains to get an overall picture of the resulting solution and its consequences. Besides, the process involved also local residents affected by decisions on measures for flood risk reduction as well as the city administration (see below).

4.1.2 Background and the Idea of House Lifting in Brockwitz

The flood events of the last decades led to immense economic damage and highlighted the need to plan and implement appropriate measures for damage and risk mitigation. Due to a further increase in event frequency and intensity caused by climate change, robust and sustainable solutions are becoming increasingly important.

In recent years, therefore, enormous efforts have been made to limit the effects of flood events. The Free State of Saxony, for example, has invested around 2.6 billion Euros in flood protection and in the elimination of flood damage to existing protection systems since the major flood event in 2002 (SMUL 2017).

The prioritization of new flood protection measures to be built by the Free State of Saxony was based on uniform criteria that took into account the extent of the damage potential, the cost–benefit ratio, water management aspects, as well as particular impacts, consequential hazards and protection requirements (SMUL 2005). Based on these evaluations, many priority projects were established. These projects showed their effectiveness during the 2013 flood and they prevented numerous damages.

However, the assessment also reveals that there are a number of projects that have a low priority and consequently will not (or cannot) be implemented in the near future. The main reasons are often local or small-scale projects in combination with less favorable benefit–cost ratios. The situation described leads to the fact that flood risks in these areas will continue to exist for the time being and that other precautionary strategies will have to gain in importance.

Brockwitz, a village within the municipality of Coswig (Saxony, Germany) located on the Elbe River with a 1000-year history, has also been affected by floods and was severely affected by the events in 2002 and 2013. Due to the local conditions, a stationary flood protection facility (dyke) is contested here, as it would represent a significant intervention in the cultural landscape and the historic townscape. At the same time, it is possible to protect only a relatively small number of buildings with such a massive intervention, so that this project—from an overall Saxon perspective—has a low priority and the implementation of the measure in the near future is questionable.

This prompted the identification of suitable alternatives for damage and risk reduction, an assessment of their feasibility, and an evaluation of the consequences for the village, its residents, and the surrounding area. The aim is to maintain or improve the attractiveness and quality of life of the town and the natural functions of the Elbe floodplain. The municipality of Coswig is pursuing an innovative solution approach of *house lifting* for the flood-affected houses in order to mitigate the flood risks in accordance with principles of sustainability and of avoiding subsequent operative costs.

This chapter reflects the chosen approach with the investigations carried out—in the sense of a feasibility study. The chapter gives an overview of the work conducted to date and the results achieved, which serve as a basis for an evaluation of the alternative courses of action in the Brockwitz case study (cf. Schinke et al. 2019).

4.2 Methodology

4.2.1 Overall Approach for Analyzing Flood Resilience and Sustainability

Following the idea of an area-related house lifting, the aim was to investigate key issues for a resilience and sustainable development with regard to appropriate flood mitigation measures. Our intension was to find a comprehensive approach, which ensures the transferability of the methodical results. For this purpose, essential influencing factors had to be investigated and evaluated in an interdisciplinary context.

At first, the investigation focuses on a detailed view of the flood hazard situation in the catchment of the Elbe River. For this purpose, characteristic (mean) flood hydrographs and flood peak values for different occurrence probabilities were derived by means of extreme value statistical methods. Based on this, hydro-numerical modeling was carried out, which was based on the 2D-HN model of the Elbe River. For the extracted section, which is about 31 km long, the digital terrain model and the building stock were updated and the roughness occupancy was adjusted, in addition to the hydrological parameters. By refining the calculation network in the area of the buildings, the evaluation of flow velocities was also possible between the buildings. The calculations were performed for actual and planned conditions under quasi-stationary conditions, in particular to derive the required height for the envisaged flood protection, and under transient conditions to obtain realistic information on inundation areas and flow velocities (Carstensen et al. 2018).

Of central importance was the analysis of the building stock, which focused on three fundamental aspects:

- A building typological differentiation of the settlement structure as well as incorporation of object-specific building parameters as a basis for damage modeling and the assignment of vulnerability information,
- An assessment of the building stock including the existing cultural monuments and the historic settlement with regard to their significance for the preservation of monuments, cultural history and the view of the place, as well as
- An initial structural assessment with regard to technologically relevant boundary conditions for house lifting.

The investigations are based on on-site inspections, individual case studies and archival research. A central result are the recommendations and guidelines for the selection and scope of the objects to be preserved, which were developed from the perspective of monument preservation. These are aimed at preserving the culturally and historically valuable objects in the ensemble and in their spatial relationship to each other. In addition, the specific character of the village could be strengthened by a targeted arrangement of replacement buildings in the building line.

The structural and constructional investigation of the existing building fabric in conjunction with interviews with experts served for the detailed consideration of process-related and constructional boundary conditions for house lifting. House lifting is not an unknown procedure. It is used in civil engineering for the solving of various tasks. Typical fields of application are in particular the correction of foundation problems, e.g., as a result of subsidence in former mining areas, and the avoidance of rising groundwater, e.g., after the cessation of mining dewatering. Technologically, house lifting can be differentiated, for example, according to the attachment points/attachment system of the lifting tools:

- Lifting via load-bearing foundation slab or ceiling construction,
- Lifting via load-bearing wall constructions,
- Lifting via auxiliary constructions (cf. Melenhorst et al. 2019a).

Depending on the structural conditions, the lifting techniques can be combined, so that a variety of adaptations and special solutions are possible. Especially in recent years, a number of house lifting projects has been carried out, which includes some historic buildings. Regardless of this development, the lifting of rural residential buildings, some of which were built before 1870, in conjunction with quarry stone wall and partial basements, remains a challenge that should not be underestimated. Here, it can be assumed that additional measures are necessary to stabilize and improve the load-bearing capacity of the constructions. A limitation of the lifting height can be circumvented by a stepwise approach.

Another key aspect of the study is the impact of the flood protection measures on nature and landscape (see subsection 4.2.3). For this purpose, biotope structures as well as plant and animal species composition were mapped for the actual state. On this basis, indications for the protection and preservation of the biotopes and biodiversity during and after the construction measures could be provided.

The aim of this part of the investigations was a nature conservation analysis and evaluation of the current state of the affected landscape. A subsequent assessment and prognosis of the adverse effects of flood protection on nature and landscape aimed to compare the two construction options of house lifting including land filling and dyke construction to show the advantages and disadvantages as well as the degree and extent of negative impacts on the natural area and thus provide decision-making support. In addition, proposals for minimizing damage to nature and the landscape were developed as well as compensation and replacement measures to improve the situation for native flora and fauna.

All in all, the results of the investigations and explorations carried out lead to drafts for local and open space planning, which contribute to the development of resilient landscape and settlement areas. The focus here is on the question of the usability and adaptation possibilities of the link between “house—garden—landscape space” as well as the effects of house lifting on the townscape and the public space.

A major emphasis was also given to involving the affected citizens and property owners in order to develop common ideas and perceptions for the precautionary concepts. An important component here was the implementation of participation workshops, whose results were incorporated into the conception of measures and are also reflected in the resulting inspiration manual (Melenhorst et al. 2019b).

4.2.2 Analysis of Risk and Risk Mitigation

In the light of the case study with its focus on house lifting, there is a need for a detailed damage simulation that analyses the changes of risks for each individual object. The HOWAD/GRUWAD model provides an appropriate basis, which is characterized by (i) a multi-scale approach analyzing risks and risk mitigation from local to regional scale, (ii) innovative methods to describe the urban structure and the vulnerability as well as (iii) a high spatial and contextual resolution of the resulting risks (Neubert et al. 2016; Schinke et al. 2012, see also Hutter et al. in this volume, especially chap. 2 for a summary on the HOWAD/GRUWAD). The model has been used for many years in risk modelling and in the evaluation of flood protection concepts that includes a continuously further development of methods and their data basis.

Within the approach, the urban structure is characterized by a building typology that uses a differentiation of structure types, construction periods and considers the main construction of every individual building. Due to field survey, there was the possibility to collect damage dominating attributes like the 'ratio of basement floor area to building footprint' and the 'depth of foundation' (see Schinke et al. 2012). Due to a significant variation in building types, the parameter could considered here directly on the building polygon and the building related analysis. Depending on the flood hazard, it allows the exact definition of the lifting height (see Fig. 4.1).

The derivation of synthetic depth-damage functions to describe the vulnerability of buildings, as a decisive basis for the model approach used, based on detailed analysis of characteristic buildings. The flood stages are used to identify damage, to specify remediation techniques as well as to calculate refurbishment costs (Schinke et al. 2016). Due to the small case study area, there was the possibility to adapt and to create individual depth-damage functions on specific house lifting and construction conditions.

4.2.3 Analysis of Nature and Environmental Issues

In addition to a sampling-based faunistic and floristic survey in summer/fall 2017 (birds, bats, reptiles, amphibians, butterflies, dragonflies, grasshoppers, xylobiont beetles as well as plants), an area-wide status analysis and assessment of biotopes was carried out. This was conducted in fall 2018 and covered all biotopes that would be affected by the planned house lifting and land filling as well as dike construction.

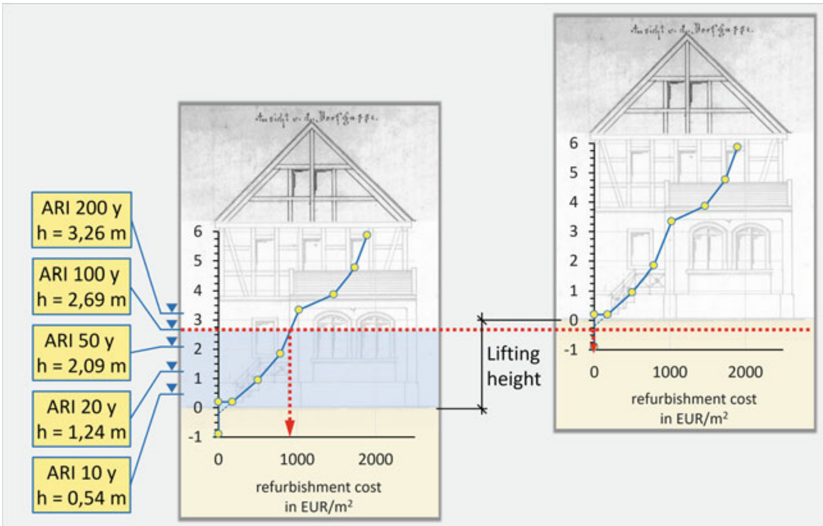

Fig. 4.1 Approach to consider house lifting in damage and risk models with high spatial and contextual resolution. (*Source* Schinke et al. 2019, modified)

Taking into account a suitable biotope mapping method (Schulte et al. 1993) and according to legal requirements regarding protection status according to the Nature Conservation Act of Saxony (SächsNatSchG) and the EU Habitats Directive, as well as on the basis of knowledge about the binding of value-giving species to the corresponding habitats in the study area (e.g., Bellmann 1993; Flade 1994; Hardtke and Ihl 1999), all affected areas/biotopes have been classified according to the following three-part scale: low, medium and high nature conservation value. According to this, legally protected biotopes (according to § 21 SächsNatSchG), such as scattered orchards and lean fresh meadows as well as extensively used lean grassland of fresh sites, which can also be assigned to habitat type 6510 'Lean lowland meadow' according to the EU Habitats Directive if they have a characteristic appearance and corresponding floristic composition, are considered to be of 'high value'. Other extensively used grassland and relatively structurally rich, near-natural gardens with native shrubs and fruit trees have a 'medium value'. In contrast, weekly mowed short lawns, beds with foreign ornamental shrubs and wood chip cover are considered 'low value'. All sealed surfaces were also identified.

Furthermore, all trees in the project area were mapped and also classified from a nature conservation point of view according to a three-level scale of value. Old fruit trees with tree cavities and prominent native deciduous trees/solitary trees with a diameter at breast height of more than 60 cm were classified as ‘high value’, younger fruit trees without tree cavities, other native and typical deciduous trees in the area have a ‘medium value’ and conifers that are not typical for the site and foreign conifers, such as blue spruces, are classified as ‘low value’.

4.3 Results and Discussion

4.3.1 Action Alternatives Investigated for the Case Study Brockwitz

A first step was directed towards a more detailed description and characterization of the action alternatives as an essential basis for all further investigations. This includes general specification to different restrictions, dependencies, and impacts. It is closely linked with the hazard analysis to derivate the protection level for the case study area. In summary, Fig. 4.2 reflects the action alternatives considered. It illustrates the focus on comprehensive comparison between traditional flood protection (dyke) and a measure of house lifting including land filling, which was proposed in this special case as a smart alternative. The conditions for house lifting are favorable, because the severely affected buildings stay close together and the rising terrain facilitates the integration in the landscape. The protection level was set to the water level of a recurrence interval of 100 years under steady-state conditions that ensures a flood freeboard of 50 cm. For the house lifting, the protection level was determined by the minimum level of the ground floor.

The dike variant is based on a first routing draft developed for the flood management concept of the Free State of Saxony. The dike line is located close to the village and has a construction mean height of about 3.5 m and a maximum height of about 4.5 m.

The house-lifting variant integrates central results of the research. It is characterized especially by the recommendations of historic preservation with its focus on an area-related house lifting without singularities, preservation of the historic building fabric as well as retention the view of place. The lifting height are between 1 and about 3 m, in individual cases up to 4 m.

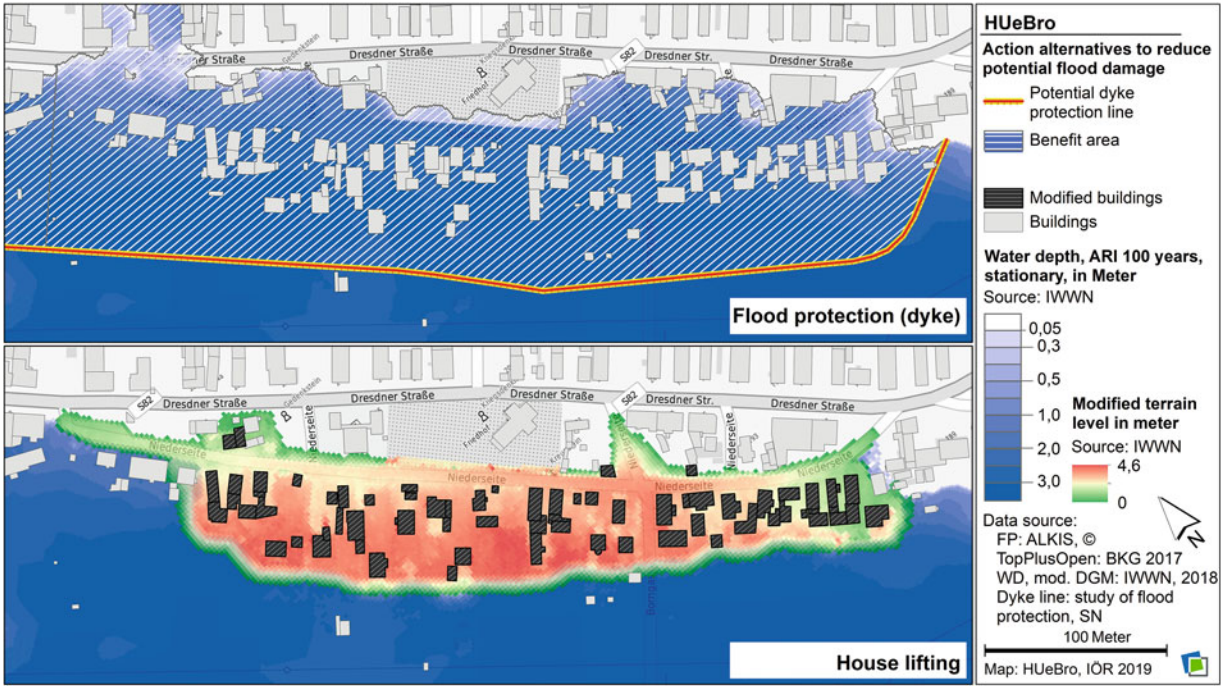

Fig. 4.2 Main action alternatives to mitigate flood risks, investigated in the case study. (*Data sources* Results of the hydrological analysis: IHM; Results of the hydro-numeric modelling: IWWN; Image source: Schinke et al. 2019, modified)

4.3.2 Results of Environmental and Nature Conservation Aspects

The result of the nature conservation evaluation of the affected areas as well as the affected woody plants is shown in Fig. 4.3. In the case of the house lifting with land filling, the proportion of areas of high nature conservation value is only just under 1% (approx. 190 m^2), and that of medium value is 6% (approx. 1,632 m^2), so that a relatively small area of 0.2 ha relevant to nature conservation would be affected. In contrast, 60% of the area in this variant is sealed (building area, roads, paths, access roads, terraces, etc.). More than 30% (approx. 8,010 m^2) of the area can be assessed as low-value from a nature conservation point of view, because it is intensively maintained short lawn, foreign conifer hedges and beds with foreign ornamental shrubs, which are partly covered with wood chips. Such intensively overgrown areas represent hostile areas for a large part of the native flora and fauna, which offer them hardly any development opportunities and therefore have only a low nature conservation value.

In the case of the dike construction variant, the proportion of areas of high nature conservation value affected by the construction measure is just under 40% (approx. 12,754 m^2), of areas of medium value 20% (approx. 8,459 m^2) and of areas of low value just under 40% (approx. 12,593 m^2). The proportion of sealed surfaces is less than one percent and is limited to two driveways and one building. This means that the construction of a dike would destroy about 2 ha of areas of high and medium nature conservation value (e.g., meadow orchards and lean fresh meadows as well as other extensively used grassland) and thus 60% of the total affected area. This does not take into account that woody habitats are additionally affected by clearing on the dike distance space.

In terms of mapped trees, the following result is found: 59 trees were mapped in the area of the house lifting and land filling. Of these, 5 trees have a high conservation value and 12 trees have a medium conservation value. Almost three quarters of all trees (42 items) in the vicinity of the residential buildings are blue spruce or other alien or non-site-specific tree species, all of which have a low conservation value.

On the planned area of the dike construction variant, 297 trees were mapped. 29 trees are classified as high and 182 as medium nature conservation value. Just under a third of the trees (86) have a low conservation value. Figure 4.3 clearly shows that with a potential clearing area of 10 m in the dike foreland and hinterland, additional trees would be affected; with a potential clearing area of 30 m, additional trees would be affected.

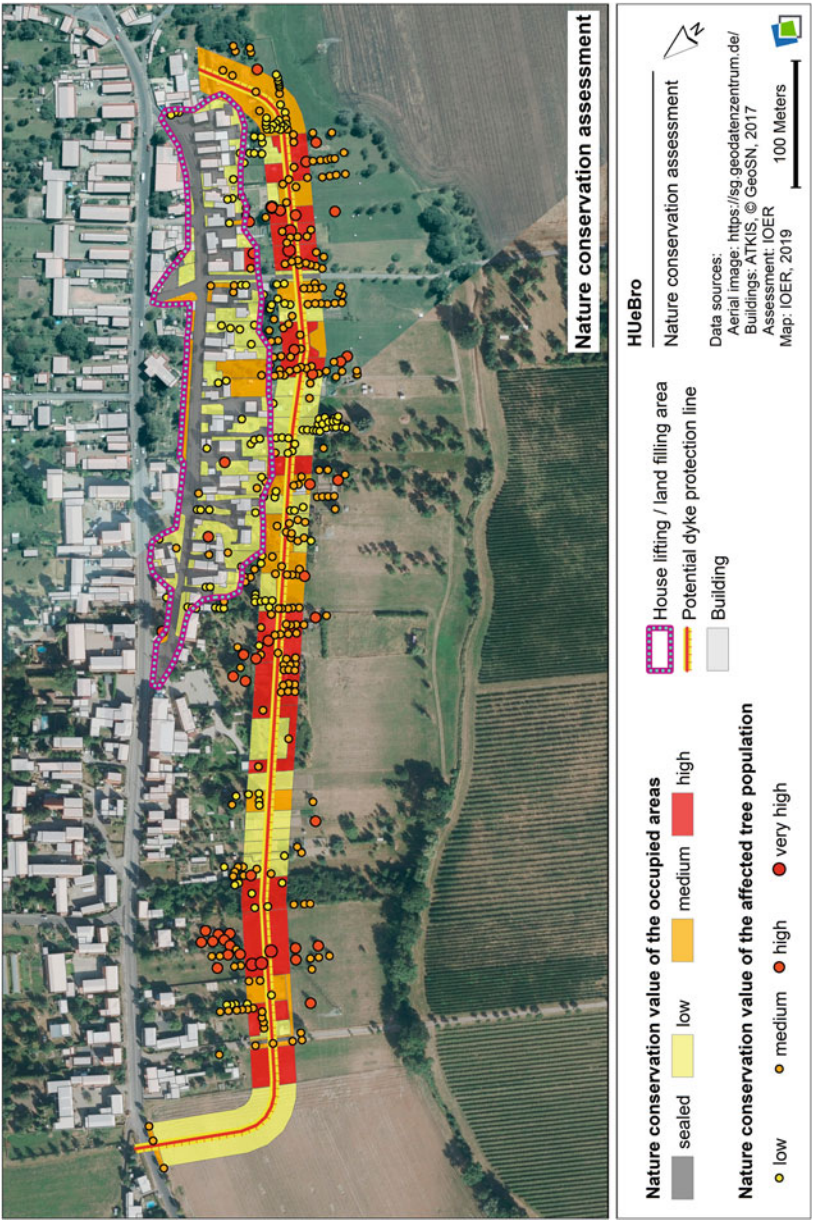

Fig. 4.3 Result of the nature conservation value assessment of the occupied areas as well as the affected tree population. (*Source* Carstensen et al. 2020, modified)

The planned construction measures will inevitably lead to impairments in nature and landscape in both variants, as there will be a massive change in the surface structures.

The area affected by the house lifting including land filling amounts to 2.6 ha. Within this area, the buildings cover approx. 5,000 m^2 and roads, paths, access roads and other sealed areas 10,250 m^2. At this stage, there is a total sealed area of 15,250 m^2 or ample 1.5 ha, and there is an unsealed area of about 1 ha that will be backfilled but will remain unsealed.

In the case of the dyke construction, a crest height of up to 4.5 m is determined for the project area, as well as a width of about 34 m and a length of about 1,000 m according to technical specifications, e.g., angle of inclination. Thus, an area of about 3.5 ha will be completely built over, i.e. on this area the original biotopes will be removed and the landscape functions will be permanently impaired. On this dike area, for example, it can be assumed that the water absorption capacity is limited due to the construction technology and relief, due to the use of stone fill, stone inserts, geogrid mattresses, soil consolidation by adding binding agents, etc. In addition, there is the mandatory dyke defense path. With a width of about 3.5 m, an additional area of about 0.3 ha is sealed, which is currently still unsealed. In this respect, the construction of the dike would directly remove about 3.5 ha of retention area from the floodplain, as well as another 4–5 ha through the embankment of terrain, which would remain unchanged in the house lifting and land filling variant. In total, the loss of habitat amounts to almost 4 ha and the loss of retention area to at least 8 ha.

In the case of house lifting and land filling, only just under 0.2 ha of areas of high and medium value in terms of nature conservation would be affected. On the other hand, there is a potential area of 0.2 to 1 ha that can be unsealed and/or ecologically upgraded in the course of the site filling and redesign of the terrain around the buildings.

The dike construction variant, on the other hand, would destroy about 2 ha of area on which high-quality and medium-value biotopes were identified from a nature conservation perspective.

According to Code of Practice DWA-M 507-1 (DWA 2011), there is a requirement that a distance of 10 m or 30 m (copses class I, such as poplars, sycamores, robinias, etc.) must be free of trees on both sides of the dike, measured from the dike bottom (Haselsteiner 2018). This results in a considerable encroachment. In this respect, the dike construction variant would destroy many more trees (51), of which 6 are high nature conservation value and thus legally protected cavity trees, while the house elevation and terrain filling would have a much smaller impact on or negative effects on high nature conservation value areas and high value woody plants.

The house lifting and land filling alternative would only advance the existing terrain level of the river terrace by a few feet. All visual relationships and the typical landscape grading would be only slightly changed compared to the dike construction variant. In contrast, the levee construction alternative would involve a massive encroachment on the natural zoning of the floodplain landscape, which would result in an extreme visual barrier from both sides throughout the landscape section.

A similar assessment can be made for protected and endangered animals and plants: Significantly more legally protected and endangered species would be impacted or their habitats destroyed during construction of a dike than under the house lifting and land filling alternative. The few breeding sites on buildings that have been identified so far would be preserved, provided that the houses are raised, or can be adequately replaced after reconstruction of the outbuildings.

In summary, we conclude that house lifting and land filling in comparison to dike construction represents a significantly lower intervention from a nature conservation point of view and should be preferred for this reason. In addition, there is the potential to ecologically improve the filled-in settlement areas through design and planting that increases biodiversity. At the same time, this would make the settlement more resilient to other climate change-related influences such as heat and drought.

4.3.3 Economic Aspects

The economic investigation is based on the shown model approach calculating the flood damage to buildings. It uses the results of (i) the hydro-numerical modelling (Carstensen et al. 2018), (ii) the detailed surveys of the building stock and (iii) the analysis of the building vulnerability in the case study area. It forms the basis for the variant analysis, taken into account the flood hazards for different recurrence intervals. Moreover, it considers the current situation without mitigation measures as well as the derived planed situations with the effects of mitigation measures due to flood protection (dyke) and area related house lifting.

Figure 4.4 provides an important summary of the variant analysis and their results. The shown risk curves reflect the expected, potential damage to buildings depending on the recurrence intervals of the flood events. The damage values are displayed in percent related to the current situation with an average recurrence

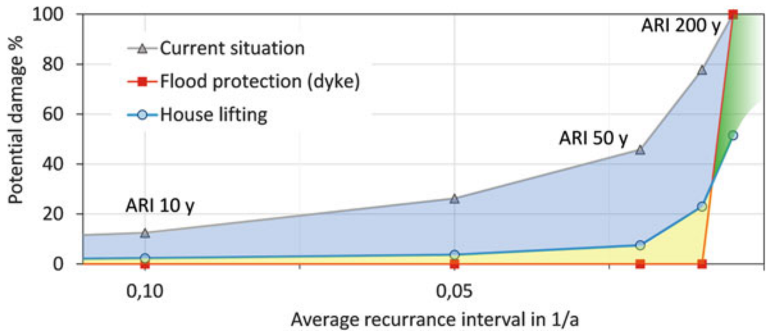

Fig. 4.4 Risk curves for the case study area. (*Source* Schinke et al. 2019, modified)

interval of 200 years. The colored, differential area between the curves of the current situation without and the planed situation with mitigation measures indicates the prevented damage to buildings.

With a view of the recurrence interval up to 100 years, the flood protection (dyke) will prevent all damage behind the dike. If the house lifting variant refers to the same protected area, then some damage to buildings remains in this area (about 20%). The main reason is here that the protected area of the dyke is much greater than the area of house lifting (see Fig. 4.2).

Regardless of this, the dike will not provide any protection, if the flood level exceeds the level of a 1 to 100 year event. Due to an uncontrolled, fast overtopping of the dyke, such events could lead to a catastrophic situation with (i) destroying parts of the dyke structure, (ii) destroying of several buildings by flood levels in the first floor and (iii) danger to life by a potential delayed evacuation. In the same way, such an extreme event will lead to moderate flood levels for the lifted buildings and there is the possibility to prevent the damage by mobile systems. Figure 4.4 highlights these important advantages by the green color between the relevant curves and illustrates the improved resilience of the village.

A further economic aspect focuses on measurement costs. In a first raw estimate, it is to assume that the costs of house lifting are higher than for a dike construction. In our case study, the investigation costs of both measures are relatively similar. One reason is the massive construction of the dyke with a length of about 1,000 m on the one hand and the smart, focused measure on the other hand. In contrast to house lifting and land filling, the dyke results in a construction structure and needs maintenance cost or reinvestment costs. This is why both measures lead to cost benefit ratios in a similar range, which allow further investigations and planning steps to justify all results in more detail.

4.3.4 First Overall Assessment of House Lifting in Brockwitz

The extensive and interdisciplinary investigations were used as a basis for a comparative assessment between the innovative house lifting including land filling and the conventional dike construction variant. Even though the evaluation and overall assessment is still tentative and was carried out at a relatively coarse level in the sense of a feasibility study, some factors can already be highlighted here:

As explained in subsection 4.3.3, the main objective, i.e. the protective effect of both variants—dike and house lifting with land filling—is comparable up to a protection level of a flood recurrence interval of 100 years. For higher events, the protective effect of the house lifting exceeds that of the dike, while both the costs and the cost–benefit ratio are similar.

Positive secondary effects of the house lifting can be seen from the point of view of historic preservation, since a house lifting that is compatible with the view of the location means a less severe intervention for the landscape as well as the culturally and historically valuable building ensemble and, in addition, the historic building fabric would be secured in the long term.

In addition, there are major advantages for the natural environment and landscape. In the case of house lifting with land filling, the intervention is mainly limited to the area of the current development, so that—in comparison to the dike solution—the areas in the floodplain of the Elbe that are valuable in terms of nature conservation are affected to a significantly lesser extent. The leveling of the terrain required by the elevation can also be used for an ecological enhancement of the area. This is in line with the various design options and upgrading possibilities that arise in local and open space planning.

4.4 Conclusions

The article gives a general overview of the investigations carried out in the sense of a feasibility study. It became clear that the house lifting has a number of sustainable and positive aspects, but is also associated with additional effort. It should be emphasized that the flood protection achieved with the house lifting is almost invisible, counteracts an impairment of the natural space and can thus make a valuable contribution to the development of the village. At the same time, the existing views of the surrounding area are maintained or even improved. The house lifting will not result in the construction of any new facilities, so that the corresponding maintenance costs will be avoided. Further detailing of the property-specific development options will enable the advantages for users and owners to be elaborated more specifically and funding opportunities to be identified, which should increase acceptance of the necessary individual effort. The workshops conducted represent a suitable format to further support the implementation of the precautionary concept.

Based on the project results, funding for the implementation of the project was applied from the German federal government as a model project. Fortunately, the funds were approved in 2020 and the implementation is planned therefore in the next few years.

Acknowledgements The presented work was part of the joint research project 'House lifting in flood-prone areas based on the example of the Elbe village Brockwitz' (in German: Haushebung in Ueberschwemmungsgebieten am Beispiel des Elbe Dorfes Brockwitz, HUeBro). There was an interdisciplinary cooperation with the scientific institutions of

• Institute of Hydraulic Engineering and Water Resources Management (IWWN), Technische Hochschule Nürnberg (Nuremberg Institute of Technology, lead partner)

• Institute of Hydrology and Meteorology (IWH), TU Dresden

• Institute of architectural history, architectural theory, and historic preservation, TU Dresden

• Detmolder Schule für Architektur und Innenarchitektur, University of Applied Sciences and Arts Ostwestfalen-Lippe.

Furthermore, it includes the concept to evaluate the results with a holistic view of a sustainable and resilient development. The concept represents the basis for the common assessment of the overall project results together with all project partners.

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References

Albano, R., Mancusi, L., A. Sole, & J. Adamowski. (2015). Collaborative strategies for sustainable EU flood risk management: FOSS and Geospatial tools—Challenges and

opportunities for operative risk analysis. *ISPRS International Journal of Geo-Information, 4*(4), 2704–2727.
Bellmann, H. (1993). *Heuschrecken beobachten—bestimmen.* Augsburg: Naturbuch Verlag.
Carstensen, D., Schwarze, R., Ahlers, C., & Koszinski, C. (2018). Hochwasservorsorge für das Elbedorf Brockwitz—Ein unkonventioneller Ansatz. In N. Schütze, U. Müller, R. Schwarze, T. Wöhling, & J. Grundmann (Eds.), *M3—Messen, Modellieren, Managen in Hydrologie und Wasserressourcenbewirtschaftung. Beiträge zum Tag der Hydrologie am 22./23. März 2018 an der Technischen Universität Dresden* (pp. 1–18). Dresden: TU Dresden.
Carstensen, D., Ahlers, C., Battis-Schinker, E., Bellmann, C., Dally, B., Häusler, A., Koszinski, C. M., Lorenz, J., Mathey, J., Melenhorst, M., Neubert, M., Renneke, J., Schade, C., Schinke, R., Schinker, N. M., Schwarze, R., Volk, K., & Will, T. (2020). HueBro—Haushebung in Überschwemmungsgebieten am Beispiel des Elbe-Dorfes Brockwitz. Projektbroschüre. Nürnberg: TH Nürnberg. https://www.yumpu.com/de/document/read/64766570/huebro-infobroschure. Accessed: 28. Jan. 2021.
Connelly, A., Gabalda, V., Garvin, S., Hunter, K., Kelly, D., Lawson, N., O'Hare, P., & White, I. (2015). Testing innovative technologies to manage flood risk. *Proceedings of the Institution of Civil Engineers—Water Management, 168*(2), 66–73.
De Bruijn, K. M. (2020). Resilience. *Journal of Flood Risk Management, 13: e12670*, 1–3.
De Moel, H., Jongman, B., Kreibich, H., Merz, B., Penning-Rowsell, E., & Ward, P. (2015). Flood risk assessments at different spatial scales. *Mitigation and Adaptation Strategies for Global Change, 20*, 865–890.
Disse, M., Johnsona, T. G., Leandroa, J., & Hartmann, T. (2020). Exploring the relation between flood risk management and flood resilience. *Water Security, 9*, 100059.
DWA. (2011). *DWA-Regelwerk. Merkblatt DWA-M 507-1. Deiche an Fließgewässern Teil 1: Planung, Bau und Betrieb.* Hennef: DWA—Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.
Flade, M. (1994). *Die Brutvogelgemeinschaften Mittel- und Norddeutschlands. Grundlagen für den Gebrauch vogelkundlicher Daten in der Landschaftsplanung.* Eching: IHW-Verlag.
Hardtke, H.-J., & Ihl, A. (1999). *Atlas der Farn- und Samenpflanzen Sachsens.* Dresden: Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie.
Hartmann, T., & Jüpner, R. (2017). The European flood risk management plan: Between spatial planning and water engineering. *Journal of Flood Risk Management, 10*, 143–144.
Hartmann, T., & Jüpner, R. (2020). Implementing resilience in flood risk management. *Wires Water, 7*, e1465.
Haselsteiner, R. (2018). Gehölze an und auf Hochwasserschutzanlagen an Fließgewässern—Erfahrungen aus Deutschland. Proceedings 48th International Symposium on Hydraulic Engineering Aachen (IWASA) and 6th Symposium 'Security of Dams, Dikes and Reservoirs', Aachen. https://docplayer.org/141402751-Gehoelze-an-und-auf-hochwasserschutzanlagen-an-fliessgewaessern.html. Accessed: 28. Jan. 2021.
Meerow, S., & Newell, J. P. (2016). Urban resilience for whom, what, when, where, and why? *Urban Geography, 40*(3), 1–21.
Melenhorst, M, Renneke, J., Kreplin, S., Naumann, C., & Schade, C. (2019a). Gesamtkatalog Haushebung Brockwitz—Architektur & Technologie. Detmold: Technische Hochschule Ostwestfalen-Lippe, Forschungsschwerpunkt urbanLab. https://www.th-owl.de/files/

webs/gestaltung/download/11_Forschung/constructionLab/3_Projekte/Abgeschlossene_Projekte/HUeBro/Gesamtkatalog_Haushebung_Brockwitz.pdf. Accessed: 28. Jan. 2021.

Melenhorst, M., Volk, K., & Schade, C. (2019b). Handbuch Haushebung Brockwitz. Detmold: Technische Hochschule Ostwestfalen-Lippe, Forschungsschwerpunkt urbanLab. https://www.th-owl.de/files/webs/gestaltung/download/11_Forschung/urbanLab/02_Projekte/HueBro/Handbuch_Haushebung_Brockwitz.pdf. Accessed: 28. Jan. 2021.

Neubert, M., Naumann, T., Hennersdorf, J., & Nikolowski, J. (2016). The geographic information system-based flood damage simulation model HOWAD. *Journal of Flood Risk Management, 9*(1), 36–49.

Serre, D., Barroca, B., & Laganier, R. (2012). *Resilience and urban risk management*. London: CRC Press Balkema.

Serre, D., Barroca, B., Balsells, M., & Becue, V. (2016). Contributing to urban resilience to floods with neighbourhood design: The case of Am Sandtorkai/Dalmannkai in Hamburg. *Journal of Flood Risk Management, 11*(S1), 69–83.

SMUL – Sächsisches Staatsministerium für Umwelt und Landwirtschaft. (2005). *Ergebnisse der landesweiten Priorisierung von Hochwasserschutzmaßnahmen*. https://www.umwelt.sachsen.de/umwelt/download/wasser/051206_HwskMaListe_GU_HswskRang_051206.pdf. Accessed: 28. Jan. 2021.

SMUL – Sächsisches Staatsministerium für Umwelt und Landwirtschaft. (2017). *2,6 Milliarden Euro für Hochwasserschutz*. https://www.medienservice.sachsen.de/medien/news/212538. Accessed: 28. Jan. 2021.

Schmidt, C. (2020). *Landschaftliche Resilienz*. Wiesbaden: Springer Spektrum.

Schinke, R., Kaidel, A., Golz, S., Naumann, T., López-Gutiérrez, J. S., & Garvin, S. (2016). Analysing the effects of flood-resilience technologies in urban areas using a synthetic model approach. *International Journal of Geo-Information, 5*(11), 202.

Schinke, R., Neubert, M., Hennersdorf, J., Stodolny, U., Sommer, T., & Naumann, T. (2012). Damage estimation of subterranean building constructions due to groundwater inundation—the GIS-based model approach GRUWAD. *Natural Hazards Earth System Sciences, 12*, 2865–2877.

Schinke, R., Schwarze, R., Carstensen, D., Neubert, M., Schinker, N., Schade, C., Melenhorst, M., & Lier, O. (2019). Haushebung, eine geeignete Maßnahme zur Hochwasservorsorge?—Das Fallbeispiel Brockwitz. In Technische Universität Dresden, Institut für Wasserbau und technische Hydromechanik (Eds.), *Komplexe Planungsaufgaben im Wasserbau und ihre Lösungen* (pp. 373–382). Dresdner Wasserbauliche Mitteilungen 62. https://hdl.handle.net/20.500.11970/106315. Accessed: 28. Jan. 2021.

Schulte, W., Sukopp, H., & Werner, P. (1993). Flächendeckende Biotopkartierung im besiedelten Bereich als Grundlage einer am Naturschutz orientierten Planung. *Natur Und Landschaft, 68*(10), 491–526.

Tell, F. (2011). Knowledge integration and innovation: A survey of the field. In C. Berggren, A. Bergek, L. Bengtsson, M. Hobday, & J. Söderlund (Eds.), *Knowledge Integration and innovation. Critical challenges facing international technology-based firms* (pp. 20–38). Oxford: Oxford University Press.

Vojinović, Z. (2015). *Flood risk: The holistic perspective—From integrated to interactive planning for flood resilience*. London: IWA Publishing.

5 Sustainability and Resilience—A Practical Approach to Assessing Sustainability in Innovative Infrastructure Projects

Alfred Olfert, Jörg Walther, Martin Hirschnitz-Garbers, Katharina Hölscher, and Georg Schiller

5.1 Introduction

Infrastructure systems fulfil essential functions and services of great public interest, such as the provision of energy, water, mobility and communication or the managing of waste and wastewater. Currently, digitization, urbanization, demographic change, climate mitigation, climate change adaptation and the ongoing energy transition including nuclear and coal phase-out in Germany put infrastructure under great pressure and propel fundamental changes. A shift from

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centralized to decentralized or from passive to smart infrastructure can be observed (Loorbach 2010; Malekpour et al. 2015; Markard 2011). New technical possibilities of information and communication technologies (ICT) and their proliferation accelerate the dynamic of change additionally as they make existing services more user-convenient or enable completely new services. In all these changes, infrastructure systems and their services need to ensure economic and resource efficiency, supply security and social justice.

In this context, the transformation of existing infrastructure systems offers great potential to contribute to sustainability transitions (Frantzeskaki and Loorbach 2010; Hölscher et al. 2020). The transformation of infrastructure systems means to create radically new socio-eco-technical systems through the co-construction of social and technological changes, including policy ambitions, social practices, institutional arrangements, knowledge and values (Chester et al. 2019; Monstadt and Coutard 2019). Innovative infrastructure solutions can contribute to such transformation by leading to new market structures, new demands, social innovations or new forms of interaction between interest groups (e.g. 'prosumers') (Frantzeskaki and Loorbach 2010). This opens up space for contributing to sustainability transitions.

Great hopes are placed specifically on coupled infrastructure solutions as a way to achieve more sustainability in the delivery of infrastructure services. In policy-oriented debates on resource efficiency, resilience and 'smart' development, coupled infrastructures are put forth as a way to leverage previously unexploited synergy potentials by interacting resource flows, technological interconnections, institutional interactions and financial interdependencies between different infrastructure domains (Monstadt and Coutard 2019). They have thus the potential to generate ecological, social and economic benefits such as resource efficiency, maximizing returns on investment and more citizen-focused approaches to service provision (Anderies et al. 2016; van Broekhoven and Vernay 2018).

However, the transformation of infrastructure systems is complex and contested. Once in place, infrastructure systems are hard to change due to sunk costs, vested interests, societal expectations and existing regulatory frameworks (Frantzeskaki and Loorbach 2010; Schiller 2010). Especially the coupling of sub-systems from different sectors counters existing regulatory frameworks and implies the involvement of a larger number of actors and interests (Monstadt and Coutard 2019). Overturning existing regimes will inevitably cause conflict, resistance and chaos, and some innovations might imply controversial social and economic consequences (e.g. geographical shifting of industries and jobs, further concentration of wealth) (Bulkeley et al. 2014). In addition, transformation does not automatically lead to more sustainability. While sustainability gains importance in infrastructure planning, there is little empirical information on sustainability effects of innovatively coupled systems. The transformation of infrastructure systems for sustainability transitions requires continuous social learning about effects of intended actions, taking systemic synergies and trade-offs as well as diverse actors' perspectives into account. The latter is a practical challenge.

Operators, municipalities and regions face the task of supporting or even propelling the sustainability transition of infrastructures through a targeted management of change processes. Informed decisions are a key challenge that can be solved by a systematic and differentiated consideration of sustainability impacts. These can help to draw attention on the strengths and weaknesses of options in early phases of change processes and to develop sustainable options while addressing the unexpected challenges they pose.

We present results from ongoing work that developed and tested an easily accessible sustainability check for the screening of potential sustainability effects of coupled infrastructure solutions. Resilience is integrated and operationalized as part of a sustainability check for in-progress sustainability assessment for local infrastructure projects (Sect. 5.2). We base our work on a resilience understanding explicitly applied to local level socio-eco-technical infrastructure systems (Sect. 5.3). After presenting the application framework for hypothetic and real world cases we introduce types of results achievable by applying the sustainability check (Sect. 5.4). Finally, results and applicability of the sustainability check are discussed and conclusions drawn (Sect. 5.5).

5.2 Sustainability Check for Innovative Infrastructure Projects

5.2.1 Integrating Sustainability and Resilience

Infrastructure and sustainability are closely related. In many respects, infrastructure has the potential for direct and indirect impact on the sustainability of a society. According to Thacker et al. (2019), 72% of the 169 Sustainable Development Goal (SDG) targets are influenced by infrastructure. Adshead et al. (2019) make a distinction between 30 direct and 91 indirect pathways how infrastructure can influence sustainability targets. In addition to impacts through individual systems, explicitly coupled solutions are also named (Adshead et al. 2019, p. 4).

The discussion of sustainability and resilience of infrastructure takes place simultaneously (Bhatkoti et al. 2018; Olfert et al. 2020a, b; Thomé et al. 2016;

Uda and Kennedy 2018). The discourses on ‘Sustainable Urban Systems’ (SUS) (Dong et al. 2016; Kennedy 2016; Ramaswami et al. 2012; Sahely et al. 2005), on ‘Infrastructure Ecology’ (Brown 2014; Pandit et al. 2017; Xu et al. 2012) or on ‘sustainable urban infrastructure’ (SUI) (Pandit et al. 2017) are specifically oriented towards sustainability implication of municipal infrastructure services.

We regard resilience as an integral part of a sustainability concept adapted to the needs of infrastructure. If we accept that infrastructure services are a basic requirement of our societies, than we can follow Folke (2006) that there is no sustainability without resilience. This is not uncontroversial. While sustainability provides a framework for normative discussions resilience is often understood as a complex non-normative system property (e.g. Elmqvist et al. 2019). As for sustainability, we take recourse to the “triple bottom line” concept (e.g. Schweikert et al. 2018) and adapt it to the particular needs of infrastructure sustainability. This “three-pillar model” of ecology, economy and social issues has been differentiated and interpreted in many ways. Important contributions discuss the prioritization of the three dimensions among themselves (Dietz and Neumayer 2007; Neumayer 2013)—but remain rather theoretical and thus little instructive. Important conceptional contributions to the operationalization of sustainability referring to infrastructures is made by the politically motivated “energy policy target triangle” (BMWi and BMU 2010) developed in the context of the German debate on energy system transformation and the closely linked SDG 7 adopted in 2015. Both approaches (triangle and SDG 7) focus on three main criteria for sustainable energy systems: security of supply, economic efficiency and environmental compatibility. These three dimensions can be directly linked to discussions on resource efficiency, resilience and economic efficiency. We integrate this understanding with the triple bottom line to capture both, social justice and security of supply (Fig. 5.1) in an adapted concept. Security of supply introduces the direct link to the resilience of infrastructure systems.

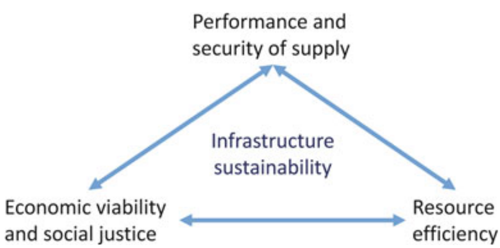

Fig. 5.1 Dimensions of infrastructure sustainability (Olfert et al. 2021, adapted)

One main argument for integrating resilience and sustainability is that the provision of services as the primary and societally unquestioned goal of infrastructure systems is insufficiently covered by the efficiency criterion traditionally dominant in sustainability—both with regard to resources and the economy. Resilience in this context stands for the provision of structures, processes and resources needed to ensure functionality and is the "natural" complement to the efficiency criterion. It is important to consider these two aspects (efficiency and resilience) separately and differentiated but still connected, since they partly compete in their perspectives. At the same time, they are inseparable in the sense of social and economic fulfilment of infrastructure goals. The perspective of efficiency is to contribute to the conservation of resources, or, in absolute terms, to reduce the consumption of resources through their more efficient use. This understanding is in contrast to a widely accepted concept of efficiency that looks at the relationship between input and output and consequently can also regard those developments as efficient where a higher use of natural resources leads to disproportionately more output—or, of course vice versa, efficiency is formally achieved by reducing the input of resources such as goods and services, personnel, investments etc. In practice, higher efficiency is not necessarily achieved only by technological improvements, but also by a positively connoted "streamlining" through reducing resource buffers, the exhaustion of system reserves or the reduction of redundancies. However, what makes operation more efficient under normal conditions can trigger failures and disrupt the provision of infrastructure services under crisis conditions.

In contrast, resilience requires suitable structures, resources and capabilities to ensure secure supply even if regular operations are impaired by internal or external factors (even if just looking at minimum supply, cf. Fekete et al. 2019). Structures, resources, and capabilities serve the goal of preventing, delaying, or shortening the passage of critical thresholds that jeopardize or make impossible the provision of infrastructure services (operational engineering resilience). The search for a balance between efficiency and resilience is thus an important management task in the operation of infrastructures.

Beyond this operational perspective on resilience as we pursue in our approach, the medium- to long-term goal-oriented development (in terms of transformation) of infrastructure systems remains important in order to deal with uncertainties and changing hazard situations, e.g. in the context of climate change, or to make use of new technical opportunities to achieve more climate protection (strategic/evolutionary socio-ecological resilience). While resilience factors are essential for securing infrastructure service, they inevitably counteract too narrow efficiency targets in implementation and are thus an important counterpart to the efficiency criterion (cf. e.g. Schiller et al. 2012 referring to the efficiency of settlement structures).

5.2.2 Sustainability Check—A Practical Screening Approach for Infrastructure Projects

So far, little is known about how innovative solutions affect different aspects of sustainability. In part, because the solutions are too new, but also because a systematic sustainability assessment does not take place in practice. Established procedures such as environmental impact assessments (EIA) or strategic EIA are very time-consuming and expensive. They start at an advanced stage of planning and cover only selected areas of sustainability. Therefore, also the screening stages of these established procedures do not offer a suitable option for sustainability assessment. Sustainability ratings applied in consulting practice are also very costly and rather tailored to the classical fields of sustainability (Clevenger et al. 2013; Diaz-Sarachaga et al. 2016). Aspects of resilience or supply security are usually not covered—certainly also because the resilience concept appears difficult to operationalize (especially quantitatively) in many respects.

Particularly, the development of novel solutions requires a creative and flexible environment, which tends to be rather inhibited by formal, complex and often expensive processes. Therefore, the application of existing approaches for environmental impact assessment, technology impact assessment or sustainability assessment seems to be less suitable to accompany innovative processes of search and development. In the TRAFIS project,[1] a low-threshold sustainability check is being developed and tested for early phases of project development. Early phases are particularly promising, as the openness and scope for design are great and sunk costs are still low. The check is intended to help keep an eye on the various infrastructure-specific aspects of sustainability before formal decisions have created first path dependencies.

The check has a simple structure. A manageable number of criteria and the simplified evaluation procedure make it a low-budget instrument. The check is designed to analyze variants of emerging solutions for their strengths and weaknesses in terms of sustainability. It uses locally available personnel and can be applied repeatedly if required. In this way, potential problems and challenges can

[1] TRAnsFormation towards sustainable, coupled InfraStructures (TRAFIS), see acknowledgements.

be identified at an early stage and taken into account in the development of a new solution—ideally before first decisions have been taken.

The sustainability check helps to answer the question, which sustainability effects a new infrastructure solution may have. Thus, the check is a screening instrument that also provides indications of potential challenges that require special attention in the development of the solution in order to minimize undesired effects. The check does not answer, whether a change will make an infrastructure system sustainable in absolute terms (as defined by the Brundtland report, UNWCED 1987). However, it shell help to find a way towards more sustainable solutions. The following three dimensions form the basic framework for making the sustainability concept operational by providing criteria that can be applied at an operational real world project level:

- Security of supply (including performance and resilience)
- Resource efficiency
- Economic viability and social justice

As discussions and test applications with potential users have shown, the framework of the sustainability check can be used for various purposes (Olfert et al. 2021):

- to structure discussions on infrastructure sustainability and to moderate different perspectives within the involved actors or staff (see case Rödental below),
- to qualitatively assess novel options for which little empirical sustainability knowledge is available (see hypothetic cases below) or
- to structure and to foster legitimation of innovative approaches beyond the classical topics of economic efficiency or CO2 reduction by setting innovative solutions into the context of various societally important discourses.

Criteria of resilience are applied to substantiate the security of supply and complement the notions of performance, economic viability, social justice and resource efficiency. While the latter are altogether represented by output and outcome criteria, resilience, being a dynamic system property, is mainly covered by structural and process criteria. We are aware that a combination of various types of criteria in one set faces the critics of inconsistence with requirements for a sustainability check. Nevertheless, we think that the criteria set provided meets well the topic as it applies to a real life operational level which it is designed for. This is because at this level questions of intended output, intended and unintended outcomes as

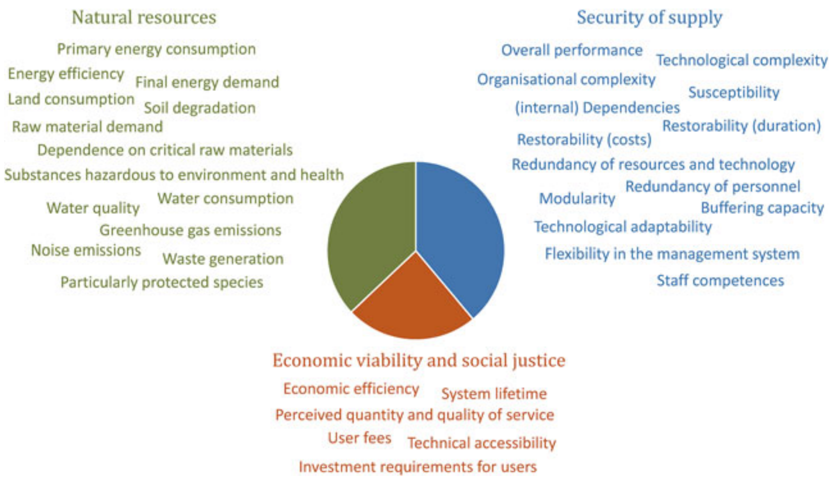

Fig. 5.2 Overview of criteria proposed for the sustainability check. (Adapted from Olfert et al. 2020a, b; VDI 2017)

well as associated structures, processes and inputs are raised. A development process must consider all of those at the same time if interrelations between these elements shall be consistently included in a process looking for well-functioning and still more sustainable solutions. Currently, over 30 criteria are discussed for our approach (Fig. 5.2) in a still ongoing development process.

Our goal in the following is to explain how we understand and operationalize resilience, how the sustainability check is applied and which kinds of learnings it enables.

5.3 Resilience Understanding for Infrastructure Innovation

As introduced, the sustainability check we propose for innovative infrastructure projects is made up of criteria in three dimensions: “security of supply”, “economic viability and social justice” and “resource efficiency”. The full array of currently used criteria is mentioned in Fig. 5.2. In this contribution, we do not emphasize “economic viability and social justice” and “resource efficiency” (for more details cf. Olfert et al. 2020a, b; Olfert et al. 2021). This section is dedicated to the explication of our understanding of the resilience concept as it may be applied to infrastructure. In the last section of this chapter, the operationalization of resilience for assessment is presented. As part of resilience, our approach also covers two important aspects of criticality: its analysis (sensitivity, dependency) and its management (e.g. redundancy, buffer potential, modularity).

We characterize our resilience understanding with the help of seven guiding questions. An explicit differentiation of the understanding of resilience is important for the operationalization of both its assessment and as a basis for concrete management of system resilience. Meerow and Newell (2019) describe five W's of resilience: *"… resilience for whom, what, when, where, and why?"* Possible (guiding) questions to characterize the understanding of resilience may well have a longer history in this regard with prior work and, for example, perspectives from White and O'Hare (2014): „Whose resilience? "; Carpenter et al. (2001): „Resilience of what to what? "; Colker (2020) and White and O'Hare (2014): "Why resilience?". Furthermore, especially from an operational perspective, it seems useful to fundamentally raise the W-question, "Which resilience?" (White and O'Hare 2014). Particularly when considering socio-eco-technical systems, it is fundamental to clarify not only which technical and/or social subsystems or which perturbations are in focus (*What to What?*) but also whether a narrower understanding of resilience (engineering resilience in the sense of a "bounce back") or an expanded evolutionary understanding (in the sense of "bounce forward") is being used (Doorn et al. 2019; Folke 2016). Finally, the question arises of how to operationalize resilience for practical applications. We frame this additional "W" as *"Resilience—how?"* This question is deliberately ambiguous. On the one hand, it refers to the aspect of a summative or formative assessment *(Resilience—how to measure?).* On the other hand, it refers to the operational goal of managing or building resilience *(Resilience—how to improve?).* Both perspectives are directly linked if one assumes that criteria for measuring resilience can also be seen as relevant parameters for achieving better resilience. Thus, we follow an expanded array of guiding questions:

- Why resilience?
- Resilience of what to what?
- Which resilience?
- Resilience—for whom, when, where?
- Resilience—how?

5.3.1 Why Resilience?

Infrastructure systems (IS) are not an end in themselves. As backbone of social and economic life, infrastructure supplies services upon which basically all actors across all domains (social, economic etc.) rely. In some cases, infrastructure and its services is considered critical—this is whenever even a short-term interruption of the service may lead to a major impact on social and/or economic life of a society. Infrastructure services can be placed among fundamental needs of human life. Where infrastructure services are disrupted, economic and social activities lose momentum and safety is endangered. As a result, the reliable provision of infrastructure services (understood as security of supply) has increasingly become a central topic of resilience research on infrastructure (cf. e.g. Shafiee 2016). Libbe et al (2018) describe the sustainability of infrastructure by three central properties:

- universal availability of services—anywhere, anytime, for anyone,
- universal accessibility of infrastructure services in spatial, temporal, technological, economic, cognitive or safety terms, and
- high quality and resource efficiency of services provided.

Thus, security of supply is a central point when it comes to the dealing with infrastructure services. As seen in the context of the CoViD 19 pandemic, availability and accessibility of IS services is particularly important in times of crisis, e.g. to keep medical and social infrastructures and the physical access to those running, to ensure information flow and communication in times of social distance rules, or to enable a safe and informed isolation of the most vulnerable.

Infrastructure is expected to provide its services reliably and universally. That is, even when internal or external factors threaten the functioning of the infrastructure system through a strong deviation from the normal range (cf. Table 5.2). At the same time, the performance of infrastructure is influenced by internal and external conditions, which, on the one hand, set a changing fundamental framework for the functioning of infrastructure, but which also define new challenges for the required inputs and the intended and unintended outputs (cf. Table 5.1).

Uncertainties coming from changing conditions and potential hazards can pose major challenges to the functioning of infrastructure and the reliability of services. Resilience in this context is not just a descriptive (multiple) property of the system under consideration, but also a strategy with respect to the design, operation and development of systems including elements, linkages, interdependencies, capabilities, resource inputs in the broad sense and various kinds of

Table 5.1 Inputs, outputs and conditions for the functioning of socio-eco-technical infrastructure systems

	Technological dimension	Socio-economic dimension	Ecological dimension
Inputs	Technology, operation systems Artificial resources (energy, data, etc.)	Knowledge and Skills—management, technical operation, planning, sales, etc Investments and expenses	Natural resources (energy, raw materials, space, etc
Outputs	Energy, Matters, Data	Revenues	Sink function of the environment (CO2, pollution, waste, noise)
Conditions	(Internal) technical and organizational complexities (variety of artefacts, actors, connections, dependencies, processes, etc.)	(internal) Operating organization, networks, routines, access to technology (external) Societal expectations, regulations, user-preferences and capabilities (skills, technical equipment, finances)	(external) availability of input and output resources

outputs. A resilience strategy aims at maintaining the functionality of a system, both in internal operation and with regard to the services provided, even under tense and disturbed conditions, and at quickly remedying functional losses if necessary before the social or economic functioning of society suffers significant damage (narrow resilience, engineering resilience, mono-equilibrium resilience, short term operational resilience). However, resilience can also be interpreted as a strategy that enables systems to evolve in response to or in anticipation of important events and conditions in order to ensure security of supply even under changing demands and resources (extended resilience, socio-ecological resilience, multi-equilibrium resilience, long term resilience). Resilience is thus a response to risks and uncertainties caused by external and internal influences, as a result of which critical thresholds for the provision of services (incl. e.g. elements, processes, resources, cf. subsection 5.3.5*)* are exceeded. As a result, resilience is also an answer to an ongoing discussion on criticality, pursued mainly with regard to critical infrastructures.

Table 5.2 Sources of disturbance for infrastructure systems. (inspired by Rehak et al. 2019, pp. 128, extended)

	Naturogenic	Technogenic	Anthropogenic
internal	organizational perturbations (staff shortfall during epidemics/pandemics)	process-technological perturbations	human error in analysis, decision, implementation
external	geological (e.g. earthquakes, **landslides, underground instability** tsunamis) **meteorological** (e.g. frequency, severity, duration of weather extremes) **resource related** (natural scarcity) **health related** (e.g. vector based diseases)	**cascades of perturbations** relating to goods and services	cyber threats physical threats (terroristic attacks) political decisions, instabilities economic implications societal pressure (acceptance)

5.3.2 Resilience of What to What?

If resilience is to describe the ability of a system to maintain or restore functionality despite adverse conditions or disturbances, the often quoted question "Resilience of what to what?" is logical. This means: Resilience of which system (WHAT 1) to which conditions (WHAT 2)? Thus, this is also the question of general resilience against specific resilience (Folke et al. 2010). However, this differentiation is only seemingly clear, as it does not explain how general is general resilience and how specific is the specific one. We assume, that a kind of a "continuum" of undefined intermediate forms extends between "general" and "specific". Also, the regarded system can be more specific than the regarded perturbation(s) and vice versa. The Matrix in Fig. 5.3 proposes one possible stepwise differentiation of specific against general perspectives of resilience. As one criterion, it differentiates the specificity of system complexity by considering discrete or interdependent (sub-) systems or parts of it. This differentiation if far from being clear or even under discussion. Here, it is meant to describe possible steps of increasing complexity as they might be assumed for a system. Of course, other than the proposed grades are possible. We think that the applied complexity levels are helpful to explain the perspective on this topic. Even though artefacts or parts

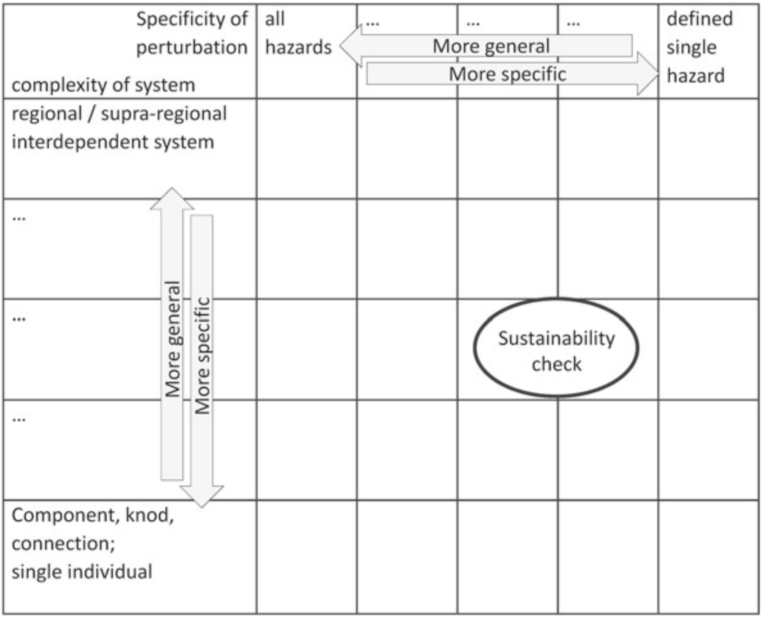

Fig. 5.3 Variants between general and specific resilience. (*Source:* Olfert et al. 2021, adapted)

of systems cannot be called systems, these are important objects of failure, analysis and adaptation to improve system resilience, as seen in criticality oriented approaches such as dependency and sensitivity analysis (e.g. Dierich 2019).

A similarly stepwise approach to define types or groups of possible perturbations can be helpful to understand how specific or general the resilience focus can be from the perspective of failure sources. As a result, we also describe a kind of a "continuum" between a specific and general perspective on possible perturbations. Thus, resilience can focus specifically one discrete sub-system or even a part of it against one perturbation with a defined magnitude in terms of extent, dynamics, duration etc. In a general perspective, resilience may look at systems of various complexities against all kinds of perturbations. Of course, the more general the resilience perspective becomes, the more general become methods, data and results. However, the latter is no petitum for a most specific focus to be applied as systems of interest do have different specifics and the focus on one hazard does not replace a wider view on the more diverse reality. We use

Fig. 5.3 to discuss the raised question *"Resilience of what (1) to what (2)?"* in this subsection.

WHAT (1): Which system are we talking about?

Each infrastructure is a complex system. By providing essential services, infrastructure systems are deeply interwoven with society. Most infrastructure is enabled by a densely related interplay of technological, socio-economic and ecological elements and conditions. The functioning of such socio-technical (Frantzeskaki and Loorbach 2010; Moss 2014) or better socio-eco-technical systems (Chester et al. 2019; Grabowski et al. 2017) integrates physical artefacts, technologies, societal expectations and behavior, market patterns, institutional structures, knowledge and skills, legal regulations, technical standards and natural resources (Fig. 5.4). Inputs, outputs and conditions in those three dimensions are summarized in Table 5.1.

In the *technological dimension* infrastructure is often perceived as technical or physical artefacts or single elements such as roads, pipes or small facilities. However, already at this lowest level, usually multiple technical components are interconnected including communication lines, traffic lights or pumps which enable the technical functioning. Technologies are required to produce defined services. More or less complex operation systems enable the processing of maters, energy and information.

Conditions of the *ecological dimension* are represented by resources used to produce and deliver infrastructure services. On the one hand, facilities, processes and often the actual services require continuous inputs of resources such as energy, matters or space (inputs). On the other hand, natural resources such as air, water or soil are used as a "sink" for various waste-products released into the environment such as CO_2, pollutants, waste, noise or heat (outputs).

Most underestimated seems the *socio-economic dimension.* On the one hand, this dimension includes the operating organization including established routines, internal and external networks, societal expectations, legal regulations as well as the preferences and the capabilities of the user. The latter is as important as the

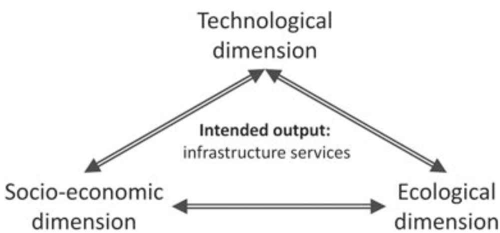

Fig. 5.4 Infrastructures as socio-eco-technical systems. (*Source:* Olfert et al. 2021, adapted)

other factors—a service which is not used is irrelevant; a service which cannot be used due to inaccessibility's is not socially just. On the other hand, knowledge and skills of the personal are crucial inputs that enable management, planning or technical operation of the infrastructure. Last but not least, investments and expenses need continuous financial input and revenues often need to ensure the covering of the full cost of services provided.

For the system perspective (see Fig. 5.4), we differentiate five levels:

- Single components (e.g. a pump, a sensor, a control module, a road pavement), connections between elements (one communication line between two components). While the given example is deduced from a technical system, the level may also be applicable to social system-systems, e.g. by looking at one single individual (cf. e.g. Jönsson et al. 2008).
- Artefacts, meaning a first e.g. functional agglomeration of elements making up a waste water channel incl. pipes, pumps etc. At this level nods of connections without the connected elements could be located. From a social perspective, a household consisting of more than one person can be associated with this level.
- Sub-systems include various artefacts connected by communication and control to form first complex functional units but still differentiating between domains such as technical, social etc. A community level perspective may be applied here involving e.g. multiple spatially (geographically) related households reaching from a quarter to city districts or even whole small to middle-sized towns.
- A next, potentially higher local level complexity can be considered by looking at interconnected and interdependent (sub-)systems from different domains, thus focusing e.g. socio-technical or socio-eco-technical systems. Here, a differentiation between sub-systems from different domains is not proposed, however not excluded.
- Finally, a regional-supra-regional level of interwoven cross-domain systems could be the most general complexity level.

What (2): Which Disturbances/perturbations do we look at?

Physical or virtual disruptions caused by natural hazards, human error, cyber-attacks etc. can cause damage to infrastructure systems and jeopardize the reliability of services. Restrictions of the services in quantity (e.g. capacity of the sewage network, data volume …) or quality (e.g. drinking water quality, frequency stability in the electricity network …) are the result. These often reach deep into the processes of daily life, economy and administration. Socio-economic consequences of infrastructure failures often far exceed the damage caused to the infrastructure itself (cf. e.g. Chang 2016). Contemporary or future hazards, from which sources ever, are therefore the primary interest of resilience management. Table 5.2 proposes a systematic for internal and external sources of disturbance for infrastructure systems, of which naturally only some are related to climate change (marked bold in the Table).

It needs not much explanation that a system can be more susceptible to one hazard than to another. However, possible hazards are already very divers and extremely manifold in their expression. Natural hazards such as floods or heat waves may, despite all uncertainties regarding time, place, frequency or magnitude, be still relatively well predictable as they follow widely understood physical processes, patterns and limits. As the Fukushima power plant disaster shows, even those relatively well understood hazards such as a tsunami can be physically underestimated. This example also shows that man-made internal management failure can be as decisive for the pathway a perturbation takes in doing harm to the system. And the same example is very well suited to show that external natural, internal human and external political failure can cascade to form a complex context for a natural hazard to take a pathway towards a catastrophe (Funabashi and Kitazawa 2012).

To differentiate the space between a specific and a general degree of perturbations the following levels are proposed:

1. As a relevant potentially most specific level, one single hazard such as inundation or heat wave of a defined design level (magnitude incl. intensity, dynamics, spatial extension, duration) is assumed. Of course, also a specific human internal failure could be located at this level. However, for most manmade failures design levels may hardly be defined.
2. The perturbation definition could also remain less specific by assuming several hazards such as all weather extremes. This level would typically be applicable if dealing with climate change influenced hazards including their different dynamics, physical properties and spatial patterns such as those of floods, heavy rainfall, heat waves, droughts, wind storms etc. If there are types of human failure, they would probably be paced here.
3. More generally, all potentially definable natural, manmade or climate change related hazards (incl. landslides and cascading effects) might be taken as a reference to look at system resilience.

4. Even more general (or more complicated), external and internal hazards may be considered thus additionally including by far less definable political, economic distortions, side effects, erroneous decisions or hardly predictable terrorist attacks.
5. Finally, all internal and external perturbations including cascades of those could be addressed at the potentially most general (most abstract) level.

As these levels indicate, the question of specific and general resilience implies the complexity of methods to evaluate resilience. And it goes along with increasing uncertainty or decreasing robustness of evaluation results the more general the resilience perspective becomes. As seen in Fig. 5.3, the different abstraction levels of possible perturbations can be helpful to identify the level of specificity of the resilience perspective applied.

5.3.3 Which Resilience?

The resilience concept is caught between two fundamental approaches: a stability-oriented and an evolutionary understanding of resilience (Doorn et al. 2019; Folke 2006; Seeliger and Turok 2013; White and O'Hare 2014). On the one side, there is a resilience understanding (stability-oriented mono-equilibrium resilience), where agile adaptation and resilience (Lundberg and Johansson 2015) aim at a short-term (operational) return to an original state (the one defined equilibrium state) of the system in response to more or less expected disturbances ("bounce back", engineering resilience, cf. Doorn 2017; Folke 2016). On the other hand, there is an evolutionary understanding of resilience with the claim of a dynamic, i.e. process-oriented, purposefully induced and learning-based transformation of the systems to another, e.g. more resilient or sustainable system state (multi-equilibria resilience, socio-ecological resilience) (multi-equilibria resilience, socio-ecological resilience, cf. Doorn 2017; Folke 2016).

These tensions also apply to infrastructure of general interest at the municipal level: they should withstand disruptions, they are expected to ensure a minimum supply even under unfavorable conditions, and they must recover as quickly as possible. This operational perspective on resilience is central in terms of security of supply. The requirement for the shortest possible downtimes precludes system reconstruction immediately after disruptions—a short-term return to the original state is mandatory in the first instance. Nevertheless, in the medium and long term, municipal infrastructures also may face the challenge of implementing radical changes (transformation) of the systems in order to respond to new expectations, threats and technical possibilities, or to achieve greater sustainability while maintaining or improving resilience.

The narrow understanding of engineering resilience has in the past led, not without good reason, to criticism that by focusing on the return to a previous state, resilience is too focused on preserving a status quo of existing systems (Folke 2016; Meerow and Newell 2019). The main criticism here is that the return to the original state always renews old path dependencies, thus preserving conventional, non-resilient or unsustainable, or/and socially inequitable structures and solutions, and thus preventing the necessary transformation of systems under the "guise" of resilience (cf. e.g. Davoudi et al. 2012; Seeliger and Turok 2013; Davoudi 2018). Resilience has even been interpreted as close to neoliberal patterns of thought, in that existing systemic failures or a purposeful "withdrawal of the state" from traditional tasks such as hazard prevention (Davoudi et al. 2012; White and O'Hare 2014, p. 940) is supposed to be compensated by (involuntary or forced) flexibility and resilience of the affected parts of society, rather than making the system more equitable and resilient for all (Davoudi 2018; Meerow and Newell 2019).

This fundamental critique of resilience approaches does not appear to be necessarily applicable to the resilience context of our work. On the one hand, because the medium to long-term perspective on the transformation of systems is not the focus of our approach (see sustainability check). The focus is on innovative sustainability-oriented projects that already are part of a transformation and that should be kept "on track" by considering sustainability. On the other hand, the services provided are so important in an operational sense that only short-term impairments can be socially tolerated. Here, the sustainability check can help in the search for potentially sustainable long-term solutions.

The narrower, stability-oriented understanding of resilience based on the approach of "engineering resilience" (Doorn et al. 2019; Folke 2006; Holling 1996) seems to be well suited for adopting an operational perspective on technically based infrastructure systems, as they are the subject of our work (water, wastewater, energy, transport, waste, ICT sectors). In the context of disruptions, these systems are in fact mostly concerned with being able to maintain the planned performance as reliably as possible or to return to exactly the previous performance mode as quickly as possible, i.e. with the ability to bounce back, as is the basis of the understanding of engineering resilience.

However, beyond this narrow understanding applied in our work, when considering technical infrastructures, it makes sense to broaden this operational understanding of resilience in the sense of a more evolutionary "resilience thinking" to consider resilience as the ability to proactively and purposefully change the structures, resources, and capabilities of the affected systems in the sense of supply security (i.e., improved resilience) or to completely redesign and purposefully rebuild them.

5.3.4 Resilience Where, for Whom and When?

In our work, we focus on innovative infrastructure systems that are implemented and operated on a local or regional level as individual or interdependent systems. We do not address large-scale systems such as supra-regional power distribution networks. Thus, as an overall goal, we see community-level resilience in a social sense understood as the "ability of groups and communities to cope with external stresses and disturbances as a result of social, political and environmental change" (Adger 2000). Infrastructure at the community level plays a prominent role by ensuring a reliable supply of vital resources and services, which simultaneously places high expectations on their resilience.

However, the target group of our work is primarily the operators of municipal infrastructure systems in the broader sense, which includes operating companies and responsible parts of the public administration. With the help of the sustainability check introduced in Sect. 5.2, the personnel responsible for planning, administration and operation shall be supported in strengthening the resilience of systems in the context of the ongoing change. The focus is on incipient change processes in which proposals for new solutions are to be made in the foreseeable future (e.g. weeks to months). Due to the high persistence in infrastructure systems, the impact of these decisions and thus the possible resilience effects are expected to be rather long-term.

5.3.5 Resilience—How?

The discussion of the resilience understanding as it may be applied to infrastructure forms an important basis for the operationalization of the sustainability check and particularly of resilience as part of it. The following is the summary from previous subsections, which guides the operationalization.

- Our approach is motivated by an understanding of resilience orientation as a suitable strategy for maintaining the ability to act in the face of uncertainties, hazards and other challenges caused by external and internal perturbations through the targeted development and maintenance of suitable structures, resources and capabilities, and for ensuring security of supply even beyond "normal operation".

- We focus socio-eco-technical infrastructure systems at local level considering sub-system co-operations between different sectors. And we look at external perturbations related to climate change influenced weather extremes such as heat, heavy rain, inundations, wind storms etc. Thus, our approach follows a rather semi-specific perspective of resilience.
- As a reference for the sustainability check, an operational stability-oriented understanding of resilience based on "engineering resilience" ("bounce back") is adopted.
- Bearing local level community resilience in mind, our work addresses mainly the operation and administration of local level infrastructure utilities engaged in short and middle term innovation processes as a part of a local sustainability transitions.
- As a result, to assess security of supply, we introduce resilience criteria which describe relevant system properties describing structure, resources and abilities. These properties are assessed applying a qualitative five step rating scale. In our approach, resilience assessment is embedded in a sustainability check designed to support early stage assessment at project level.

For the dimension "security of supply" we propose 14 criteria which describe effects on the system performance (output criterion) and the structure, resources and abilities of the system behind it (Table 5.3) (for more details cf. Olfert et al. 2020a, b). The latter three aspects can be understood as resilience and are represented mainly by structural criteria which describe parameters relevant to secure the supply of services, but which are not the service itself. Where new interconnections (couplings) of infrastructure systems are the object of assessment, some of the criteria need to be applied for each of the coupled sub-systems (see Fig. 5.5). As we focus a rather specific system level, mainly looking at the internal functioning and provision of services, the selected criteria mainly deal with the questions of the technical system and its operation. This means that the social dimension of resilience is restricted to the management part of the infrastructure system. As a result, the operationalization is dedicated to the questions: (a) Do involved technical sub-systems have the structure and resources to deliver the infrastructure services? and (b) Does the management have the staff, skills, flexibility, time and money to keep the technical system functional? Both questions are primarily related to conditions of pressure which go beyond normal operation. This is consistent with the conceptionalization proposed by Davoudi et al. (2013) including four components of resilience: persistence, preparedness,

Table 5.3 Criteria of performance and resilience applied in the dimension "security of supply"

Sub-dimension	No	Criterion (short)	Explanation (short)
Performance	1	Overall performance (sub-system perspective)	… meaning the ability of the (coupled?) sub-systems to deliver required services
Resilience (structures)	2	Technological complexity *(sub-system perspective)*	… of the (coupled?) sub-systems described by components, connections, dependencies, etc.
	3	Organizational complexity *(sub-system perspective)*	… of the (coupled?) sub-systems described by involved actors, management structures, etc.
	4	Susceptibility (sub-system perspective)	… of the (coupled?) sub-systems against disturbances (internal, external, climate change related, etc.)
	5	(internal) Dependencies *(sub-system perspective)*	… of the (coupled?) sub-systems functionally connected to form the IS solution
	6	Technological adaptability	… of the system allowing to address new challenges
Resilience (resources)	7	Redundancy of resources and technology	… allows to compensate temporary shortcomings
	8	Redundancy of personnel	… increases staff reserves to cope with disturbances (e.g. during long term hazards such as pandemics)

(continued)

Table 5.3 (continued)

Sub-dimension	No	Criterion (short)	Explanation (short)
	9	Buffer potential	… increases system capacity to overcome temporary shortage of required resources or fluctuating demand
Resilience (capacities)	10	Modularity	… allows local control over important system functions
	11	Flexibility in the management system	… allows to operatively adapt procedures
	12	Staff skills	… asks whether the staff has the skills needed to run the innovative system
	13	Restorability (duration)	… of the system after disturbances by internal means
	14	Restorability (costs)	… of the system after disturbances by internal means

adaptability and transformability. As explained, in our approach we do not focus transformability.

5.4 Applying the Sustainability Check

5.4.1 How to Apply the Sustainability Check?

Public administrations, infrastructure operators and local partner companies usually have well-trained and experienced staff with excellent knowledge of site-specific conditions. The proposed sustainability check makes use of this locally available expertise. It is voluntary and provides an opportunity for important stakeholders to bring existing knowledge and different perspectives into the planning process. Ideally, the application provides an important impetus for the development of suitable infrastructure solutions that (a) meet typical primary objectives, such as economic efficiency, attractiveness or CO2-reduction, and (b) take into

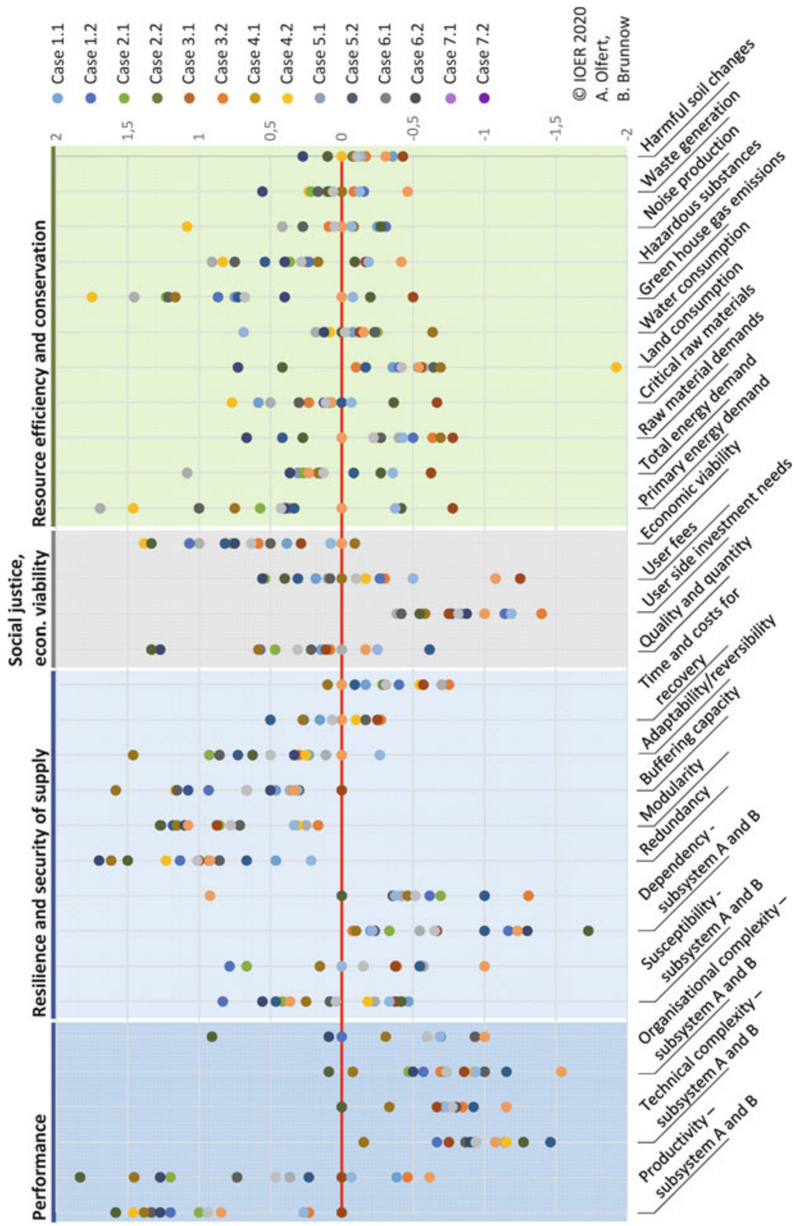

Fig. 5.5 Result overview for 14 hypothetical cases. (Adapted from Olfert et al. 2020a, b)

account possible undesirable side effects. The application of the check is carried out in five steps:

Step 1: Define the objectives and the configuration of the system. At the start of the evaluation process, the infrastructure solution of interest is defined. The technical and organizational configuration of the solution and the services it is meant to provide should be clear to all participants as a basis for the assessment. The solution can then be further refined together with the involved experts based on the assessment results.

Step 2: Select appropriate experts. Included experts should represent key perspectives on project implementation and potential impacts. Typically, this may involve (a) the middle and lower management level of the operating company, (b) if municipal infrastructures are addressed, the municipal administration, (c) the environmental authority, and d) if applicable, local/regional infrastructure planning partners.

Step 3: Tailor criteria to the discussion and assessment process. Infrastructure projects are always characterized by site-specific features and needs. (a) It may therefore be useful to specify the applied sustainability criteria based on the criteria set provided and to reduce (or supplement) them as necessary. (b) The understanding of the criteria must be ensured by means of questions comprehensible to all participants. If necessary, questions provided with the check can be adapted. (c) The evaluation mode should be specified in advance—anonymous or face-to-face, joint meeting or decentralized. Anonymous evaluations can be useful in high-tension constellations. Preference should be given to a transparent consideration of perspectives.

Step 4: Assessment and analysis. First, the assessment is conducted by selected experts (approx. up to 45 min) during scheduled project development meetings or in advance. The evaluation approach focuses on the question: How does the transition from an existing infrastructure solution (e.g. traditional) to a novel solution (e.g. coupled) affect resilience and other sustainability parameters? The assessment is based on a qualitative five-point scale (Table 5.4) which delivers trend-information from “not suitable” (−2) to “very well suited” (+2). The scale was operationalized as part of our research work in an iterative process involving test persons selected from science and infrastructure management in several stages.

Second, analysis of the assessment is carried out as a basis for the discussion of different variants or for the (further) development of a specific solution. A visualization of results, e.g. as a spider diagram (see example Rödental below), is beneficial for further discussion. Good visibility of perspectives from different parties involved is helpful to inform a discussion process.

Table 5.4 Five-stage assessment scale

Rating	Scale	Context-related examples
strongly negative	−2	not suitable—e.g. significant increase in costs, significant increase in raw material demand, etc.
slightly negative	−1	fairly unsuitable—e.g. slight increase in costs, rising demand for raw materials, etc.
neutral	0	no change compared to a traditional solution
slightly positive	+1	fairly well suited—e.g. slight cost reduction, tendency to decrease raw material demand, etc.
strongly positive	+2	very well suited—e.g. significant cost reduction, significant decrease in raw material demand, etc

Step 5: Repeat if necessary. The impact of a solution depends largely on its design and operation. The results of the assessment should give reason to optimize the envisaged solution with regard to different aspects or to develop alternative solutions. In case of changes to solution options, a repeated assessment of the sustainability impacts may be useful. The flexible and "easy" application of the check ("low-budget instrument") makes this possible.

5.4.2 Application with Hypothetic and Real Cases

We applied the sustainability check in a Delphi-based online-survey based assessment involving more than 100 Experts. As object of assessment *14 hypothetic cases* of innovatively coupled infrastructures where used from the sectors water, sewage, energy, transport, waste and ICT (see Table 5.5) organized in seven panels with two content-related cases per panel. Each case was defined in general terms to ensure a common understanding of the technical solution in question.

Applied criteria where operationalized to ensure the understanding by different professional groups applying pre-tests and tests with external experts. For each hypothetic case the criteria definitions were specifically adapted. Involved experts where thoroughly selected to ensure best quality of assessment and considering the perspectives of infrastructure operation, infrastructure planning, related public administration and infrastructure research to balance professional bias. The Delphi-based survey was implemented in two rounds with provision of anonymized interim feedback.

Table 5.5 14 hypothetical cases of coupled infrastructures

Panel No	Cases
Panel 1	1.1 Central heat and waste heat recovery from waste water; 1.2 Decentralized heat generation in wastewater networks
Panel 2	2.1 Feed-in of (industrial) waste heat in heat networks; 2.2 Feed-in of solar thermal energy into heating networks
Panel 3	3.1 Control of hybrid energy networks on a local/regional scale; 3.2 Virtual power plants - Swarm-controlled operation of generation plants for power load regulation
Panel 4	4.1 Power grid stabilization through integration of accumulator-based electric vehicles; 4.2 Induction-based charging of vehicles in areas of flowing traffic
Panel 5	5.1 Power to Heat (PtH)—storage of excess electricity in heating networks; 5.2 Power to Liquid (PtL)—electrolysis of renewable electricity to hydrogen
Panel 6	6.1. App-supported management of virtual vehicle fleets by merging private vehicles in a car sharing model; 6.2 App-supported fleet management in free-floating car sharing
Panel 7	7.1 Intelligent rainwater management; 7.2 Controlled sewer overflow in combination with multifunctional open spaces in urban areas

5.4.3 Sustainability Trends for Innovative Infrastructure Solutions

The Delphi-based results of the assessment can help to differentiate strengths and weaknesses of selected solutions or as a general trend over various innovative solutions (see Fig. 5.5). A trend can express positive or negative effects or, as frequently encountered, neutrality of effects. For some criteria, a wide range of ratings can be observed indicating uncertainty or even polarization of estimations. Effects are usually specific for the subsystems involved in a coupling. The displayed results are based on a previous criteria set which was smaller than the one presented in Fig. 5.2 and partly criteria come in a different order and with different names. In summary, the following trends are observed:

Performance and resilience: The examined interconnections usually have the potential to deliver the expected performance and, by leveraging previously unexploited synergies, in some cases can even have higher performance potential than conventional non-coupled systems. However, the relation of coupled sub-systems is often asymmetric where only one sub-system gains while the other provides—even though usually without losses. The assessed solutions often go along with a partly significant increase in technical and organizational complexity. Corresponding with the stated performance potentials, coupled infrastructure can locally or regionally strengthen security of supply by improving the redundancy, modularity and buffer capacity of involved infrastructure systems. However, new interconnections often also create new susceptibilities to faults and dependencies between the coupled systems.

Economic viability and social justice: The studied interconnections generally seem not to cause losses in the quality and quantity of service. However, economic consequences are expected for many of the novel solutions including higher operation costs for the provider and higher end user prizes of the innovative infrastructure services. This usually does not call into question the economic viability of coupled infrastructures. However, the access to the new infrastructure services often requires noticeable investments on the part of the users, e.g. to enable the access to mobile online services or in case that buildings need to be adapted to reduce temperatures in the heating system where regenerative or alternative heat sources are integrated.

Resource efficiency: The effect of coupled infrastructures on most of the resource indicators is usually rated neutrally or often slightly positive. We interpret both as positive in the context of possible performance improvements described above. Especially for primary energy demand, final energy demand and greenhouse gas emissions mainly positive effects are expected. The assessments regarding the demand for land, raw materials and critical raw materials vary from case to case. The space requirements of coupled solutions are usually higher. However, comfortable new services can be more resource consumptive or even impede other societal goals.

5.4.4 How Do Real World Projects Profit from the Sustainability Check

Based on the experience of applying the sustainability check with synthetic cases, the approach was also tested with two real-world cases as part of transformative case study research (see Hirschnitz-Garbers et al. 2020b): a) Case study "Rödental"—Demand-Side-Management in the municipal sewage plant; b) case study "Augsburg"—Mobility-App linking the city of Augsburg's multiple transport services and improving their accessibility. In the following results of the Rödental-case are considered.

Case description "Rödental": Applying demand-side management measures to help stabilizing the grid by a bundle of measures including (a) switching off existing micro-gas-turbines, (b) starting the heat pump or co-operating a Power-to-Heat system as a heat source, and providing positive control power by sustaining micro-gas-turbines for on-site power generation. The sustainability check was carried out in November 2017 involving the management, the technical management of the wastewater treatment plant and the wastewater treatment master. The aim of the sustainability check was to screen in particular the economic, technical and ecological potentials as well as the manageability of demand side management in the Rödental wastewater treatment plant.

In order to apply the sustainability check to real world cases, we first specified the questions to reflect the case study contexts. Based on an in-depth understanding of the cases, informed by literature review and interviews with the utilities, relevant indicators were selected and reframed in the process. The rules of the procedure were detailed to the participants. The real world implementation of the sustainability check was enabled by the transformative research approach pursued by our project (Hölscher et al. accepted). In particular, long-standing exchange between researchers and practice actors with multiple personal meetings and an agenda oriented towards practice relevant support provided by the research team helped building trust and positioning our work as relevant for the utilities. This allowed creating the environment, in which the utilities agreed to experiment with such participatory sustainability assessment.

The assessment results of the sustainability check for case "Rödental" are summarized in Fig. 5.6. For Rödental, results referring to security of supply and social justice are most salient. Experts see …

- …positive and negative effects on 'performance'. New signal transmission will need to be established and integrated into daily routines which will increase both the technical and the organizational complexity of the planned solution. A clearly positive effect of the coupling is expected on local and regional energy grid stabilization.
- …positive effects on the security of supply because decentralized energy generation enhances the robustness of service provision and eases replacement of local grid hubs.
- …positive and negative effects on economic viability and social justice. Local and regional supply of energy will be strengthened due to grid stabilization effects. However, connection to a virtual power plant needs additional digital components and will thus require additional investments.

In the Rödental case, the experts intuitively used the sustainability check to discuss changes to the complex solution which was the object of assessment. While

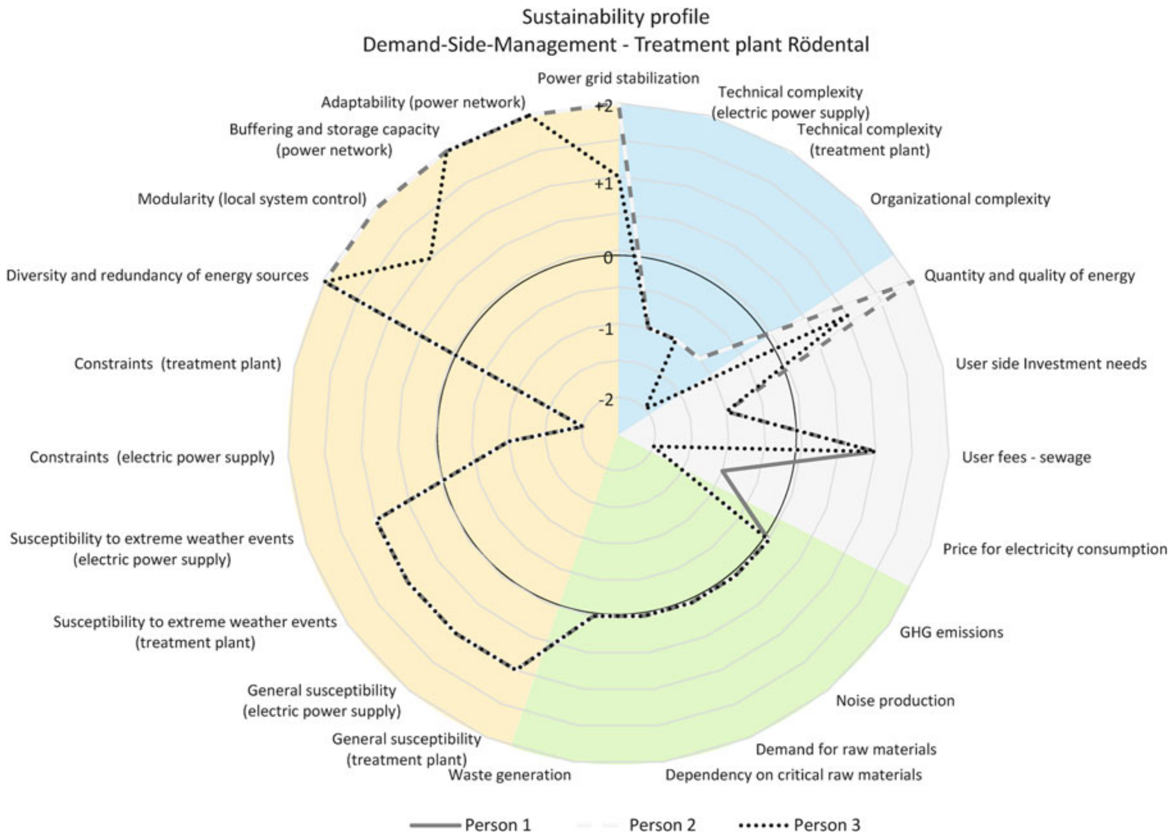

Fig. 5.6 Sustainability check for demand side management options in the real-world case "Rödental". (Adapted from Hirschnitz-Garbers et al. 2020a, b)

the advantages of the evaluated solution were basically not in question, the focus was on the identified critical results and their attribution to single components of the proposed solution. As reported by the involved personnel, the check provided a good framework for discussing different perspectives on equitable terms. The evaluation of the originally planned configuration revealed weaknesses that had not been taken into account until then. In particular, the risks for wastewater treatment and for consumer prizes became clear. On this basis, the team discussed alternative solutions and combinations of measures. Ultimately, a different, smaller technical solution was implemented on site that provides grid stabilization, does not require additional fuel, and does not increase costs or limit plant operation. The discussion conducted with the help of the sustainability check helped to ensure that a comprehensive exchange took place around the pros and cons of the new infrastructure solution.

5.5 Concluding Discussion of Results and the Assessment Approach

Sustainability is an important challenge for infrastructure development. In addition to the established focus on economy and resource efficiency, novel infrastructure solutions must also deliver on resilience and social justice. Resilience indicators do make the difference if a comprehensive sustainability perspective at transformation of infrastructure shall be taken.

Sustainability effects of innovative infrastructure are specific for each solution. However, general conclusions can be drawn. Innovative solutions change the standard technical configuration of infrastructure systems, are usually more complex, involve multiple and new actors and are often characterized by decentralized and redundant structures. Often, constant or even improved performance can be expected from new coupled systems. Many of the solutions can effectively reduce primary energy demand and greenhouse gas emissions while not negatively influencing most of the other resource criteria. The need for space usually increases to accommodate new system elements and connections, in some cases (e.g. solar power integration) significantly. To access the services provided by novel solutions, often additional user side investment is required. This poses socio-political challenges.

Security of supply is operationalized by resilience parameters describing structures, resources and capacities which altogether make up the system's ability to consistently prepare for and react to threats. Structural indicators confirm higher technological and organizational complexities in novel infrastructure solutions and can lead to new dependencies. Also the susceptibility of novel solutions can, but need not necessarily be negatively affected. Innovative solutions can also improve important resilience parameters such as redundancy, buffer capacity and modularity.

The proposed sustainability check is operational and flexible. The application with more than 100 experts allows the conclusion that the sustainability check is well suited as an instrument to enable a fast and simple evaluation of uncertain questions related to sustainability effects of innovative infrastructure solutions in early planning stages. The assessment can address one or compare several variants, take into account different time horizons or consider several scenarios and it can be used with coupled and uncoupled infrastructure solutions. One important strength of the approach lies in its ability to generate indications for effects that require particular attention in planning and management. On this basis, important input can be given particularly in early stage process of solution development.

The sustainability check is applicable in real planning situations. The suitability of the evaluation concept and the criteria has been confirmed. Involved experts have accepted the sustainability concept in its thematic scope and have used it for a reflected assessment. The case-specific operationalization of the indicators has proved to be particularly important in order to facilitate the experts' access to the criteria. As confirmed in real world cases, the easily accessible assessment concept enables researchers and managers to map different aspects of sustainability on the basis of expert knowledge, with limited effort.

The sustainability check can be used to mediate between different professional perspectives. A value-free coexistence of different dimensions and criteria as applied in the check can promote the exchange between actors with different perspectives. In case "Rödental" the check helped to mediate between the different perspectives of involved parties. As a surprise, the sustainability check thus became an instrument that facilitated structured communication and promoted mutual understanding in the specific planning process. In particular, the instrument has helped to neutralize hierarchies between the participants and the dominance of single perspectives. This has created a solid basis for a factual discussion. Even though an unintended effect, this result is an important impetus for the further development of the sustainability check.

In our discussion we show, that a deliberate resilience understanding is crucial to make the concept operational for practical applications. The questions discussed in Sect. 5.3 are central to define the abstraction level of analysis, to select appropriate criteria and to make them operational for real world application. Such deliberate procedure will allow to generate valuable information inputs for innovation projects in the sustainability transition of infrastructure systems.

For our purposes, we stayed with a "soft" qualitative definition of the criteria. Other criteria may be included responding to the regarded level of system complexity, focused perturbations or management goals addressed. It is well possible, that for the assessment of the same criteria more "deliberate" and quantitative methods may be applied. For some of the criteria such as the overall performance or redundancy, quantitative estimations should be attainable. For others, such as susceptibility or dependency, quantitative methods are being discussed in literature. Others however, mainly those relating to capacities may remain qualitative. The proposed approach allows a flexible application of different methods which can accommodate various needs in early phases of innovation processes. We believe such approaches can help to position resilience as an operational management paradigm in sustainability transitions of infrastructure.

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References

Adger, W. N. (2000). Social and ecological resilience: Are they related? *Progress in Human Geography, 24*(3), 347–364. https://dx.doi.org/10.1191/030913200701540465

Adshead, D., Thacker, S., Fuldauer, L. I., & Hall, J. W. (2019). Delivering on the sustainable development goals through long-term infrastructure planning. *Global Environmental Change, 59*, 101975. https://dx.doi.org/10.1016/j.gloenvcha.2019.101975

Anderies, J. M., Janssen, M. A., & Schlager, E. (2016). Institutions and the performance of coupled infrastructure systems. *International Journal of the Commons* 10(2), 495. https://dx.doi.org/10.18352/ijc.651.

Bhatkoti, R., Triantis, K., Moglen, G. E., & Sabounchi, N. S. (2018). Performance assessment of a water supply system under the impact of climate change and droughts: Case study of the Washington Metropolitan Area. *Journal of Infrastructure Systems, 24*(3), 05018002. https://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000435

BMWi & BMU. (2010). *Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung* (p. 36). Berlin: BMWI, Bundesministerium für Wirtschaft und Energie. https://www.bmwi.de/BMWi/Redaktion/PDF/E/energiekonzept-2010,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf.

Brown, H. (Ed.). (2014). *Next generation infrastructure: Principals for post-industrial public works.* Washington: Island Press.

Bulkeley, H., Castán Broto, V., & Maassen, A. (2014). Low-carbon transitions and the reconfiguration of urban infrastructure. *Urban Studies, 51*(7), 1471–1486. https://dx.doi.org/10.1177/0042098013500089

Chang, S. E. (2016). *Socioeconomic impacts of infrastructure disruptions.* (Vol. 1) Oxford University Press. https://dx.doi.org/10.1093/acrefore/9780199389407.013.66

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems, 4*(8), 765–781. https://dx.doi.org/10.1007/s10021-001-0045-9

Chester, M. V., Markolf, S., & Allenby, B. (2019). Infrastructure and the environment in the Anthropocene. *Journal of Industrial Ecology, 23*(5), 1006–1015. https://dx.doi.org/10.1111/jiec.12848

Clevenger, C., Ozbek, M., & Simpson, S. (2013). Review of sustainability rating systems used for infrastructure projects. *Proc. 49th ASC Annual Int*, 10–13.

Colker, R. M. (2020). A vision for resilient infrastructure. In Colker, R. M. (Ed.), *Optimizing community infrastructure* (pp. 263–269). Elsevier. https://dx.doi.org/10.1016/B978-0-12-816240-8.00016-1.

Davoudi, S. (2018). Just Resilience. *City & Community, 17*(1), 3–7. https://dx.doi.org/10.1111/cico.12281

Davoudi, S., Brooks, E., & Mehmood, A. (2013). Evolutionary resilience and strategies for climate adaptation. *Planning Practice and Research, 28*(3), 307–322. https://dx.doi.org/10.1080/02697459.2013.787695

Davoudi, S., Shaw, K., Haider, L. J., Quinlan, A. E., Peterson, G. D., Wilkinson, C., Fünfgeld, H., McEvoy, D., & Porter, L. (2012). Resilience: A bridging concept or a dead end? *Planning Theory & Practice, 13*(2), 299–333. https://dx.doi.org/10.1080/14649357.2012.677124

Diaz-Sarachaga, J. M., Jato-Espino, D., Alsulami, B., & Castro-Fresno, D. (2016). Evaluation of existing sustainable infrastructure rating systems for their application in developing countries. *Ecological Indicators, 71*, 491–502. https://dx.doi.org/10.1016/j.ecolind.2016.07.033

Dierich, A. (2019). System der Systeme: Komplexität der gegenseitigen Abhängigkeiten zwischen KRITIS. In A. Fekete, F. Neisser, K. Tzavella, & C. Hetkämper (Eds.), *Wege zu einem Mindestversorgungskonzept Kritische Infrastrukturen und Resilienz* (pp. 24–27). Köln: TH Köln. ISBN 978-3-946573-14-2.

Dietz, S., & Neumayer, E. (2007). Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological Economics, 61*(4), 617–626. https://dx.doi.org/10.1016/j.ecolecon.2006.09.007

Dong, H., Fujita, T., Geng, Y., Dong, L., Ohnishi, S., Sun, L., et al. (2016). A review on eco-city evaluation methods and highlights for integration. *Ecological Indicators, 60*, 1184–1191. https://dx.doi.org/10.1016/j.ecolind.2015.08.044

Doorn, N. (2017). Resilience indicators: Opportunities for including distributive justice concerns in disaster management. *Journal of Risk Research, 20*(6), 711–731. https://dx.doi.org/10.1080/13669877.2015.1100662

Doorn, N., Gardoni, P., & Murphy, C. (2019). A multidisciplinary definition and evaluation of resilience: The role of social justice in defining resilience. *Sustainable and Resilient Infrastructure, 4*(3), 112–123. https://dx.doi.org/10.1080/23789689.2018.1428162

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., & Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability, 2*(4), 267–273. https://dx.doi.org/10.1038/s41893-019-0250-1

Fekete, A., Neisser, F., Tzavella, K., & Hetkämper, C. (Eds.). (2019). *Wege zu einem Mindestversorgungskonzept Kritische Infrastrukturen und Resilienz.* Köln: TH Köln. ISBN 978-3-946573-14-2.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change, 16*(3), 253–267. https://dx.doi.org/10.1016/j.gloenvcha.2006.04.002

Folke, C. (2016). Resilience (Republished). *Ecology and Society* 21(4), art44. https://dx.doi.org/10.5751/ES-09088-210444.

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society* 15(4), art20. https://dx.doi.org/10.5751/ES-03610-150420.

Frantzeskaki, N., & Loorbach, D. (2010). Towards governing infrasystem transitions: Reinforcing lock-in or facilitating change? *Technological Forecasting and Social Change, 77*(8), 1292–1301. https://dx.doi.org/10.1016/j.techfore.2010.05.004

Funabashi, Y., & Kitazawa, K. (2012). Fukushima in review: A complex disaster, a disastrous response. *Bulletin of the Atomic Scientists, 68*(2), 9–21. https://dx.doi.org/10.1177/0096340212440359

Grabowski, Z. J., Matsler, A. M., Thiel, C., McPhillips, L., Hum, R., Bradshaw, A., et al. (2017). Infrastructures as socio-eco-technical systems: Five considerations for interdisciplinary dialogue. *Journal of Infrastructure Systems, 23*(4), 02517002. https://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000383

Hirschnitz-Garbers, M., Hinzmann, M., Langsdorf, S., Olfert, A., Schiller, G., Brunnow, B. et al. (2020a). *Analyse von Nachhaltigkeitspotentialen und Einflussfaktoren (Synthese) – Teilbericht des Vorhabens: "Transformation hin zu nachhaltigen, gekoppelten Infrastrukturen" (No. 102/2020).* Dessau: Umweltbundesamt.

Hirschnitz-Garbers, M., Hinzmann, M., Langsdorf, S., Walther, J., Olfert, A., Schiller, G., et al. (2020b). *Erfolgsbedingungen und Prozessgestaltung/-begleitung für eine nachhaltige Umgestaltung von Infrastrukturkopplungen Infrastrukturen—Teilbericht des Vorhabens: "Transformation hin zu nachhaltigen, gekoppelten Infrastrukturen" (No. 101/2020).* Dessau: Umweltbundesamt.

Holling, C. S. (1996). Engineering resilience versus ecological resilience. In P. C. Schulze (Ed.), *Engineering within ecological constraints.* (pp. 31–44). The National Academies Press.

Hölscher, K., Wittmayer, J. M., Hirschnitz-Garbers, M., Olfert, A., Walther, J., Schiller, G., & Brunnow, B. (accepted). *Transforming science and society? Methodological lessons from and for transformation research.* Research Evaluation. Accepted.

Hölscher, K., Wittmayer, J., Olfert, A., Hirschnitz-Garbers, M., Walther, J., Brunnow, B. et al. (2020). *Infrastrukturkopplungen als Beiträge zur Nachhaltigkeitstransformation: Einflussfaktoren und Handlungsmöglichkeiten. Teilbericht des Vorhabens: „Transformation hin zu nachhaltigen, gekoppelten Infrastrukturen" (No. 100/2020).* Dessau: Umweltbundesamt.

Jönsson, H., Johansson, J., & Johansson, H. (2008). Identifying critical components in technical infrastructure networks. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 222*(2), 235–243. https://dx.doi.org/10.1243/1748006XJRR138
Kennedy, C. A. (2016). Industrial ecology and cities. In R. Clift & A. Druckman (Eds.), *Taking stock of industrial ecology* (pp. 69–86). Cham: Springer International Publishing. https://dx.doi.org/10.1007/978-3-319-20571-7_4.
Libbe, J., Petschow, U., Trapp, J., Arndt, W.-H., & Floeting, H. (2018). *Diskurse und Leitbilder zur zukunftsfähigen Ausgestaltung von Infrastrukturen. Abschlussbericht* (p. 102). Dessau-Roßlau: Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-12-07_climate-change-33-2018_klaris.pdf. Accessed: 15 Feb. 2019.
Loorbach, D. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. *Governance, 23*(1), 161–183
Lundberg, J., & Johansson, B. J. (2015). Systemic resilience model. *Reliability Engineering & System Safety, 141*, 22–32. https://dx.doi.org/10.1016/j.ress.2015.03.013
Malekpour, S., Brown, R. R., & de Haan, F. J. (2015). Strategic planning of urban infrastructure for environmental sustainability: Understanding the past to intervene for the future. *Cities, 46*, 67–75. https://dx.doi.org/10.1016/j.cities.2015.05.003
Markard, J. (2011). Transformation of infrastructures: Sector characteristics and implications for fundamental change. *Journal of Infrastructure Systems, 17*(3), 107–117. https://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000056
Meerow, S., & Newell, J. P. (2019). Urban resilience for whom, what, when, where, and why? *Urban Geography, 40*(3), 309–329. https://dx.doi.org/10.1080/02723638.2016.1206395
Monstadt, J., & Coutard, O. (2019). Cities in an era of interfacing infrastructures: Politics and spatialities of the urban nexus. *Urban Studies, 56*(11), 2191–2206. https://dx.doi.org/10.1177/0042098019833907
Moss, T. (2014). Socio-technical change and the politics of urban infrastructure: Managing energy in Berlin between dictatorship and democracy. *Urban Studies, 51*(7), 1432–1448. https://dx.doi.org/10.1177/0042098013500086
Neumayer, E. (Ed.). (2013). *Weak versus strong sustainability: Exploring the limits of two opposing paradigms.* (4th ed.). Cheltenham: Edward Elgar.
Olfert, A., Brunnow, B., Schiller, G., Walther, J., Hirschnitz-Garbers, M., Langsdorf, S., Hinzmann, M., Hölscher, K., & Wittmayer, J. M. (2020a). *Nachhaltigkeitspotenziale innovativer, gekoppelter Infrastrukturen - Teilbericht des Vorhabens: "Transformation hin zu nachhaltigen, gekoppelten Infrastrukturen" (No. 99/2020).* Dessau: Umweltbundesamt.
Olfert, A., Schiller, G., Brunnow, B., Walther, J., Hirschnitz-Garbers, M., Hölscher, K., & Wittmayer, J. M. (2020). Prozessbegleitende Nachhaltigkeitsbewertung als Werkzeug für ein Nachhaltigkeitsorientiertes Infrastrukturmanagement. *InfrastrukturRecht, 17*, 17–20
Olfert, A., Schiller, G., Walther, J., Hirschnitz-Garbers, M., Langsdorf, S., Hinzmann, M., & Hölscher, K. (2021). *Nachhaltigkeit bei der Verbreitung von innovativen Infrastrukturlösungen. Bericht an das Umweltbundesamt*. Dresden: Leibniz-Institut für ökologische Raumentwicklung.
Pandit, A., Minné, E. A., Li, F., Brown, H., Jeong, H., James, J.-A. C., Newell, J. P., Weissburg, M., Michael E.Chang, M.E., Xu, M., Yang, P. Wan, R., Thomas, V. M., Yu, X. W., Lu,

Z., & Crittenden, J.C. (2017). Infrastructure ecology: An evolving paradigm for sustainable urban development. *Journal of Cleaner Production 163,* 19–27. https://dx.doi.org/10.1016/j.jclepro.2015.09.010.

Ramaswami, A., Weible, C., Main, D., Heikkila, T., Siddiki, S., Duvall, A., et al. (2012). A social-ecological-infrastructural systems framework for interdisciplinary study of sustainable city systems: An integrative curriculum across seven major disciplines. *Journal of Industrial Ecology, 16*(6), 801–813. https://dx.doi.org/10.1111/j.1530-9290.2012.00566.x

Rehak, D., Senovsky, P., Hromada, M., & Lovecek, T. (2019). Complex approach to assessing resilience of critical infrastructure elements. *International Journal of Critical Infrastructure Protection, 25*, 125–138. https://dx.doi.org/10.1016/j.ijcip.2019.03.003

Sahely, H. R., Kennedy, C. A., & Adams, B. J. (2005). Developing sustainability criteria for urban infrastructure systems. *Canadian Journal of Civil Engineering, 32*(1), 72–85. https://dx.doi.org/10.1139/l04-072

Schiller, G. (2010). *Kostenbewertung der Anpassung zentraler Abwasserentsorgungssysteme bei Bevölkerungsrückgang.* Dresden: Rhombos.

Schiller, G., Blum, A., & Behnisch, M. (2012). Resource efficiency of settlement structures: Terms, conceptual implications and connecting factors to the resilience debate. *Raumforschung & Raumordnung, 70*(4), 377–386. https://dx.doi.org/10.1007/s13147-012-0168-9

Schweikert, A., Espinet, X., & Chinowsky, P. (2018). The triple bottom line: bringing a sustainability framework to prioritize climate change investments for infrastructure planning. *Sustainability Science, 13*(2), 377–391. https://dx.doi.org/10.1007/s11625-017-0431-7

Seeliger, L., & Turok, I. (2013). Towards sustainable cities: Extending resilience with insights from vulnerability and transition theory. *Sustainability, 5*(5), 2108–2128. https://dx.doi.org/10.3390/su5052108

Shafiee, M. (2016). Modelling and analysis of availability for critical interdependent infrastructures. *International Journal of Risk Assessment and Management, 19*(4), 299. https://dx.doi.org/10.1504/IJRAM.2016.079608

Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J., Watkins, G., & Hall, J. W. (2019). Infrastructure for sustainable development. *Nature Sustainability, 2*(4), 324–331. https://dx.doi.org/10.1038/s41893-019-0256-8

Thomé, A. M. T., Ceryno, P. S., Scavarda, A., & Remmen, A. (2016). Sustainable infrastructure: A review and a research agenda. *Journal of Environmental Management, 184*, 143–156. https://dx.doi.org/10.1016/j.jenvman.2016.09.080

Uda, M., & Kennedy, C. (2018). Evaluating the resilience of sustainable neighborhoods by exposing LEED neighborhoods to future risks. *Journal of Infrastructure Systems, 24*(4), 04018030. https://dx.doi.org/10.1061/(ASCE)IS.1943-555X.0000443

UNWCED. (1987). *Our common future (Brundtland Report).* Geneva: United Nations, World Commission on Environment and Development. https://www.ask-force.org/web/Sustainability/Brundtland-Our-Common-Future-1987-2008.pdf. Accessed: 10. May 2017.

van Broekhoven, S., & Vernay, A. (2018). Integrating functions for a sustainable urban system: A review of multifunctional land use and circular urban metabolism. *Sustainability, 10*(6), 1875. https://dx.doi.org/10.3390/su10061875

VDI. (2017). *VDI Richtlinie 4605 "Nachhaltigkeitsbewertung" (No. VDI 4605).* Düsseldorf: VDI Verein deutscher Ingenieure.

White, I., & O'Hare, P. (2014). From rhetoric to reality: Which resilience, why resilience, and whose resilience in spatial planning? *Environment and Planning c: Government and Policy, 32*(5), 934–950. https://dx.doi.org/10.1068/c12117

Xu, M., Weissburg, M., Newell, J. P., & Crittenden, J. C. (2012). Developing a science of infrastructure ecology for sustainable urban systems. *Environmental Science & Technology, 46*(15), 7928–7929. https://dx.doi.org/10.1021/es3025534

6 Building Heat-Resilient Neighborhoods—Testing the Implementation on Buildings and in Open Spaces in Two Sample Quarters Dresden and Erfurt

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https://doi.org/10.1007/978-3-658-33702-5_6

6.1 Introduction

Summer heat is one of the most serious environmental impacts of climate change. The average annual temperature has been rising since the beginning of the twentieth century, and temperatures are expected to continue to rise until the end of this century (IPCC 2013). A changing climate is driving these warming tendencies. While natural fluctuations continue to play an important role in extreme heat events, climate change has shifted the odds and increased the probability of these events occurring (EPA 2016). Climate projections show a clear trend towards summer heat, i.e. an increase in both mean and maximum temperatures (IPCC 2018). Projections for Saxony also show an increase in temperatures (Spekat and Enke 2020). In addition to rising mean temperatures, especially in spring and summer, increased maximum temperatures are also projected. The frequency of summer days (Tmax ≥ 25 °C), hot days (Tmax ≥ 30 °C) and warm general weather conditions such as in the summers of 2003 and 2018 will increase (Imbery et al. 2018). This applies in particular to dense urban neighborhoods without networked green corridors and ventilation strips (Magistrat der Stadt Wien 2015), where there is a great need for action in terms of resilience to heat.

Strengthening people's resilience in the context of their living environment, with a level of detail that extends into concrete implementation, has received surprisingly little attention, although it is known that rising temperatures will lead to increasing risks for the effects of heat on work, human performance, and daily life (Kjellstrom et al. 2015). Heat exposure through the combination of air temperature, humidity, air movement and heat radiation leads to heat stress, heat exhaustion, heat stroke and heat-related mortality of people. The performance and the so-called thermal comfort of people are significantly affected in their neighborhood, both inside and outside buildings. In order to maintain or even improve the quality of life of people in spite of climate change, it is necessary to focus on ensuring their coping capacity and thus on resilience.

The chapter explores how coping capacity can be improved through adaptation to climate change, and at which different levels such adaptation can be implemented effectively and in a socially acceptable manner. Firstly, the human organism is in principle capable of adapting to changing climatic conditions within certain limits. This ability is inherent in people to varying extents and is not the focus of consideration in this chapter, although the differences are always kept in mind in the reflections below. Secondly, the environment—buildings and open spaces in the neighborhood—can be adapted to absorb thermal effects to a certain extent and thus reduce the exposure of people. The latter aspect forms the basic idea for the concept of establishing heat-resilient urban neighborhoods in this chapter. We therefore follow up on the hypothesis that targeted adaptation measures can counteract these problems and thus "build resilience in buildings". At the level of the city quarters, urban greenery, e.g. parks, gardens and individual trees, plays a decisive role in terms of resilience in the sense of local climate regulation (e.g. Bolund and Hunhammer 1999; UN 2019). This is followed by the hypothesis that appropriate adaptation measures can contribute to "building heat-resilient neighborhoods". The quality of human life can therefore be maintained or even improved at various levels by adapting to climate change.

In this chapter, we will explore the questions of how we need to consider resilience at different levels of the neighborhood and how the understanding of resilience is operationalized in the course of planning and implementing adaptation actions. With regard to the implementation of adaptation measures for resilience building, not only their general effectiveness must be questioned, but also site-specific boundary conditions that influence the selection and feasibility of such measures. This leads to other specific questions that we will consider in this chapter: Which structural and technical adaptation concepts are physically effective while meeting the criteria of citizen participation and acceptance for successful implementation? How can we identify the demand for adaptation in open space from an ecological perspective and from the citizens' point of view, and which implementation measures may require further action? Can we derive specific factors that enable or inhibit planning and implementation from the experience with the adaptation measures on buildings and in open space described here?

In the project HeatResilientCity, concrete adaptation measures were implemented on buildings and in open spaces in two selected sample quarters[1] in Dresden Gorbitz and Erfurt Oststadt each with different urban structure and building types that are characteristic of many cities in Germany and Europe. The most visible and largest part of the example quarter Dresden Gorbitz is predominantly built up with industrial prefabricated concrete apartment buildings (so-called post-war large-panel construction), which were constructed in the early 1980s. A large part of these buildings are owned by the housing cooperative "Eisenbahner-Wohnungsbaugenossenschaft Dresden eG" (EWG). Slightly more than twenty thousand people live on an area of about 200 hectares. Compared to the city as a whole, the district has a higher spatial concentration of socially and economically disadvantaged people. However, Gorbitz has a relatively high

[1] An urban living lab approach is underlying as a research method (cf. Bulkeley et al. 2019; Evans 2016; Karvonen and van Heur 2014; Schneidewind and Singer-Brodowski 2015). Urban living labs emphasize the potential of experimentation and failure to foster social learning, change, and innovation (Fuenfschilling et al. 2019; Karvonen et al. 2013).

proportion of green spaces. In the sample quarter Erfurter Oststadt almost 12,000 people live on an area of about 140 hectares, distributed among the Hanseatic quarter, the inner and outer Oststadt. The inhabitants of the Hanseatic Quarter predominantly belong to the older population group, while the inner Oststadt is a demographically young district due to a comparatively high proportion of students. The Hanseatic Quarter is characterized by the social housing of the 1920s and 1930s, while the inner Oststadt is characterized by large Wilhelminian-style apartment buildings (so-called 'Gründerzeitgebäude'), which were built between 1880 and 1960. The ownership structure is very heterogeneous compared to Dresden Gorbitz. There are many individual owners of apartments within the buildings. Erfurt's Oststadt has a high degree of sealing and densification and few public open spaces.

The HeatResilientCity project aimed to develop and implement innovative, socially equitable, and user-acceptable adaptation measures that support the reduction of summer heat stress on people in buildings and open spaces. Selected measures were physically implemented in the sample neighborhoods and are now benefiting inhabitants. A quantitative and qualitative assessment of effectiveness forms the basis for the selection of suitable adaptation measures. The evaluation of measures was carried out using effectiveness analysis methods based on indicators that are suitable for measuring heat stress, in combination with user surveys on their perception. The assessment methodology differs somewhat between the efficacy analysis for adaptation measures on buildings and for the provision analysis in open spaces. The general methodology of the efficacy analysis is to compare potential changes in the indicators in scenarios with respect to a starting situation (current base case), which serves as a reference value. Measures in open space were derived from a provisioning analysis for heat stress relevant ecosystem services by means of matching demand and supply potential. In both cases, the physical effectiveness analyses were complemented by examination of the economic and social feasibility using stakeholder and citizen[2] participation

[2]The term stakeholder means the actors who have decision-making power because they are, for example, property owners, homeowners or landlords, and/or members of municipalities and which ultimately implement and finance the adaptation measures. In the case of the measures presented here, for example, these are representatives of the housing cooperative or the state capitals. Citizens means the individual persons who are either directly affected by the measures, for example as users of a rented apartment that is being renovated, but who do not actually have any decision-making control themselves (in Germany, rental apartments are the standard case) and who are using urban neighbourhoods for crossing through or staying. Ultimately, both types of actors—stakeholders and citizens—should benefit from the selected adaptation measures.

and social science analysis methods such as surveys and mental maps of inhabitants and passers-by as well as citizen participation workshops to arrive at an integrative overall assessment (Baldin and Sinning 2019a, b, c). The integration of knowledge of the involved actors from different scientific disciplines and from practice is an indispensable basis for the decision-making on the selection of the implementation measures described here. The individual measures should be transferable to other cities, and therefore representative building types and open spaces were selected. This chapter therefore focuses on the types of measures rather than the sample quarters.

The chapter follows the logic of the receptors affected by heat, starting from the residents, to their apartments in the building, and finally to the open spaces in the neighborhood which are occupied by these residents. It is structured as follows: Following the introduction here, we clarify the understanding of resilience in this chapter in relation to different understandings of resilience commonly used in the literature and place it in the context of heat adaptation of urban neighborhoods. Sections 6.3 and 6.4 form the core of the chapter and focus on the adaptation measures implemented in the sample quarters. Section 6.3 is dedicated to adaptation measures on different representative building types and then addresses issues that the project team faced during planning and implementation. Section 6.4 describes the assessment of ecosystem services as a basis for planning and prioritization of adaptation measures in green spaces and a collection of implemented measures in open space. The chapter concludes with an outlook on opportunities with regard to future implementation of measures for resilience building in urban neighborhoods that result from the learning process here.

6.2 Multi-level Understanding of Resilience

Readers of this chapter will agree that the term resilience can be understood in a wide variety of ways, depending on the discipline and scientific context in which it is used. The contribution of this chapter relates to an interdisciplinary and transdisciplinary context. We therefore first want to clarify the understanding of resilience for this chapter and contextualize it within the scope of concepts that are well known in the literature.

6.2.1 Meanings of Resilience

Different definitions of resilience exist in the literature, which often result from the different understanding of several disciplines and the problems to be considered. Folke (2006), for example, approaches the topic from the perspective of the dynamics of social-ecological systems and essentially distinguishes between three concepts of resilience: (1) Engineering resilience, (2) Ecological/ecosystem resilience and 3) Social–ecological resilience. While the first implies a very strict conservative understanding in terms of recovery towards a constant system, the ecological understanding focuses more on persistence and robustness in terms of withstanding shocks and maintaining function. The social-ecological perspective focuses on adaptive capacity and transformability in the context of cross-scale dynamic interactions which includes characteristics such as reorganization and developing.

Similar to Folke's ecological/ecosystem resilience understanding, Pelling (2011, p. 51) formulates resilience as "functional persistence in a changing environment" with reference to climate change adaptation. A focus on developing and supporting adaptive structures and systems that can maintain their function even when individual elements are impaired unites many applications, including in the area of disaster risk reduction and urban development (Tappeser et al. 2017, p. 23). This approach is also pretty much at the heart of the present chapter, because building heat-resilient neighborhoods aims to preserve the function of neighborhoods for the inhabitants living there in the future, despite climate change. This implies the need for the implementation of adaptation measures to compensate for the negative effects of the changed hazard "heat" on the receptors *human*, *building* and *open space*.

Davoudi (2018) provides a somewhat different framework and terminology with regard to the concept of resilience, which is also relevant to the differentiation of the understanding of resilience in this chapter. Thus the meanings of resilience are clustered in (1) resilience as (functional) persistence where the main criterion here is a temporal component, i.e. the focus is on the return speed, (2) resilience as adaptation, whereby here the focus is mainly on an intensity component, i.e. on the extend of the tolerable disturbance, and (3) resilience as transformation, but here the capacity for transformative change is in the foreground, meaning that the focus is on process dynamics. The latter will not be the subject of this chapter. However, the first two play an essential role in the selection of adaptation measures because they are important for defining the characteristics of the target systems after implementation of the adaptation measures. To put it more precisely, with reference to sub-systems on the different scale levels considered in the urban district, a distinction must be made between the different types of understanding of resilience. This applies to the buildings and the building services therein as well as the open spaces and the plants growing on them, and finally to the people living in in the neighborhood as users of all these things. So, we are dealing here with a multi-level understanding of resilience.

6.2.2 Resilience of Individual Persons

Ensuring *human* well-being, capability and healthiness provides the framework for the development of measures to adapt to climate change to build resilience both at the neighborhood level and at the smaller scale levels. For the individual human being, the preservation of bodily functions under heat stress is of primary importance, i.e. the ability to absorb this stress due to its buffer capacity or robustness, which enables it to persist. Thus, for the receptor "human", a social-ecological understanding of resilience as adaptation is most likely to be applicable. However, the physiological adaptability of humans or their robustness is limited.

In light of these physiological limitations, we consider resilience of individual persons in a larger context that opens up more effective opportunities for action e.g., in terms of relaxed staying and moving in buildings and neighborhoods. This means that we consider the person in a unit with his living environment in which it lives. Heat adaptation measures on buildings, for example, primarily serve to increase the resilience of the individual as a receptor for heat stress, rather than the building itself, which is practically unaffected by heat in its building structure, as will be explained in more detail below.

6.2.3 Resilience of Buildings

The receptor *building*, including its flats, components and technical installations as well as its physical properties, forms a technical system. In this respect, the term engineering resilience comes to mind first. This narrow understanding of resilience does not go far enough in the context of heat resilience. The individual technical subsystems such as components or exhaust systems must meet the requirements for resistance to disturbances and return to the old path, but the building itself as a receptor is not affected by the heat. The building would therefore not be damaged by the heat, but the function that enables the well-being of the residents may be temporarily reduced during a heat wave. In this respect, not only the current state of climate conditions must be considered, but also future developments — in other words, according to Pelling's definition of resilience, functionality must be ensured even in a changing environment caused by climate change. The above-mentioned temporary functional disorder can be quantified in terms of both time and severity which refers to the first two meanings of resilience after Davoudi (2018). The combined indicator *overheating degree hours* in the German standard DIN 4108-2:2013-02 (see Sect. 6.3.2) is an example of this. Using the example of an attic apartment, resilience as persistence and adaptation can be explained more vividly. Heat exposure during the day heats up the apartment, so the temperatures put a stress on the residents. The system "attic apartment" can bounce back to equilibrium "normal temperatures" overnight if the return speed through ventilation during the cool night time is sufficient. In this case we have daytime wave-like fluctuations in temperature stress but no accumulation, i.e. no loss of system stability over a longer period of several days (resilience as persistence). However, this ability also depends essentially on the magnitude of the disturbance, i.e. how much the attic has heated up during the day. If the heat input is greater than the possible compensation from cool night temperatures, the system can no longer absorb this disturbance over a longer period of time. Only as long as the heat input is not greater than the possible compensation by cool night temperatures, the system can absorb this disturbance during a heat wave lasting several days (resilience as adaptation). This adaptation capacity and thus the resilience of these systems can be increased by appropriate measures, which are described in the following in this chapter.

6.2.4 Resilience of Open Spaces

In terms of *open spaces*, this chapter focuses on urban ecosystems such as green spaces. The essential functions of these areas are valuable ecosystem services that are important for human well-being. The maintaining of these functions can best be described with Folke's ecological ecosystem resilience understanding (Folke 2006). Resilience in this ecological understanding is different from what is known as "technical" resilience as discussed above, which is a measure of the rate at which a system approaches a certain state of equilibrium after a disturbance (Folke et al. 2004). Nevertheless, these ecological sub-systems may be in different conditions with respect to the degree or state of disturbance or with respect to possible changes in vulnerability in the future. As an extreme example, an ecosystem that has been converted into a sealed area is, from a temporal perspective, in a permanently disturbed state. The degree of disturbance is so severe that the system has already changed its state from green to grey. The resilience of this disturbed ecosystem is low. It needs to be removed—in this case, sealing—in order to regenerate and re-establish its ecosystem (service) function. For green spaces as an ecosystem with different subsystems such as trees and shrubs, resilience as adaptation is the most important aspect with respect to the intensity of the disturbance. Plants form a resilient ecosystem when their buffer capacity is high enough to survive the shock in the form of a heat wave, both in terms of duration and intensity. Some functions, i.e. certain ecosystem services can—just like in technical systems—be temporarily restricted or come to a standstill during the shock event (e.g. climate regulation through evaporation). The decisive factor for ecosystem resilience, however, is that they maintain their function over the long term.

6.2.5 Multi-level Understanding of Neighborhood's Resilience

When we approach the topic of building heat-resilient neighborhoods on its different scale levels, we have to take into account the specific boundary conditions of the individual subsystems. These cannot be described with a uniform understanding of resilience. We consider social-ecological resilience as an overarching perspective, although individual subsystems—especially the technical ones—must also be viewed from the perspective of engineering resilience. This means that we use a multi-level understanding of resilience.

Of course, in the sense of the multi-level understanding, different actors from the sectors of government (municipalities, politicians, etc.), economy (homeowners, housing industry, etc.) and civil society (associations, initiatives, etc.) must also be considered. That is because they contribute at different levels to the accomplishment of tasks (multi-actor and multi-level governance e.g. Greiving and Fleischhauer 2008; Ritter 2007; Benz 2007; Ostrom 2010; and in the context of HeatResilientCity Baldin and Sinning 2021). So, for example, actor networks for resilient cities have proven as a meaningful future strategy (e.g. in Melbourne; Sinning 2018). However, this aspect will not be discussed further in this chapter.

Since the various green and gray subsystems are related to the individuals living in the neighborhood, the implementation of adaptation measures on these subsystems directly influences the resilience building of the individuals, focused on in these considerations as receptors for heat stress, especially if their neighborhood is an urban heat island with hot spots. In this sense, it is a multi-level understanding of resilience because interventions at one scale level, such as tree planting in open space, affect other adjacent scale levels—for example, neighborhood (local climate), building (shading), individual person (heat stress reduction).

6.3 Structural and Technical Adaptation Solutions for Heat-resilient Buildings

The following section addresses the question of which structural and technical adaptation concepts are physically effective while meeting the criteria of citizen participation and acceptance. This is an essential prerequisite for successful implementation in practice. The type of building, including the ownership structure, also provides strict boundary conditions for the feasibility of measures. To make this clear, planned and implemented adaptation measures are presented here for two different existing building types and for a new building. Using the examples of the existing buildings, we show in detail how to quantify the physical effectiveness of adaptation measures based on sound engineering effectiveness analysis. From the experience gained during the planning and implementation of the described adaptation measures, an attempt is made to identify factors that enable and inhibit implementation.

6.3.1 Adaptation Concepts for Buildings and the Criteria of Citizens Involvement and Acceptance

When developing *adaptation concepts* to optimize the summer thermal insulation of existing buildings, a wide range of boundary conditions must generally be taken into account. For example, it is a priority to meet the requirements of winter thermal insulation, e.g. according to the currently valid energy saving regulations, such as "Gebäudeenergiegesetz" (GEG 2020), and the previous versions "Energieeinsparverordnung" (EnEV 2016) and "Erneuerbare-Energien-Wärmegesetz" (EEWärmeG 2015). In addition to climate adaptation, climate protection must also be taken into account in the adaptation concepts.

It should be noted that individual measures can have different effects on the desired objectives. Some measures improve both summer and winter thermal insulation. Other measures, on the other hand, improve thermal insulation in summer but have negative effects on thermal insulation in winter or vice versa. Accordingly, it is necessary to investigate in detail the positive and negative effects of building-related measures as well as their interactions in order to be able to evaluate the sustainable effect on or in the building.

Furthermore, the structural conditions on site must also be taken into account when planning measures. For existing buildings, it is therefore necessary to carry out a detailed inventory in order to obtain information on the building history, geometry and construction.

For the development of concrete heat adaptation measures, four strategies were defined in a first step:

1. Reduction of heat input,
2. Optimization of the heat storage capacity,
3. Optimization of the air exchange and
4. Cooling.

The adaptation strategies must always be dealt with in the listed order, since they take into account the mechanisms of interior heating-up or cooling-down from heat input to heat output. In order to prioritize, it is necessary to first plan measures in the first strategy that reduce or minimize the heat gains into the building. Both external and internal heat gains must be taken into account. Subsequently, the second strategy involves the development of measures for the targeted intermediate storage of thermal energy. During prolonged hot weather periods, this delays the heating-up of rooms, and when outside temperatures drop, the stored heat is dissipated again, e.g. by ventilation. A ventilation system also makes it possible to ensure sufficient air exchange for cooling the building at night, even during periods of high outdoor temperatures during the day. If the measures of strategies 1, 2 and 3 cannot be implemented or are only partially effective, air conditioning systems must be used for active cooling in a fourth strategy. Against the background of climate protection, such installations should be given the last priority due to the high energy demand during operation. In this context, it should be noted that due to the diverse boundary conditions and requirements, no individual measures can normally achieve the desired effects on and in the building, but only suitable combinations of measures.

According to the current state of the art, a variety of measures can be implemented to optimize summer thermal insulation in both existing and new buildings. Table 6.1 shows a selection of structural and technical adaptation concepts that are assigned to the four strategies. It should also be noted that measures that are effective from a technical point of view can only achieve their full effects if the

Table 6.1 Strategies as well as exemplary structural and technical adaptation measures to reduce thermal stress in buildings (Ortlepp and Schiela 2019)

Strategy	Adaptation measures
1. Reduction of heat input	Shading, insulation of exterior components, building greenery
2. Optimization of the heat storage capacity	Increase of storage mass, phase change materials (PCM)
3. Optimization of the air exchange	Natural air exchange, mechanical support of the air exchange
4. Cooling	Centralized/decentralized mechanical air conditioning

user applies them correctly. If the user does not use a measure such as an external shading system or an automated ventilation system for certain reasons, or if he applies the measure incorrectly, it will usually not have sufficient effect.

In order to *involve* the residents and to consider the *citizens acceptance* of building-related adaptation measures, the Institute for Urban Research, Planning and Communication of the Erfurt University of Applied Sciences (ISP) conducted participation workshops, activating user consultation and citizens surveys in the summer period 2018 in Dresden Gorbitz and in Erfurt (Baldin and Sinning 2019a, b). An important part of the survey was, among other things, which measures on and in residential buildings the residents considered to be reasonable. The surveys showed that approx. 75–80% of those questioned in Dresden and Erfurt considered external sun protection to be a reasonable measure for reducing summer heat in residential buildings. The citizen survey in Erfurt showed a similarly high approval rate of around 75% with regard to roof and facade insulation and for interior sun protection such as curtains, etc. In Dresden, the approval for these latter types of measures was significantly lower in percentage terms (40–60%), but they were also far ahead in terms of the ranking of measures considered effective. The comparison of expert opinions and citizens' estimates has confirmed that the recommended measures are mostly in agreement. An accompanying advisory board of the HeatResilientCity project discussed both perspectives—from citizens as well as from experts from science and practice—and supported the prioritization of measures by integrating findings from simulations and citizen surveys.

Implementation measures on existing buildings usually require more effort than on new buildings. The reason for this is that, on the one hand, the basic conditions for existing buildings are already specified with regard to existing geometry, window orientation, materials and load bearing capacity and, on the other hand, each retrofitting measure requires extra construction site equipment, which leads to extra costs. This problem arose with the selected pilot building in Erfurt Oststadt, where, for example, an extra scaffold would have been required for certain roof measures (cf. Sect. 6.3.3). The retrofit measure can be implemented without additional costs if construction measures are planned anyway and the heat adaptation can then be carried out at the same time. This advantage could be used for the adaptation measures of the pilot buildings of the EWG in Dresden Gorbitz (cf. Sect. 6.3.2). With new buildings there is the advantage that the heat-resilient construction method can be taken into account right from the start when planning the geometric shape and dimensions of a building and its individual components as well as their statics, for example with regard to the load-bearing capacity of the roof construction for a green roof (cf. Sect. 6.3.4).

6.3.2 Implementation of Measures in Existing Large Panel Construction Buildings

In the sample quarter of Dresden Gorbitz, two residential buildings from the 1980s were selected from the EWG stock and analyzed with regard to their summer thermal insulation. Specifically, these are residential buildings erected in 1984 and classified in the housing construction series "WohnungsBauSerie WBS 70/14.40", a large panel construction of the post-war period. The designation "14.40" corresponds to the building width in meters. During the project period, comprehensive renovations were planned for these buildings anyway, such as a thermal insulation upgrade of the facades, the installation of elevators, a change of floor plans in some areas, and the creation of barrier-free flats. The selected buildings are typical examples of multi-family residential buildings, which were built in large numbers in industrial prefabricated concrete slab construction on the territory of the former GDR (IEMB 1997, p. 4). The results of the present investigations can thus be transferred to other cities with similar building types.

A systematic series production of uniform building elements in stationary panel factories was characteristic for this type of construction. In addition, the designs were optimized with regard to the static design in order to make the load transfer as effective as possible. This procedure reduced the amount of basic materials, such as concrete and reinforcing steel, which, however, has the disadvantage that subsequent adaptation measures may hardly add any additional weight. On

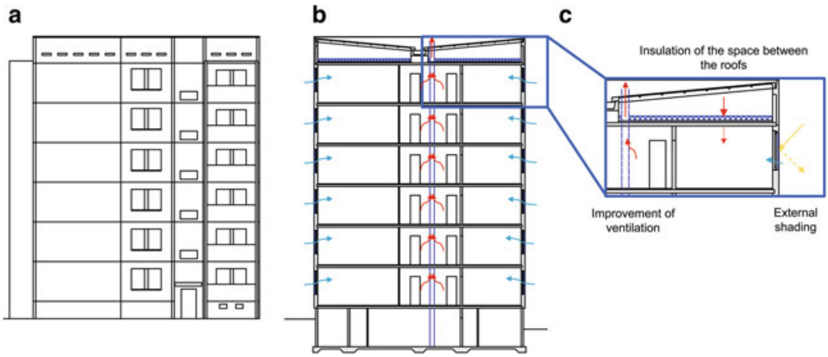

Fig. 6.1 Post-war large-panel construction building in the sample quarter Dresden Gorbitz. **a**) Eastern view, **b**) vertical section with air flow, **c**) detail with adaptation concepts for the pilot building (*Source* based on Ortlepp and Schiela 2019)

the basis of the results, adaptation measures were developed which were implemented in connection with EWG's existing renovation concepts on and in the buildings in the years 2019 and 2020 on a pilot basis.

One of these buildings was selected for the analysis of summer thermal insulation, where a high thermal load within the building was expected during hot weather periods due to the orientation of the building and the proportion of window areas (Fig. 6.1a). The building was modeled as a 3d object in its entirety. The results are transferable to the rest of the WBS 70/14.40 building stock, taking into account some boundary conditions. The essential structural design characteristics of the building are summarized in Table 6.2.

In order to make existing buildings heat-resilient for their residents, it is first necessary to *identify thermal weak points* and then *derive technically feasible adaptation measures* for these points including *efficacy testing*.

Because, as described above, winter thermal insulation in Germany is strictly regulated, it must always be considered in context when planning summer thermal insulation. To do this in accordance with the Energy Saving Ordinance (EnEV 2016) and the thermal protection and energy economy in buildings standard (DIN 4108-2:2013-02), the components of the building envelope are particularly important. Accordingly, the building's facades with integrated windows and the flat roof must be examined for *thermal weak points*. The building components must be designed in such a way that both transmission heat losses in winter and solar heat input in summer are reduced. In addition, the issue of ventilation must be

Table 6.2 Selected key data of the post-war large-panel construction building in the sample quarter Dresden Gorbitz

Component	Characteristics
External walls	Upper floors: sandwich panel elements, thickness 26 cm Basement: reinforced concrete elements, thickness 15 cm
Internal walls (load-bearing)	Reinforced concrete elements, thickness 15 cm
Floor slabs	Pre-stressed concrete elements, thickness 14 cm
Windows	Wooden frame windows with a 2-pane insulating glazing No external or internal shading

taken into account for summer thermal insulation. In particular, the possibilities for daytime and/or post-ventilation must be assessed.

For the development of concrete *technically feasible adaptation measures*, the focus was placed on strategies for reducing heat input, optimizing storage capacity and optimizing air exchange (strategies 1–3). The strategy of cooling (4) was abandoned since the use of energy-intensive air conditioning systems is not in the sense of climate protection and it was assumed that in the considered building type sufficient cooling effects can be achieved by implementing the strategies one to three. Furthermore, a comprehensive renovation was already planned for the selected pilot building when the summer heat adaptation measures were developed, so some boundary conditions had to be met (see detailed discussion on strategies below). Based on these facts, the measures shown in Fig. 6.1c were identified for an in-depth effectiveness analysis.

In the course of the project, the participating project partners were regularly consulted on a variety of adaptation options for the buildings. At this point it must be mentioned that the concepts for the optimization of summer thermal insulation, which are described below, were developed under consideration of the existing renovation concepts of the EWG. Due to this fact, some potential adaptation measures on the buildings were only partially or not realizable under the time restrictions of the project duration. Other measures would only be possible with considerable additional costs. In the following, a selection of the discussed measures is used to show which difficulties or which new requirements can arise with some of the measures.

1. Strategy *Reduction of heat input*: In order to reduce the heat input into the buildings during hot summer periods, the first step was to discuss internal and external shading systems. The external systems are always to be preferred, as they have the greatest effect. Exterior systems radiate their stored heat back to the outside environment, while interior systems additionally heat the interior by emitting heat. The external shading system should also meet the following requirements: (i) high wind resistance, (ii) manual control and (iii) low maintenance. External roller shutters are best suited for this. When installing them on existing buildings, further boundary conditions must be taken into account. For example, the roller shutter boxes can decrease the window height, which reduces the amount of daylight entering the rooms behind. Such constraints further limit the choice of technologies. Enlarging the window openings requires extensive cutting work and additional static strengthening measures, which would cause considerable additional costs. With regard to reflective component surfaces, a fundamental discussion took place on the use of an exterior coating with a high degree of reflection. However, the planned design concept already provides for an exterior painting with a light colour; also, the arrangement of a facade greening is not possible due to this concept. The realization of a subsequent green roof has only a very small effect on the indoor climate of the reference buildings, since the roof surface and the uppermost floor are thermally decoupled from each other. Furthermore, in this case the roof construction might have to be statically strengthened due to insufficient load bearing capacity.
2. Strategy *Optimization of the heat storage capacity*: In order to optimize the heat storage capacity, the area above the heat-loaded top floor ceiling was considered in particular. Different variants are possible in principle, such as (i) mineral insulation panels, (ii) insulation boards made of perlite, (iii) cellulose fiber insulation material, or (iv) screed board and mineral wool insulation, whereby the load-bearing capacity of the floor limits the maximum of the additional storage mass that can be applied. In addition, possible changes to the wall cross-sections were discussed. A thickening of the walls towards the inside is not possible, because too much living space would be lost for the barrier-free conversion. Also, the variant of a ventilated curtain wall is not feasible for structural and cost reasons.
3. Strategy *Optimization of the air exchange*: For the reasons described above, the windows of the buildings cannot be enlarged to optimize the air exchange.

Therefore, the project investigated the possibility of increasing the exhaust air volume with a mechanical ventilation system. This adaptation measure was implemented as a pilot in one of the buildings.

4. Strategy *Cooling*: The involved actors have started to think about the use of district cooling. However, this would require considerable procurement and maintenance costs for the machines, which is not economically feasible. In addition, the possibility of constructing an underground gravel storage for passive air cooling was considered. Here, however, there is the difficulty of how the cooled air is fed into the rooms. The building services infrastructure or the installation room, which would be necessary for this, is missing in the buildings. To install them would require a disproportionate effort for the existing buildings.

Specifically, the following combinations of heat-adaptation measures were finally implemented in the pilot buildings:

1. Strategy: *Reduction of heat input* by external shadows on selected windows by means of installation of roller shutters
2. Strategy: *Optimization of the heat storage capacity* in the roof area by means of installation of materials that have a high heat storage capacity and a high insulation effect at the same time
3. Strategy *Optimization of the air exchange* by ventilation concept to improve the possibility of night ventilation by means of installation of windows with external air passage elements, which ensure the necessary infiltration and user-independent air exchange, and in one building additionally by means of increase of the exhaust air volume.

To measure the effectiveness of adaptation measures, an indicator is required that provides information about the thermal stress on people inside buildings. The German standard DIN 4108-2:2013-02 specifies limit values for the so-called operative temperature in indoor rooms depending on summer climate regions. The region classification takes into account the adaptability of humans to the prevailing temperatures. In the Dresden Elbe Valley, people are accustomed to slightly higher temperatures than in Erfurt, which means that the limit value for the operative temperature was set in the standard for this summer climate region at 27 °C, one degree higher than for the Erfurt region (26 °C, see subsection 6.3.3). The limit value forms the basis for the calculation of the exceedance as an indicator of the thermal overload, the so-called ‘overheating degree hours’.

Overheating degree hours form an indicator for the assessment of overheating of indoor rooms of buildings. The indicator includes excessive temperature and radiation loads that accumulate over the course of one year. It is calculated from the annual sum of the hourly values of temperature exceedances in Kelvin above the limit value of the operative temperature. If, for example, an operative temperature of 29 °C is reached for 3 h in Dresden, this corresponds to a three-hour excess of 2 K, i.e. 6 Kh (Kelvin hours) of overheating degree hours. Both extreme values and long-lasting summer periods are reflected in this indicator via the multiplication of the exceedance height (degree temperature) and duration (hours). For residential buildings, the standard specifies a limit value of 1200 Kh/a (Kelvin hours per year), which must not be exceeded. For rooms that exceed this limit value, there is therefore a need for action with regard to adaptation measures that are suitable for reducing the thermal load of the room below this limit value. As the state of the art in civil engineering, this value of overheating degree hours is also used here as an indicator for assessing the effect of measures.

In addition to the status quo, the three adaptation measures were each modeled individually and as a combination in the thermal building simulation to evaluate the effectiveness of the adaptation measures on the future indoor temperatures. All boundary conditions of use were assumed to be identical in all variants investigated in order to ensure comparability of the results. For the roller shutters in particular, use is assumed to depend on the outdoor temperature and that the residents close the shutters only for three fourths of the way in order to still get sufficient daylight.

Table 6.3 shows the overheating degree hours determined from the simulation results for the bedroom and adjacent children's room on the fifth floor and for the identical rooms on the sixth floor. In the status quo, the limit value of 1200 Kh/a of overheating degree hours is exceeded in all four rooms. The sixth floor, and there especially the bedroom, is most affected by heat stress. The three different adaptation measures individually show different effects. Compared to the other adaptation measures described (1 and 3), measure (2) on the top floor ceiling has the smallest effect on reducing the thermal load. The external shading devices (1) show the greatest single effect in the simulation carried out here. that the residents, as in the present model, actually close all the roller shutters when the outdoor temperature exceeds 23 °C on the previous day, this measure alone is sufficient to comply with the limit value of overheating degree hours in the children's room on the fifth floor. However, it should also be noted that the limit value is only just complied with there. By combining the measures of external shading devices, additional storage mass and increased night ventilation, the overheating degree hours in all rooms are significantly reduced. The thermal load in the children's

Table 6.3 Overheating degree hours for two different rooms on the upper two floors, compared for the current state (reference) and four scenarios: the three aforementioned adaptation strategies and a variant containing the combination of all three thermal adaptation strategies from the thermal building simulation

	States:	Reference	Scenarios including adaption measures			
	Strategy:		(1)	(2)	(3)	(1–3)
Story	Room		External roller shutters	Additional layer over top ceiling	Increased night ventilation	Combination of the three measures
6th floor	Bedroom	3.868 Kh/a	2.081 Kh/a	3.175 Kh/a	2.712 Kh/a	1.333 Kh/a
	children's room	3.071 Kh/a	1.292 Kh/a	2.405 Kh/a	2.195 Kh/a	865 Kh/a
5th floor	Bedroom	3.410 Kh/a	1.751 Kh/a	2.946 Kh/a	2.388 Kh/a	1.162 Kh/a
	children's room	2.701 Kh/a	1.081 Kh/a	2.238 Kh/a	1.947 Kh/a	747 Kh/a

rooms can thus be reduced by up to 72%. Within the reference building, the selected bedroom on the sixth floor is the only one in which the permissible limit of excess temperature degree hours is still just exceeded by 133 Kh/a. These results of the efficiency testing clearly indicate that the implemented measures lead to a considerable reduction of the thermal stress and enable a comfortable and pleasant indoor climate in the pilot buildings during the summers in the future.

6.3.3 Planned implementation for Measures in Existing "Wilhelminian-style" Buildings

The building selected in the sample quarter Erfurt Oststadt is a Wilhelminian-style apartment building—in German "Gründerzeitgebäude" (GZG)—, which was built in 1912 and has a total of eight flats. In Fig. 6.2 the eastern and western view illustrates the characteristic stucco-facade for this type of building. Representative features are also thick brick exterior walls and the wooden beamed ceilings. The building was extensively modernized and retrofitted in 2002 and 2003. In this context the attic floor was developed by insulating the roof, creating the flats structure in drywall construction and insulating the gable walls and jamb walls from the interior. For the other stories the structure of the flats remain the same and the external walls were not insulated. Only the windows are replaced by double glazing windows. In addition, balconies on the western facade (backyard

Fig. 6.2 Eastern view (left) and western view (right) of the GZG building in the sample quarter Erfurt Oststadt. (*Source* D. Schiela, IOER)

side) were installed leading to a good shading situation of the large window doors (see Fig. 6.2).

The detailed building physics and other necessary information were collected by an intense archive research in the building files of the city of Erfurt and by on-site inspections. Implementing all the available data into a 3D thermal building simulation model the GZG exhibit several characteristics concerning heat resilience in its present state:

1. The overheating risk in the full stories is considerably low. This is caused by the thick internal and external brick walls including a high heat energy storage capacity and the effective shading of the large windows at the western side by the balconies. Only small rooms on the east facade side with large windows show considerable overheating if the room doors remain closed.
2. In contrast, a high degree of overheating was achieved for the attic flats. Several reasons are responsible for this. High solar heat gains caused by the large western oriented windows which are not shaded by a balcony in addition to the unshaded roof window (like all other windows of the attic) are a main reason for high summer temperatures. Together with the very low heat storage capacity of the attic by the drywall construction this leads to a strong room temperature increase during a solar radiation intense summer day.

These results show that heat adaptation measures are only needed for the attic of the building while the full stories can remain without extra measures. Compared to the large panel construction building in Dresden Gorbitz no energetic renovation is planned for the GZG building and heat resilience measures are only necessary in the attic flat. In addition, the ownership structure in the GZG building, which is a condominium owners' association, is very different from that of the large panel construction building, which is a housing cooperative. This more complicated ownership structure of the GZG building led to several renovation concepts. All the renovation concepts only suggested changes for the attic flats.

The initial renovation concept intended exterior roller shutters on the western balcony windows and roof windows together with vertical awnings on the street side (eastern facade) for the attic. The latter one is chosen for aesthetic reasons to keep the visible impact of the shading system minimal for the street facade. In addition to these sun protection measure, the installation of an exhaust ventilation in the bathroom of the attic flats was suggested to enhance the passive night-time cooling. When indoor room temperature is above 24 °C in summertime and outdoor air temperature below room temperature, the air is exhausted in the bathroom by a high volume flow of more than 250 m^3/h to ensure cold outdoor air supply by open windows. The combination of both measures resulted in a strong reduction of overheating, which is comparable to that of the first floor (Schünemann et al. 2020a, b). The possibility of increasing the storage capacity of the attic floor with massive constructions or phase changing materials was not considered as this would lead to a considerable intervention in the building structure and to attic flats that are temporarily uninhabitable.

However, the request of quotations shows that for the installation of the sun protection system on the east facade (street side) a cost-intensive building scaffolding is required. Therefore, the concept was revised and the intended vertical awning on the east facade was substituted by highly reflecting honeycomb plisse mounted from the inside of the window. The increase in overheating intensity remains low so that the revised package of measures consist of external shutter of balcony windows (west facade) and roof windows in combination with internal shading on east facade and exhaust ventilation system in the bathrooms of the attic flats. Table 6.4 demonstrates the high impact of the small adaptation package and compares overheating degree hours of the actual state to the adapted attic dwellings. It can clearly be seen that the high overheating risk of the top floor dwellings is strongly reduced to values comparable for other full stories.

This concept could only be presented to the condominium owners' association. To decide on the implementation of the package of measures, a homeowners' meeting was convened. Unfortunately, not a single person of the eight flat owners was

Table 6.4 Overheating degree hours for rooms at different stories oriented at the eastern and western facade, compared for the current state (reference) and an adaptation scenario that includes the package of heat adaptation measures in the attic (sun protection and exhaust ventilation system) from thermal building simulation

	Eastern oriented rooms		Western oriented rooms	
Story	Reference	Adaption scenario	Reference	Adaption scenario
Attic	1400 Kh/a	60 Kh/a	1200 Kh/a	210 Kh/a
4th	170 Kh/a	70 Kh/a	810 Kh/a	590 Kh/a
3rd	40 Kh/a	30 Kh/a	300 Kh/a	270 Kh/a
2nd	90 Kh/a	70 Kh/a	690 Kh/a	660 Kh/a
1st	0 Kh/a	0 Kh/a	590 Kh/a	570 Kh/a

present in this meeting leading to the fact that the heat adaption measures could not be installed. This procedure and obstacles in this communication process is discussed in detail in Sect. 6.3.5.

Summarizing the findings highlight that GZG buildings do exhibit a high heat resilience. One exception are attic conversions carried out neglecting sun protections for windows and thermal storage capacities by massive constructions which is a typical way of conversion. Attic conversions that take these basic principles into account can lead to a low risk of overheating and thus contribute to a higher overall heat-resistance of the residents in these attic apartments.

6.3.4 Implementation of Green Roofs on New Buildings

The municipal housing construction company “Wohnen in Dresden” (WiD) has supplemented its planning for a new building in the northern part of Dresden Gorbitz with a green roof and facade, on the initiative of the HeatResilientCity project team of the state capital Dresden. The implementation, i.e. the construction of a four-story building with flat roof, began in late summer 2020. These apartments are so-called occupancy-bound apartments for low income households.

The greening of buildings prevents their surfaces from heating up, and the temperature fluctuations on the green roof or facade are reduced. Accordingly, less heat is emitted into the urban space. The greening of buildings not only contributes to an increase in heat efficiency, but also brings many other positive ecological effects:

- Rainwater retention (especially with green roofs)
- Creation and linking of habitats for flora and fauna and increase in biodiversity
- Improvement of air quality by binding dust and air pollutants
- Improvement of the quality of stay (especially for facade greening)

Economic advantages include the saving of rainwater fees through rainwater retention on the green roof. In addition, the greening of the buildings can enhance the visual appearance of the urban quarter and significantly increase the quality of living for residents.

In comparison to the existing buildings described in Sect. 6.3.2, the additional load from the green roof could be taken into account in the static calculation during the planning process. Thus, the load-bearing capacity of the new construction is high enough right from the start to support a green roof.

6.3.5 Enabling and Inhibiting Factors in Planning and Implementation

The implementation process for the buildings in Dresden Gorbitz initially functioned quite smoothly due to the ownership structure of the EWG, which is a housing cooperative whose representatives can make their own direct decisions about their stock. Shortly after the start of the project, the selection of the buildings and a first presentation of the planned renovation measures by EWG took place at the end of 2017. Immediately afterwards, the EWG provided the scientific partners with the necessary planning documents, such as plans of the existing buildings and renovation plans, so that they could start working out concrete concepts for measures. As early as spring 2018, possible adaptation measures were coordinated with the EWG and with the engineering office commissioned to plan the renovation measures. Already in the summer, the tender documents were published and tenders were obtained from construction companies.

Shortly afterwards an unexpected *restriction* occurred. The EWG was informed that one of the selected buildings had unexpectedly been classified as a *single monument* by the local Monuments Preservation Office, even though the building permit for the renovation measures was already in place. The reason for this was that there is a special type of ceramic tile on the facade (so-called “Crinitzer Baukeramik”), which was classified as worthy of preservation. In addition, the exposed aggregate concrete facade parts were to be preserved, which made up virtually the entire exterior wall.

This was a big problem because it would have meant that the heat adaptation measures could not have been implemented as planned. If the ceramic tiles and the aggregate concrete facade parts had remained visible, the outer wall of the building could not have been effectively thermally insulated. This would have meant that, in spite of the additional costs, the complete planning would have had to be re-done as well as the preparation of tender documents and the procurement to the construction companies that were already waiting to start the renovation work. This would have led to a large delay in the project and thus endangered the subsequent efficiency measurement and assessment.

Fortunately, in this case, the transdisciplinary cooperation in the project worked very well to solve the problem together. With the support of the environmental office of the state capital Dresden as a project partner and the professional expertise from civil engineering science, which was also represented in the project team, the problem could be solved by means of communication. In a discussion between the local Monuments Preservation Office and EWG as builder a compromise acceptable to all could be reached.

As a result, the facade was allowed to be insulated. The windows were also allowed to be executed as planned, and thus also the roller shutters, which are so important for heat protection. As a compromise, the appearance of the new heat-insulated facade had to be based on a historical “WBS 70” facade. This concerns the joint pattern and the colour scheme, but this is not crucial for the effectiveness of the planned heat adaptation measures. In summary, the HeatResilientCity project team has proven to be very resilient in dealing with this type of disruption to the implementation on buildings in Dresden Gorbitz.

As mentioned in Sect. 6.3.3, the *ownership structure* in the exemplary GZG building in Erfurt Oststadt leads to high challenges and *obstacles* in terms of communication processes. Reasons were the small-scale condominium owners’ association because every flat was owned by another person. None of these owners has lived in Erfurt or even lived in the city of Erfurt, but all of them are spread all over Germany and use their apartments exclusively as investment objects. No direct communication with the owners was possible, but only indirectly through property management. The latter had little ability to establish the necessary communication process from scientists to owners to inform and discuss the proposed packages of heat adaptation measures. This disadvantageous initial set of communication condition led to the fact that only a few owners were present at the condominium owners’ meetings where the measures should be presented and discussed. Also, in a second and third round with significantly reduced costs for the package of measures this kind of communication did not lead to any success, independently of the possibility of allocating the estimated costs of heat adaptation for the attic flats only to the owners of these attic flats or to the whole condominium owners' association. This obstructive communication is not untypical for small-scale ownership structures that are rented and represent a very serious problem in climate protection or adaptation measures.

These *obstacles* to communication for the GZG condominium owners' association in Erfurt did not exist in the communication process of the housing cooperative EWG, which is the owner of the large panel construction building in Dresden Gorbitz. The reasons for this are that (i) the communication process between scientists and the housing cooperative in direct exchange could be managed without an intermediary property management company, (ii) the housing cooperative was interested in strengthening the future attractiveness of its rental flats and (iii) no coordination between many owners was necessary to decide on a package of measures for heat adaptation. Concluding the observations done for Erfurt and Dresden, housing cooperatives can be seen as potential drivers of implementing adaption measures to enhance the heat resilience of buildings in short-term focus. However, the emerging need for measures to adapt to climate change or to protect the climate cannot be neglected for the condominium owners' association either, since a high proportion of residential buildings in Germany belong to this small-scale ownership structure. This process can be implemented by establishing direct communication with the different owners, raising their awareness through knowledge transfer and presenting the measures in a practical way. Compared to the housing cooperative, such a process will take more time and is not possible within one or two years. In other words, building heat resilience in buildings is generally physically possible, but the duration of the process to build resilience varies depending on the ownership structure.

6.4 Ecosystem-Based Adaptation Solutions of Green Spaces for Heat-Resilient Neighborhoods

In the following, the question of how the requirements for adaptation in open spaces can be identified from an ecological point of view and from the perspective of citizens is explored. We present four adaptation measures that have already been implemented during the HeatResilientCity project period as well as another measure whose planning is already well advanced and about to be implemented. Using the example of these concrete measures, special constellations of boundary and underlying conditions are highlighted, among other things, which can have an impeding effect on implementation. From the experience gained in planning and implementation, an attempt is made to identify more general factors that restrict and inhibit implementation.

6.4.1 Identification of Adaptation Requirements in Open Spaces

Ecosystem services to support heat resilience. Urban greenery plays a significant role, especially with regard to the predicted climatic changes (IPCC 2013) and is important for maintaining the quality of life of the existing or even growing urban population (Bolund and Hunhammer 1999; UN 2019). Urban green, such as parks, city forests, private and public gardens, orchard meadows as well as individual trees and bushes, play a key role in local climate regulation in cities (Bolund and Hunhammer 1999). In particular, trees but also various other vegetation forms can shade buildings, sidewalks and other artificial surfaces (Dimoudi and Nikolopoulou 2003). They reduce heat by preventing solar radiation from reaching surfaces that absorb heat and then transmit it to buildings and the surrounding air. The evapotranspiration and the shadow effect, which is created by e.g. tree leaves, have a cooling effect and thus minimize the thermal discomfort of urban inhabitants (e.g. Armson et al. 2012; Streiling and Matzarakis 2003). Urban greenery thus contributes significantly to the heat resilience of city quarters. The preservation and protection of urban green spaces in the course of urbanization and climate change is therefore essential and must be given strong consideration in the context of sustainable and resilient urban development. In the following, the supply and demand for the ecosystem service "local climate regulation" is analyzed and evaluated. The investigations are conducted in the two sample quarters Dresden Gorbitz and Erfurt Oststadt. Based on the results, areas deficient in ES supply and demand are identified and appropriate adaptation measures are derived and implemented for these spots.

Among local climate regulation, urban green spaces provide a variety of other services that have a positive effect on the well-being of urban inhabitants and increase the quality of life in the city without any real consideration or payment. Such services are called *ecosystem services (ESS).* For example, urban green spaces provide ESS in the form of flood protection, air pollution control, groundwater purification, recreational effects or stress reduction for people (Bolund and Hunhammer 1999). ESS are understood as direct and indirect contributions of ecosystems to human well-being, i.e. services that bring direct or indirect economic, material, health or psychological benefits to people (Naturkapital Deutschland—TEEB DE 2016, p. 24). They are directly linked to the socio-ecological understanding of resilience. In terms of ensuring human well-being, ESS are factors that increase human resilience. According to the Millennium Ecosystem Assessment (MEA 2005, p. 40) ESS can be divided into four categories, whereby the so-called *supporting services* are regarded as the basis of the other services:

- *Provisioning Services*, such as the provision of food, drinking water or wood,
- *Regulating Services*, such as flood protection, air pollution control or climate regulation,
- *Cultural Services*, such as recreation, stress reduction, environmental education and
- *Supporting Services* that ensure the necessary conditions for the existence of all ecosystems, such as the nutrient cycle (Bastian et al. 2013, p. 48).

For the assessment of ESS, a distinction is made between the potential or actual supply level of an ESS by an ecosystem, the so-called *ESS supply*, and the *ESS demand* (Burkhard et al. 2014). The latter represents the need for an ESS of people, whereas the ESS supply is determined by the condition of an ecosystem. With regard to the ESS "local climate regulation", the condition, volume and structure of the vegetation play a decisive role in addition to the spatial location of the ecosystem. The demand for this ESS within the neighborhood, on the other hand, is determined by the spatial distribution, for example, of local population, soil sealing density or building locations as well as spaces that are particularly frequented by vulnerable population groups. The provision of this ESS is equated here, in simplified terms, with the matching of supply and demand. In other words, if the supply cannot meet the demand, there is a deficit in ESS. In a generalized way, this can be seen as a lack of resilience, which must be compensated or improved by adaptation measures.

ESS assessment to identify potential need for action. In the following, the potential need for action is derived from the identification of areas deficient in the ESS "local climate regulation". These areas are identified by an analysis and comparison of supply and demand aspects. The results form the basis for the spatial prioritization of adaptation measures that should be implemented to achieve heat resilience in the sample quarter.

The *supply* in the quarter is described with the parameters:

S1: climate-relevant green spaces,
S2: climate-relevant water bodies, and
S3: green volume.

The generation of cold air, which is very important for this ESS, is known to take place mainly on large unsealed areas (S1). Water bodies (S2) generate evaporative cooling and allow air movement. The air temperature also is reduced in particular by a dense tree and woody stand with large leaf surfaces (S3) as well as the vegetative evaporation taking place. Compact areas with a minimum size of ≥ 0.1 ha are defined as "climate-relevant green spaces" (S1) (Salata and Yiannakou 2016). Narrow green strips that are less than a minimum width of 10 m are not taken into account, as they are assumed to have a low potential to generate cold air and thus show a low cooling effect on the surrounding area. Areas directly adjacent to climate-relevant green spaces benefit from the cold air generated on these spaces. This positive contribution to the local climatic regulation effect was taken into account in the analysis within a radius of 10 m. In the sample quarter Dresden Gorbitz the supply of "climate-relevant water bodies" (S2) does not come from water surfaces of larger water bodies, but mainly from not sealed riparian strips in accordance to the regulations and definition of "ecologically functional areas" in §38 WHG[3] and §24 SächsWG.[4] Following these laws, riparian strips of water bodies have a legally defined width of 10 m and are of ecological relevance with low anthropogenic intensity of use. The supply parameter (S3) "green volume" is expressed as the sum of the above-ground volume of all vegetation objects in relation to a defined area (e.g. 1 m $\times$ 1 m grid cell). It plays an important role in urban ecology such as dust binding, temperature reduction, wind attenuation or groundwater recharge. Thus, each additional m^3/m^2 of specific green volume lowers the temperature by approx. 0.3 °C (Tervooren 2015).

After combining the supply parameters (S1) to (S3), especially parts of a green belt in the east and southeast of the sample quarter Dresden Gorbitz show a high supply capacity for the ESS "local climate regulation" (Fig. 6.3). Larger parks and green spaces with trees and shrubs in are also important for this ESS, whereas the residential areas with their green spaces between the multi-story post-war large-panel construction buildings are less apparent in the ESS supply.

The *demand* in the quarter is described with the parameters:

D1: density of facilities with vulnerable user groups,
D2: total sealed floor area within a radius of 20 m, and
D3: population density (100 m grid).

[3] Wasserhaushaltsgesetz (German water resources law).

[4] Sächsisches Wassergesetz (Saxon water law).

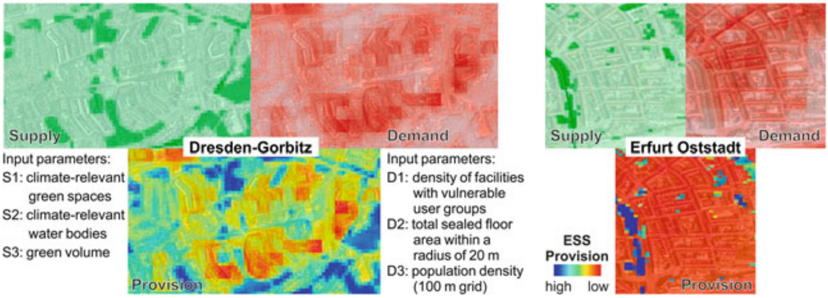

Fig. 6.3 ESS “local climate regulation” by urban greenery in the sample quarters Dresden Gorbitz and Erfurt Oststadt: Supply, demand (darker shades represent high supply and high demand) and provision (*Source* calculations and map production IOER)

The demand for this ESS specifically takes into account the vulnerability of people to summer heat and the associated vulnerability of certain groups of inhabitants (D1). Less resilient people with increased vulnerability to summer heat are especially children, elderly people and people with previous physical stress (Knopf and Maercker 2017). For example, children under the age of five have not yet fully developed their ability to regulate body temperature (BBK 2013). Furthermore, the potential for overheating and the identification of potentially heat-affected areas play a key role (D2). Parameter (D3) is concerned with how humans are affected by summer heat due to their housing location.

For the parameter (D1) the density of relevant facilities such as doctors’ surgeries, nursing homes, kindergartens and playgrounds, was calculated. Buildings or areas, which are mainly frequented by vulnerable user groups during daytime, were also considered in the calculations. This results in focal areas in which facilities with vulnerable user groups are more frequent. Using the sum of the sealed ground area within a radius of 20 m (D2), an overheating estimation of similarly complex models of urban heat islands or overheated areas was performed. High values stand for densely built-up and heavily sealed areas with little nighttime cooling, especially during heat waves with no wind. Here, the degree of soil sealing is representative of an increased potential for overheating and heat stress (see temperature effects found by Tervooren 2015). The population density (D3) represents the aspect of potential demand for climate regulation or cold air during hot summer periods. The demand is strong with a simultaneously high parameter value of (D2). The here used population data is based on the 2011 census and the derived spatial grid of 100 m × 100 m. Compared to the data basis of the other parameters, this is a low spatial resolution and therefore only allows rough evaluations.

The combination of parameters (D1) to (D3) results in the highest demand of the ESS “local climate regulation” in urban areas with high population concentration and soil sealing as well as the presence of facilities that are assumed to be visited by vulnerable people. In Dresden Gorbitz this is especially the case in the southern and eastern area of this sample quarter (Fig. 6.3). The less densely populated and built-up areas in the western part of the study area, on the contrast, show lower values.

The *provision* of ESS results from the comparison and intersection of supply and demand. The areas, where this combination show negative values, represent areas deficient in the ESS “local climate regulation” and thus justify the potential need for action. Figure 6.3 (bottom) shows the potential provision of the investigated ESS local climate regulation in the form of an index. The provision of ESS to inhabitants varies greatly within as well as between both sample quarters. Key areas of potential demand for this ESS during summer heat are highlighted in red. Areas shown in blue represent resilient areas with an ESS supply surplus. Areas that already have a high to very high demand surplus show a reduced resilience with regard to future changes in urban climatic heat stress. Therefore, these areas were the focus of the implementation analyses for potential measures for climate adaptation in the HeatResilientCity project.

In the Erfurt sample quarter, the closed building structure means that many green spaces are located in inner courtyards that are not accessible to the public. Opening these up or creating new recreational areas (e.g. a new park) would make additional areas accessible and thus usable. In the Dresden sample quarter, on the other hand, many open spaces are usable due to the high proportion of green space and the loose, open development. A targeted redesign of the existing green spaces, e.g. by planting different green structures and thus increasing the structural diversity or unsealing areas, could lead to an increased supply of heat regulating green spaces.

By balancing several relevant ESS, different levels of *need for action* can be identified. The need for action varies significantly in terms of space. In Dresden Gorbitz, many open spaces can be used due to the high proportion of green space and the open building structures. A targeted redesign of the existing green spaces could increase the provision potential in many areas, e.g. by planting different green structures and thus increasing the structural diversity or also unsealing areas. At hot spots (identified areas) with a particularly high need for action, the local actors and practice partners from the state capital of Dresden and the EWG derived potential adaptation measures. Certain measures have already been implemented on the identified areas (see Sect. 6.4.2). In Erfurt Oststadt, due to the closed development structure, many green spaces are located in inner courtyards that are not accessible to the public. Opening up these inner courtyards or creating new recreationally relevant areas (e.g. a new park) would make additional areas accessible and thus usable. Furthermore, suitable adaptation measures were planned and started to be implemented at open spaces that are already accessible to the public.

Citizen surveys and mental maps to identify potential need for action. Both citizen surveys and the mental map method complement the ESS assessment method, and contribute to the identification of hot spots in order to derive needs for action for inappropriate measures in the open space. To capture citizens' perspectives on heat adaptation in the two neighborhoods, passers-by were surveyed and mental maps were created during the summer months of 2018 (Baldin and Sinning 2019a, b). Participants identified hot as well as cool places and paths on a map of the neighborhood. The mental maps helped to survey subjectively perceived heat hot spots (Baldin and Sinning 2019c). Especially the positioning of the hot spots points out priorities of need for action from citizens' perspective. The results of the citizen surveys in Dresden and Erfurt reveal how citizens deal with the heat in their daily routine, what kind of places in their neighborhood are relevant hot spots and what kind of measures they prefer for protecting themselves against heat stress. Subsequently, based on the surveys, scientists are able to identify measures of priority from citizens' point of view.

Combining the knowledge from the assessment methods described above, the results show a great need for more green spaces, shading of paths and areas where people spend time outdoors, for example by means of street trees, including ensuring their irrigation during hot periods. On this basis, the adaptation measures were prioritized for implementation in open spaces during and after the project period.

6.4.2 Implementation of Measures in Green Spaces

During the HeatResilientCity project, some adaptation measures were implemented in open spaces, especially green spaces, in both sample quarters Dresden Gorbitz and Erfurt Oststadt with the aim of improving social-ecological resilience. All measures were developed mainly to adapt to summer heat, always taking into account that water supply is essential for vegetation. This means that vegetation must also be able to withstand prolonged periods of drought. The ESS climate

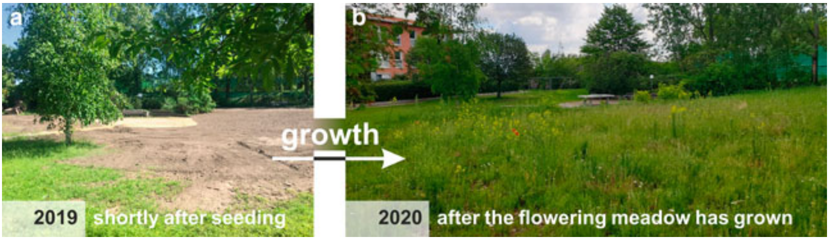

Fig. 6.4 Unused soccer ball playground in the sample quarter Dresden Gorbitz at two points in time after unsealing: **a**) with fresh seeding and **b**) grown extensive greenery (HRC 2020). Photographs: **a)** I. Fanghänel, Dresden Environmental Agency, 2019 and **b**) K. Brüggemann, Dresden Environmental Agency, 2020. Graphics: R.Ortlepp, IOER

regulation effect was usually in the foreground, but at the same time, multi-functionality was also aimed for, such as simultaneously increasing biodiversity or recreational quality.

Unsealing of a former soccer ball playground. In 2019, an unused, partially sealed soccer ball playground was unsealed in the sample quarter Dresden Gorbitz. The project partner EWG deconstructed the soccer ball playground at the edge of the "Kräutersiedlung" (herbs estate) and transformed it into a meadow area (Fig. 6.4a). Thus, the disturbed (grey) state of the sealed area was removed, and the area was transformed into a new (green) initial state that enables it to regenerate and restore its ESS function. The unsealed area is now used as an extensively maintained green space, so-called long cut area (Fig. 6.4b).

Extensively maintained green areas are mowed a maximum of 2 times a year, with the first mowing as late in the year as possible. As a rule, specific seed mixtures are not used. Rather, the meadow is left to its own devices, so that site-adapted species settle by themselves over time. Conversion should therefore be seen as a process that takes place over several years. Contiguous, larger areas that are less heavily used are suitable for extensive revegetation. laundry or playgrounds are therefore rather unsuitable.

The former soccer ball playground is a larger contiguous area well suited for extensive greening. Before the intervention, discussions took place between EWG, the Dresden Office for Urban Greenery and Waste Management, and staff from the HeatResilientCity project. Details of the seed mixture, sowing and mowing were discussed in order to promote a biodiverse meadow as rich in species as possible.

Extensification of green spaces. On extensively maintained meadows in the city, plants and animals that are displaced from more or less monotonous landscapes find valuable retreats. These extensive green spaces or long-cut meadows are also not fertilized or treated with pesticides. Flowering plants and herbs can develop, providing food for many insects such as bees and butterflies. This increases biodiversity in cities such as Dresden.

On the initiative of the HRC project team, some intensively maintained green areas of the state capital Dresden and the EWG were also converted to extensive mowing. This is intended to promote the biodiversity of plants and animals in the example neighborhood of Dresden Gorbitz, thereby providing a greater food supply for insects and bees in particular. The preferences of the inhabitants of the sample district were taken into account when deciding which areas should be extensified as a matter of priority. The selection of the areas is based, among other things, on the comments of citizens, which were collected during the surveys. On this basis, for example, the EWG is currently planning to create another flowering meadow in the "Stadtblickpark".

The long grasses of the extensive green spaces develop a positive micro-climatic effect. They delay the soil from drying out quickly. Thus, short dry periods can be better survived, and the positive effect of plant greenery on human well-being is maintained. Finally, the residential environment is to be upgraded by transforming monotonous lawns into flowering meadows. The people of the sample quarter Dresden Gorbitz can now experience the diversity and changeability of nature right on their doorstep. In this way we increase the resilience not only of the green areas but also of the people living in the neighborhood.

6.4.3 Planned Implementation of Heat Resilient Tram and Bus Stops

Another planned intervention explicitly targets human resilience by reducing heat stress at streetcar and bus stops. The need for action to reduce heat stress at public transport stops became clear in opinion surveys and temperature measurements. As early as 2017, 89% of Dresden citizens stated in the survey (LHD 2017) on climate change that they would like to see more shading at streetcar and bus stops. In July and August 2018, a survey of passers-by in Dresden Gorbitz revealed a similar picture: almost 80% of respondents rated the shading of streetcar and bus stops as a meaningful measure to reduce heat stress on hot days, and 50% were of the opinion that there should be more green and shaded shelters. Measurements of air temperature in August 2018 at several bus stops in Dresden Gorbitz showed that the air temperature under glazed shelters was mostly above the temperature measured outside in direct sunlight, while shaded areas outside the shelters were up to about four degrees cooler.

Based on the need for action identified, the pilot project "Heat-adapted public transport stop" was launched. As part of the first planning phase, a planning evaluation of heat adaptation measures was carried out taking into account various boundary conditions for five stops located in the project area. Various possible planning approaches and ideas were developed for the selected stops, integrating the existing structure and taking local conditions into account. In July 2019, the solutions developed were presented to the DVB and authorities involved. The "Julius-Vahlteich-Straße" stop was then selected as the implementation site for the pilot project with Dresden's public transport operator DVB AG. As part of the pilot project, various modules such as green roofs, pergolas, green railings and tree plantings are to be installed and evaluated in terms of effect, maintenance requirements and people's involvement and acceptance. The greening measures are intended to create shaded areas and thus improve the quality of stay in hot weather.

In the course of further planning and implementation, citizen participation took place from May to June 2020 in the form of an online survey on the participation portal Saxony. Respondents particularly favor planting trees, shrubs or hedges, and green roof shelters. Questions from people that arose during the online participation process were answered by project participants and compiled in the document "Hotter, hotter, stop? – Questions & Answers" (Großmann et al. 2020a, b). The response to the online survey with regard to the planning status to date was very positive (ca. 1200 participants overall), so that all project participants feel that their work has been essentially confirmed. About 85% of the participators feel very much or much affected of heat stress at tram and bus stops. A report of results was written specifically for the citizens, providing them with a comprehensive understanding of the results (Großmann et al. 2020a, b).

Concluding, the overall concept of the greened stop must have sufficient technical and ecological resilience to have a long-term and thus sustainable heat stress reducing effect for users. For this reason, it is imperative that an appropriate choice of species be made for the planting. It should also be possible to store rainwater on site and use it for irrigation. In addition to the ecological boundary conditions, other important aspects must be taken into account, some of which may lead to trade-offs with heat adaptation. These are, for example, aspects of crime prevention such as social control and visibility, which should be taken into account in the greening of rear and side walls. Handicapped-accessible design, the guarantee of bird protection as well as accessibility for cleaning work are further preconditions.

6.4.4 Implementation of City Tree Planting

Under the leadership of the Erfurt Environment and Nature Conservation Office as a partner in the HeatResilientCity project, the opportunity is being taken in synergy with the "Erfurt Urban Greening Concept in Climate Change" to improve conditions and initiate more tree planting in Erfurt Oststadt. 38 trees of climate-adapted tree species and numerous medium–high shrubs will be planted. The partners from the Environmental and Nature Conservation Office are coordinating these plantings with other adaptation measures in open spaces in the city of Erfurt. The existing tree population is suffering due to poor site conditions and high use pressure. Many trees have had to be felled in the past due to dieback and disease or pest infestation. Nevertheless, replanting has often been rejected due to the line stock and minimum distances to be maintained.

The technical infrastructure with its above-ground and underground media means considerable impacts on and restrictions of the crown and root space for urban trees. Due to the large number of different lines, the underground construction space is densely occupied. However, having sufficient above and below ground habitat available to anchor and provide water, air and nutrients is important for the survival of urban trees. With the changing climate conditions due to increasing heat and drought stress in particular, the already difficult habitat conditions of urban trees are further deteriorating. Thus, the planted trees and shrubs should be adapted to the future climatic requirements such as prolonged heat and drought stress or cold stress as well as to the conditions caused by the technical infrastructures such as drinking water and sewer pipelines or electrical and telecommunication lines.

Numerous internal consultations, inspections for stocktaking and on-site meetings with the utilities were carried out in order to find solutions and compromises. Furthermore, new framework agreements were drawn up between the city administration and the pipeline operators in order to allow replacement plantings to be increased again. The Office of Civil Engineering and Transportation performed this coordinative task.

The new plantings and replacement plantings in Erfurt Oststadt began in the fall of 2020 and are currently ongoing. Since the underground construction space is limited, the root pits have to adapt to the local conditions and were individually adapted for each location. The underground root space extensions extend as root

Fig. 6.5 Newly planted tree on Schlachthofstraße in Erfurt Oststadt. Photograph: G. Spohr, UNA Erfurt, 2020. Graphics: R. Ortlepp, IOER

trenches and are supplied with oxygen by aeration rods. Above ground, the open soil area around the tree and the aeration openings remain visible. The soil around the tree is covered with mineral mulch, which protects this area from compaction and silting (Fig. 6.5, right). At some locations, tree planting was not possible despite compromises due to the existing pipeline. Thus, large shrubs are used to green these areas instead.

The plantings identified here are part of the measures to contain overheating within the urban area. In the selection of tree species, emphasis was placed on species diversity and adapted climate trees, always taking into account the existing tree population (Fig. 6.5, left).

6.4.5 Implementation of Civic Watering Initiative for City Trees

Hot summers like those in recent years and long dry periods without sufficient rainfall take their toll on the approximately 90,000 trees in Erfurt. The city of Erfurt currently waters around 2,000 of these trees, 300 of which—especially the young ones—receive their elixir of life by means of irrigation bags. In addition to the birch trees, the maples, lime trees and hackberry trees in Erfurt's Oststadt are now also showing signs of deterioration due to the constant heat and drought of recent years. To counteract the situation, for years committed citizens have voluntarily cared for the well-being of trees by watering them during prolonged periods of drought. Forced by the activities of the HeatResilientCity research team, more voluntary maintenance contracts for urban trees have been taken over by citizens in Erfurt's Oststadt. A majority of 99% of 750 interviewees agreed to plant additional trees, more than half of the interviewees had interest in taking over maintenance contracts including maintenance of a tree and its tree pit on the one hand and for watering on the other hand (Großmann and Sinning 2020a, b, pp. 7, 20).

In order to further strengthen civic engagement for the city's trees, the HeatResilientCity partner Lagune e. V. came up with the idea of getting Erfurt schools involved in a tree watering project. The Thomas Mann School in Erfurt's Oststadt was the first to participate in the watering project. The irrigation bags are usually placed in pairs around the tree in spring. They are filled through a small slit, allowing water to percolate into the bale for 5 to 8 h. In the eastern part of the city, pupils from the Thomas Mann School will take on watering partnerships for the trees in their school environment. In the meantime, the pupils get support from the inhabitants of the neighborhood.

Resilience of urban greenery such as trees and shrubs can therefore not only be generated by selecting adapted species when planting new trees. It is possible to build resilience by adding human action, that is, targeted care and maintenance. In combination with civic engagement, it becomes possible to increase the ecological resilience of the originally low resilient, heat and drought susceptible trees.

6.4.6 Restricting and Inhibiting Factors of Planning and Implementing Climate Adaptation Measures

As described, there are several inhibiting factors for fostering heat adaptation for green spaces. The example of planting trees in streets has shown the far-reaching costs of doing so, as old tree roots have to be removed and existing infrastructure lines have to be managed underground. The main obstacles to green infrastructure are often land use conflicts with housing and mobility infrastructures, which restrict the availability of land that can be used for cooling the city. Urban development visions such as density or redensification are still seen as competing with green and cool cities, even though the concept of "Doppelte Innenentwicklung", that is providing residential density and green qualities in a synergetic approach, offers an integrative solution. Furthermore, there is a lack of political steering for heat-resistant cities, housing and land use.

Other inhibiting factors for climate adaptation that limit the implementation of concepts and measures in open spaces are an inadequate knowledge base or sensitivity for the issue, deficits in cross-departmental cooperation, lack of incentives for private landlords or renters, lack of personnel or financial resources in municipal budgets for climate adaptation and subsequently for the maintenance of green infrastructure. However, there are substantial differences between stakeholders in the extent to which maintenance costs for urban green space are justified or assessed as high or low respectively, often depending on the value they ascribe to urban green. Furthermore, implicit and explicit incentives, e.g. public funding and challenges for measures such as green roofs and facades, are still hardly developed in many cities to motivate stakeholders and citizens.

Another restricting aspect is the lack of control and monitoring in the implementation of measures that are mandatory and regulated in local zoning and statutes. This is due to a lack of financial and personnel resources of the local planning administration and municipal budgets as a whole (Baldin and Sinning 2021).

6.5 Conclusions

In this chapter, resilience building in relation to summer heat was demonstrated at different levels using concrete examples of implementation. Based on the knowledge integration in the inter- and transdisciplinary joint project HeatResilientCity, needs for action for the adaptation of buildings and open spaces were derived and adaptation measures to summer heat were implemented as practical examples. Local stakeholders, who were involved as partners in the project, enabled the implementation of the adaptation measures during the project period. For example, the housing cooperative EWG physically implemented a number of adaptation measures recommended by the HeatResilientCity project in its building stock, and the state capital of Erfurt facilitated implementation measures in open spaces, for example in the form of new and replacement plantings of trees and shrubs.

Ensuring human well-being plays a central role in the development of climate change adaptation measures, both at the neighborhood level and at smaller scales such as green spaces, buildings and building services. The various measures are aimed in part at different types of resilience, although the socio-ecological aspect is in the foreground from an overarching perspective. For citizens as inhabitants of the sample quarters in Dresden Gorbitz and Erfurt Oststadt, resilience is built by the interplay of resilience-building measures in individual subsystems of the overall urban neighborhood system.

During the implementation of measures, besides many specific aspects to individual technical measures, a number of general restrictions and obstacles were identified that contribute to the broader discussion on climate adaptation in cities. The case studies identified insufficiencies in the current political standing of climate adaptation and implementation strategies, their integration into administrative tasks and routines, especially in relation to the cross-departmental, collaborative approach of planning and implementing adaptation measures. Adherence to traditional urban planning principles was also identified as a major obstacle, e.g. monument preservation in Dresden Gorbitz, which does not correlate with climate adaptation to urban heat, furthermore high costs for climate adaptation measures due to complex planning requirements, e.g. planting trees in streets where the existing technical infrastructure causes expenses.

In the case of others, such as the "Gründerzeitgebäude" (Wilhelminian-style apartment building) in Erfurt Oststadt, the hurdles were too high to be overcome during the project period. The forces were then bundled into the implementation of measures in Erfurt's open spaces. It has been shown that the specific constellation of actors, independent of the technical concept and effectiveness, has a very large influence on the implementability of adaptation measures. This means that a particular adaptation concept that fails in one place may well have a chance of being implemented in another, if the actors involved have a corresponding awareness of the problem.

As has become increasingly apparent in the course of implementation in cooperation with the partners of the state capitals, one of the main reasons for the overall weak standing of climate adaptation is still the lack of a compulsory character and the low level of commitment in the municipal decision-making process compared to other sectors. Key recommendations derived from the HeatResilientCity research are therefore to increase awareness and sensitivity for the relevance of the issue in city administration and politics, e.g. by providing information and qualification measures. Additional financial and personnel resources are also necessary to manage the challenge and implement concepts and concrete measures. Furthermore, climate adaptation needs to be defined as a mandatory municipal task with clear responsibilities in the administrative structure. Besides, existing planning instruments (e.g. parking regulations, garden and greening statutes) that set binding framework conditions could be used more effectively to strengthen climate adaptation.

To strengthen climate adaptation in the political and administrative hierarchy, engaged promoters at the top levels are necessary. The ambitions of those enablers should be supported by consequent monitoring and controlling of the implementation of measures. Homeowners and the housing industry could be motivated to overcome implementation barriers by offering financial incentives, information and advice. Furthermore, multifunctional adaptation measures and so-called no-regret measures, especially with regard to extreme events such as heat waves or heavy rain events, represent intelligent strategies.

Finally, HeatResilientCity research has shown that knowledge integration through citizen involvement is beneficial in prioritizing measures at the local level, as citizen knowledge very often complements the experts' perspectives. This underlines the participatory approach of local climate adaptation, which has been successfully demonstrated by the urban living lab experiences of the HeatResilientCity research. Newly generated knowledge from the citizen surveys and the participatory workshops has supported the implementation process and produced transformative knowledge that is beneficial for the local adaptation process towards heat resilience. In summary, it can be stated that providing resilience for buildings and open spaces, and by actively involving citizens and stakeholders, creates resilience for the people living there and for the entire urban neighborhood.

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References

Armson, D., Stringer, P., & Ennos, A. R. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening, 11*(3), 245–255. https://doi.org/10.1016/j.ufug.2012.05.002

Baldin, M.-L., & Sinning, H. (2019a). Ergebnisbericht zur Befragung 2018 in Dresden. *ISP-Schriftenreihe*, Bd. 13. https://www.db-thueringen.de/receive/dbt_mods_00046114. Accessed 18 Jan 2021.

Baldin, M.-L., & Sinning, H. (2019b). Ergebnisbericht zur Befragung 2018 in Erfurt. *ISP-Schriftenreihe*, Bd. 14. https://www.db-thueringen.de/receive/dbt_mods_00045614. Accessed 18 Jan 2021.

Baldin, M.-L., & Sinning, H. (2019c). Hitzeresiliente Städte und Quartiere. Sichtweisen von Bewohnern und Experten zur urbanen Transformation in Erfurt und Dresden. *vhw FWS 5* September–Oktober 2019, 244–250. https://www.vhw.de/fileadmin/user_upload/08_publikationen/verbandszeitschrift/FWS/2019/5_2019/FWS_5_19_Baldin_Sinning.pdf. Accessed 18 Jan 2021.

Baldin, M.-L., & Sinning, H. (2021). Hitzeresiliente Städte – warum gelingt die Umsetzung nicht? Governanceanalyse zu Umsetzungs- und Kommunikationsdefiziten am Beispiel Dresden und Erfurt. *disP - The Planning Review* (forthcoming).

Bastian, O., Grunewald, K., & Syrbe. R.-U. (2013). Kapitel 3.2 Klassifikation von ÖSD. In Grunewald, K., Bastian, O. (Eds.), *Ökosystemdienstleistungen. Konzept, Methoden und Fallbeispiele* (p. 48–56). Berlin. Springer Spektrum.

BBK – Bundesamt für Bevölkerungsschutz und Katastrophenhilfe. (2013). *Abschätzung der Verwundbarkeit von Bevölkerung und Kritischen Infrastrukturen gegenüber Hitzewellen und Starkregen. Praxis im Bevölkerungsschutz.* Bonn: BBK.

Benz, A. (2007). Multilevel governance. In Benz, A., Lutz, S., Schimank, U., & Simonis, G. (Eds.), *Handbuch Governance: Theoretische Grundlagen und empirische Anwendungsfelder* (p. 297–310). Wiesbaden: Springer VS. https://doi.org/10.1007/978-3-531-90407-8_22.

Bolund, P., & Hunhammer, S. (1999). Ecosystem services in urban areas. *Ecological Economics, 29*, 293–301. https://doi.org/10.1016/S0921-8009(99)00013-0

Bulkeley, H., Marvin, S., Palgan, Y. V., McCormick, K., Breitfuss-Loidl, M., Mai, L., von Wirth, T., & Frantzeskaki, N. (2019). Urban living laboratories: Conducting the experimental city? *European Urban and Regional Studies, 26*(4), 317–335. https://doi.org/10.1177/0969776418787222

Burkhard, B., Kandziora, M., Hou, Y., & Müller, F. (2014). Mapping ecosystem service supply, demand and budgets. *Ecological Indicators, 21*, 17–29

Davoudi, S. (2018). Just Resilience. *City & Community, 17*(1), 3–7

Dimoudi, A., & Nikolopoulou, M. (2003). Vegetation in urban environment: Microclimatic analysis and benifits. *Energy and Buildings, 35*, 69–76. https://doi.org/10.1016/S0378-7788(02)00081-6.

DIN 4108-2:2013-02. Wärmeschutz und Energie-Einsparung in Gebäuden – Teil 2: Mindestanforderungen an den Wärmeschutz [Thermal protection and energy economy in buildings – Part 2: Minimum requirements to thermal insulation], 2013-02.

Energieeinsparverordnung (EnEV). (2016). Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden. Stand: Zuletzt geändert durch Art. 3 V vom 24.10.2015 I 1789.

EPA. (2016). Climate change and extreme heat: What you can do to prepare. EPA 430-R-16-061. U.S. Environmental Protection Agency (EPA). www.epa.gov/climatechange/extreme-heat-guidebook. Accessed: 20 Dec 2020.

Erneuerbare-Energien-Wärmegesetz (EEWärmeG) vom 7. August 2008 (BGBl. I S. 1658), das zuletzt durch Artikel 9 des Gesetzes vom 20. Oktober 2015 (BGBl. IS. 1722) geändert worden ist.

Evans, J. (2016). Trials and tribulations: Problematizing the city through/as urban experimentation: Trials and tribulations. *Geography Compass, 10,* 429–443. https://doi.org/10.1111/gec3.12280.

Folke, F. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change, 16*(3), 253–267

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., & Holling, C. S. (2004). Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics, 35*(1), 557–581

Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Urban experimentation & sustainability transitions. *European Planning Studies, 27*, 219–228. https://doi.org/10.1080/09654313.2018.1532977

Gesetz zur Vereinheitlichung des Energieeinsparrechts für Gebäude und zur Änderung weiterer Gesetze vom 8. August 2020 ("Gebäudeenergiegesetz" (GEG)) (BGBl. I S. 1728, PDF). https://www.gesetze-im-internet.de/geg/.

Greiving, S., & Fleischhauer, M. (2008). Raumplanung: in Zeiten des Klimawandels wichtiger denn je! Größere Planungsflexibilität durch informelle Ansätze einer Risiko-Governance. *RaumPlanung, 137*, 61–67

Großmann, L., Sinning, H., & Brüggemann, K. (2020a). Ergebnisbericht zur Online-Befragung „Heiß, heißer, Haltestelle?". In ISP-Schriftenreihe, Band 16. https://www.fh-erfurt.de/fhe/isp/isp-schriftenreihe. (forthcoming).

Großmann, L., Sinning, H., Brüggemann, K., Meinck, J., & Reinfried, F. (2020b). Heiß, heißer, Haltestelle? – Fragen und Antworten. Ergebnisse der Online-Befragung zur Hitzeanpassung von Haltestellen in Dresden-Gorbitz. https://heatresilientcity.de/fileadmin/user_upload/heatresilientcity/files/Konzepte/Online-Befragung_Haltestellen_-_Fragen_und_Antworten.pdf. Accessed 20 Dec 2020.

Großmann, L., & Sinning, H. (2020a). Ergebnisbericht zur Intervention und Online-Befragung „Platz nehmen – auch bei Hitze": Intervention und Online-Befragung zur Hitzeanpassung des Leipziger Platzes in der Erfurter Oststadt. In ISP-Schriftenreihe, Bd. 17. https://www.fh-erfurt.de/fhe/isp/isp-schriftenreihe. (forthcoming).

Großmann, L., & Sinning, H. (2020b). „Platz nehmen – auch bei Hitze!" – Ergebnisse der Online-Befragung zur Hitzeanpassung des Leipziger Platzes in der Erfurter Oststadt. Bürgerbericht. Erfurt. https://heatresilientcity.de. Accessed 18 Jan 2021.

HRC. (2020). Maßnahmen im Freiraum: Mehr Grün im Quartier – Entsiegelung des Bolzplatzes an der Kräutersiedlung. Dresden: HeatResilientCity. https://heatresilientcity.de/umsetzung/entsiegelung/. Accessed 20 Dec 2020.

Imbery, F., Friedrich, K.,Haeseler, S. Koppe, C. Janssen, W., & Bissolli, P. (2018). Vorläufiger Rückblick auf den Sommer 2018 – eine Bilanz extremer Wetterereignisse. Offenbach: Deutscher Wetterdienst (DWD). https://www.dwd.de/DE/leistungen/besondereereignisse/temperatur/20180803_bericht_sommer2018.pdf?__blob=publicationFile&v=10. Accessed 20 Dec 2020.

IEMB – Institut für Erhaltung und Modernisierung von Bauwerken e. V. an der TU Berlin. (1997). Leitfaden für die Instandsetzung und Modernisierung von Wohngebäuden in der

Plattenbauweise. Wohnungsbauserie 70 – WBS 70 6,3t. https://www.bbr-server.de/bauarchivddr/archiv/dokumente/3-4-01-2-wohnungsbauserie-wbs-70-6-3-t.pdf.

IPCC. (2013). Climate change 2013. *The physical science basis. Contribution of working group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

IPCC. (2018). Summary for Policymakers. In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla,A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), *Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above preindustrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (p. 32). Geneva: World Meteorological Organization.

Karvonen, A., Evans, J. P. M., & van Heur, B. (2013). The politics of urban experiments: Radical change or business as usual? In M. Hodson & S. Marvin (Eds.), *After sustainable cities* (pp. 104–115). Routledge.

Karvonen, A., & van Heur, B. (2014). Urban laboratories: Experiments in reworking cities: Introduction. *International Journal of Urban and Regional Research, 38*, 379–392. https://doi.org/10.1111/1468-2427.12075.

Kjellstrom, T., Lemke, B., Otto, P. M., Hyatt, O. M., Briggs, D. J., & Freyberg, C. A. (2015-07). Heat impacts on work, Human performance, and daily life. In *Climate change and public health.* Oxford: Oxford University Press. https://doi.org/10.1093/med/9780190202453.003.0004.

Knopf, D., & Maercker, J. (2017). Untersuchung der Wärmebelastung an kommunalen Kindertagesstätten und Grundschulen der Stadt Jena. *Projektbericht, Thüringer Institut für Nachhaltigkeit und Klimaschutz (ThINK GmbH)*, Jena.

LHD. (Ed.). (2017). *Meinungsumfrage zum Klimawandel in Dresden 2017. Auswertungsbericht*. Dresden: Landeshauptstadt Dresden, Umweltamt. https://www.dresden.de/media/pdf/umwelt/Klimaumfrage_Dresden_2017_Auswertungsbericht.pdf. Accessed 20 Dec 2020.

Magistrat der Stadt Wien – Wiener Umweltschutzabteilung, Magistratsabteilung 22. (Ed.). (2015). Urban Heat Islands: Strategieplan Wien. https://www.wien.gv.at/umweltschutz/raum/pdf/uhi-strategieplan-druck.pdf.

MEA – Millenium Ecosystem Assessment. (2005). Ecosystems and human well-being. A framework for assessment – Synthesis. Washington D.C. https://www.millenniumassessment.org/documents/document.356.aspx.pdf.

Naturkapital Deutschland – TEEB DE. (2016). Ökosystemleistungen in der Stadt – Gesundheit schützen und Lebensqualität erhöhen. In Kowarik, I., Bartz, R., & Brenck, M. (eds), *TU Berlin, Helmholtz-Zentrum für Umweltforschung – UFZ*. Berlin.

Ortlepp, R., & Schiela, D. (2019). Perspectives of climate change adaptation of building areas against heat waves. *IOP Conference Series: Materials Science and Engineering, 615*(1), 2004.

Ostrom, E. (2010). A multi-scale approach to coping with climate change and other collective action problems. *Solutions 1*(2), 27–36. https://www.thesolutionsjournal.com/article/a-multi-scale-approach-to-coping-with-climate-change-and-other-collective-action-problems/ Accessed 12 Nov 2020.

Pelling, M. (2011). *Adaptation to climate change. From resilience to transformation.* London: Routledge.
Ritter, E.-H. (2007). Klimawandel — Eine Herausforderung an die Raumplanung. *Raumforschung Und Raumordnung, 65*(6), 531–538. https://doi.org/10.1007/BF03183905.
Salata, K., & Yiannakou, A. (2016). Green infrastructure and climate change adaptation. *Journal of Land Use, Mobility and Environment, 9*(1), 7–24
Schneidewind, U., & Singer-Brodowski, M. (2015). Vom experimentellen Lernen zum transformativen Experimentieren. Reallabore als Katalysator für eine lernende Gesellschaft auf dem Weg zu einer Nachhaltigen Entwicklung. *Zeitschrift für Wirtschafts- und Unternehmensethik, 16(1)*,10–23. https://doi.org/10.5771/1439-880X-2015-1-10.
Schünemann, C., Olfert, A., Schiela, D., Gruhler, K., & Ortlepp, R. (2020a). Mitigation and adaptation in multifamily housing: overheating and climate justice. *Buildings and Cities, 1*(1), 36–55.
Schünemann, C., Schiela, D., & Ortlepp, R. (2020b). Upgrading potentials of founding epoch houses for heat waves intensified by climate change. In Bien, J., Biliszczuk, J., Hawryszków, P., Hildebrand, M., Knawa-Hawryszków, M., & Sadowski, K. (Eds), *IABSE Symposium "Synergy of Culture and Civil Engineering - History and Challenges", Wroclaw, Poland,* October 7–9 (pp. 1149–1156). Zürich: IABSE.
Sinning, H. (2018). Keep cool in Australia. Hitzeresiliente Stadt- und Quartiersentwicklung in Melbourne. *RaumPlanung, 6*, 9–15
Spekat, A., & Enke, W. (2020). Regionale Klimaprojektionen für Sachsen, WMSax2.0, Bereitstellung eines Ensembles regionaler Klimaprojektionen für Sachsen. In *Schriftenreihe des Landesamtes für Umwelt, Landwirtschaft und Geologie,* 3/2020. https://nbn-resolving.org/urn:nbn:de:bsz:14-qucosa2-714942. Accessed 21 Jan 2021.
Streiling, S., & Matzarakis, A. (2003). Influence of single and small clusters of trees on the bioclimate of a city: A case study. *Journal of Arboriculture, 29*(6), 309–316
Tappeser, V., Weiss, D., & Kahlenborn, W. (2017). *Nachhaltigkeit 2.0 – Modernisierungsansätze zum Leitbild der nachhaltigen Entwicklung: Diskurs „Vulnerabilität und Resilienz".* Dessau-Roßlau: UBA.
Tervooren, S. (2015). Potenziale von Grünvolumen und Entsiegelung zur Klimaanpassung am Beispiel der Landeshauptstadt Potsdam. *AGIT – Journal für Angewandte Geoinformatik*, 1-2015. Berlin. https://gispoint.de/fileadmin/user_upload/paper_gis_open/AGIT_2015/537557037.pdf.
UN (United Nations, Department of Economic and Social Affairs, Population Division). (2019). *World urbanization prospects: The 2018 revision (ST/ESA/SER.A/420).* New York: United Nations.

7

The Impulse Project Stuttgart—Stimulating Resilient Urban Development Through Blue-Green Infrastructure

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7.1 Introduction

Southwest Germany is currently undergoing a general shift of its precipitation regime towards more winter and less summer precipitation, combined with a rise in summer days (> 25 °C) and heat days (> 30 °C) as well as increased stormwater days (> 25 mm/day) (LUBW 2017). Climate change-associated effects will become even more evident in the coming decades, highlighting the urgent need to implement resilient climate adaptation measures that have a positive and compensatory effect on the urban climate (Kuttler et al. 2017).

The droughts of 2018 and 2019 in Germany shed light on future challenges that will have to be overcome. Climate change has not only led to higher general temperatures, significantly higher drinking water demand in summer (Minke 2014) and a greater number of stormwater events, which vary locally, but also to drier air and soils (Meinert et al. 2019; Niehues 2020). This causes a problem for maintaining existing green spaces as well as for renaturing urban areas and the greening of buildings due to the required irrigation demand. At the same time, it poses a threat to greening concepts as major adaptation measures in urban areas (EEA 2020). With regard to climate change, not only do adaptation measures themselves have to be questioned, but their boundary conditions as well when it comes to resilient and sustainable urban development. That leads to the following questions:

Where does the water for irrigating cooling parks, shading trees and vertical greening come from? What are resilient and sustainable alternative water resources that can decrease and relieve the demand of drinking water? Where can alternative water resources be stored and how should they be treated?

The research and development (R&D) project INTERESS-I (Integrated Strategies for Strengthening Urban Blue-Green Infrastructures), funded by the German Ministry for Education and Research (BMBF), develops solutions to these questions. It focuses on integrated blue-green infrastructures and investigates them on multiple scales, from citywide analyses to implemented projects. One of such is the Impulse Project Stuttgart, which is located in the urban development area in the Rosenstein district. It is a compact implementation measure that was developed, designed and constructed with the goal of demonstrating how integrated blue and green infrastructures can sufficiently interact with each other while achieving synergistic effects. It highlights the interaction of alternative water resources and their nature-based treatment, flood protection in case of stormwater events, storage and provision as irrigation water for urban green areas and vertical greening and serves as a model for building resilience. The Impulse Project was completed in July 2020. Here we provide an overview of the conceptual framework, the planning and implementation, and the underlying research questions that will be answered as the R&D project progresses (www.interess-i.net).

7.2 Conceptual Framework

7.2.1 Conceptualizing and Designing Blue-green Infrastructure

In Southwest Germany, like in many parts of the world, the major direct challenges of climate change comprise heavy rainfall events, floods, local overheating, as well as heat stress and water shortage (LUBW 2017). These climate impacts are further intensified by the constant pressure of urbanization.

The present study argues that these challenges can be tackled with the realization of integrated blue-green infrastructure, exemplified by the implementation of the Impulse Project Stuttgart. In general, "blue-green infrastructure" is a network of natural and semi-natural areas, which provides important ecosystem services and considers both "blue" (water-related) and "green" (vegetative) elements, from the landscape to the building level (Brears 2018). Integrated blue-green infrastructure reflects the fact that the microclimatic performance of urban greenery and building green (green infrastructure) is enhanced when it is combined with an effective resource-oriented water management, which includes rainwater and further alternative water resources (blue infrastructure) and thus counteracts the negative consequences of climate change. Integrated blue-green infrastructure therefore entails more than just finding a green solution for a blue problem (Well and Ludwig 2020; Eisenberg et al. 2019), e.g. designing retention basins in parks for flash floods; it provides climate resilience through the combination of synergistic effects between blue and green infrastructures.

Moreover, urban green areas play an important role regarding the quality of life of the urban residents. Opportunities for local recreation, closeness to nature and quality of the residential environment are important indicators for it (Aehnelt et al. 2006; Kuckartz 2006; Deffner et al. 2020).

7.2.2 Resilience of Buildings and Building Resilience

This study deals with building resilience in its two meanings as suggested by Hutter et al. (2021). Primarily, resilience is understood as physical resilience of the built environment and the building stock. It is not limited to the concept of engineering resilience but also extends to ecosystem resilience (Folke 2006), thus focusing on constancy as well as on persistence and robustness.

Based on the underlying concept of integrated blue-green infrastructure the Impulse Project Stuttgart increases resilience in the sense that it adapts the built environment and building stock, taking into account the complex relations between the different elements of the buildings and infrastructure (Fuchs and Thaler 2018). In the case of the Impulse Project Stuttgart, the relation between the urban water cycle, urban green, buildings and their users are considered.

Building resilience in its second meaning refers to a social process. The R&D project INTERESS-I, with the Impulse Project Stuttgart as a practical component, stimulates knowledge integration and learning and builds urban resilience in the sense that it increases future resilience (Coaffee et al. 2018). This is achieved by activities with various actors and groups and at several planning and design levels: First, by addressing the challenge of water shortage and urban green in discussions with local institutions; second, with the aid of conceptual designs for urban areas such as the future Rosenstein district in which the Impulse Project is situated; third, with its active promotion as a showcase, including guided tours and presentations on site and online for schools, practitioners, interested public and urban planners; finally, the concept and design process helps build resilience through learning among the involved institutions.

7.3 Project Description

7.3.1 Location, Concept and Design Process

The Impulse Project is situated in Stuttgart's largest urban development area, the future Rosenstein district. In close proximity, there are temporary accommodations for workers of the railway project Stuttgart 21, an urban gardening project (Stadtacker Wagenhallen e. V.) and the Container City, a self-organized working environment for artists. The whole area is constantly being transformed due to ongoing construction work for Stuttgart 21, which makes it a suitable environment for an urban experiment like the Impulse Project.

In order to tackle the challenges of water shortage, flood protection and overheating, three key features were selected for the design: A water supply based on alternative water resources, a combined storage and retention concept and multifunctional green spaces and surfaces. In an iterative design process, the key features were re-configured repeatedly for differing locations, which always resulted in different solutions with regard to main uses, design, technical implementation and costs (Well and Ludwig 2021). Ultimately, the integration of the container-based workers' accommodation, which in the early stages of the planning process had only been considered as a source of greywater and rainwater, led to a truly integrated blue-green infrastructure that gave the Impulse Project the character of a flagship project for urban resilience. The addition of a scaffolding in front of the workers' accommodation made it possible to install vertical greening in front of at least half of the facade, hence providing some direct benefits to vital supporters.

The project team consists of the Technical University Munich (concept, integrated planning process and stakeholder involvement), University of Kaiserslautern (greywater treatment and analyses) with the support of Dr. Bruch and Partner, University of Stuttgart (water storage, stormwater retention and modelling) and Helix Pflanzen GmbH (vertical greening and irrigation). The architectural design was conducted by the office of Daniel Schönle Architecture and Urban Planning. The overall process also included the local stakeholders ARGE Tunnel Cannstatt 21 (workers accommodation), Kunstverein Wagenhalle e. V. and Stadtacker Wagenhallen e. V who have supported the idea and the implementation of the Impulse Project from the beginning.

7.3.2 Configuration and Functionality

The nature of the Impulse Project as a time-limited intervention made it necessary to find a temporary and mobile solution. Therefore, it consists of two standard container frames: one of which contains water storage tanks and is covered by a wooden deck, while the other comprises an integrated vertical-flow constructed wetland (VFCW), as well as a laboratory and control room. In addition, an above-ground cistern for storing rain water and stormwater retention, as well as three vertical greening systems, temporarily fixed to scaffolding and wooden walkways, complete the Impulse Project. The two containers technically and design-wise represent the integrating component of the Impulse Project, where multifunctional water treatment and water supply come together in a multifunctional open space as depicted in Fig. 7.1.

As a continuous water source, water from bathrooms (showers, washing basins), so called light greywater, is collected separately from the workers' accommodation, treated in the container-based vertical-flow constructed wetland and further disinfected in the storage tanks. Rainwater is stored as a discontinuous resource in the above-ground retention cistern. The two alternative water resources

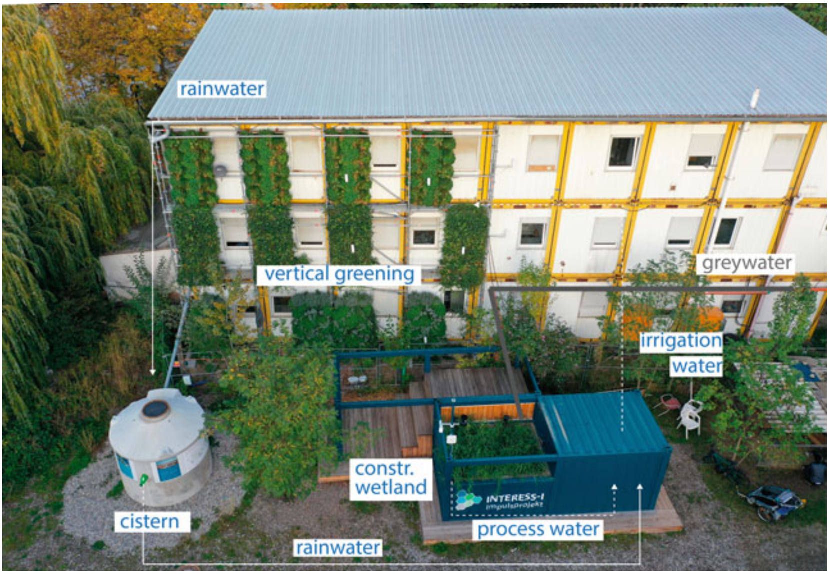

Fig. 7.1 Birds eye view of the Impulse Project (Photo: B. Eisenberg)

can be mixed on demand in the irrigation tank and can be used for watering the vertical greening modules, which partly cover the building. Fig. 7.1 displays the site from a bird's eye view: the workers accommodation, the vertical greening elements, the reinforced concrete cistern—which also serves as an advertising column for the project—as well as the two container modules. The changing pattern of the vertical greening is due to divergent facade design.

7.3.3 Water Flow, Storage and Irrigation

The alternative water resources—rainwater and treated greywater—are used to irrigate the vertical greening. The aim is to save valuable drinking water, while providing a nearly continuous supply of high-quality irrigation water. In the case of discontinuously produced water resources, such as rainwater, water storage is essential to ensure that irrigation needs are also met during dry periods. However, space is generally limited in densely populated areas, and rapidly changing precipitation regimes further aggravate this problem. Greywater, on the other hand, is generated almost continuously, thus securing sufficient water supply by providing a minimum water flow even during prolonged drought periods.

The storage units are central to the water concept. For rainwater from rooftop catchments, the retention cistern with a storage volume of 7 m^3 and a further 4 m^3 retention volume was added for heavy rain events with throttled discharge. The ratio between storage and retention volume was calculated based on the roof size of 120 m^2 and 10 year precipitation data. In the event of heavy rainfall, the retention volume fills up completely, while the additional water is discharged with a considerable delay, relieving the drainage and wastewater treatment infrastructures and ultimately the waterbodies as well (Kim et al. 2015; Meyer et al. 2008).

The storage tanks for greywater and treated greywater are considerably smaller (2 m^3 each) and are situated within one of the two container frames, covered by a wooden deck, as can be inferred from Fig. 7.1. The irrigation tank stores up to 1 m^3 water, which lasts for approx. six days during summer and is located within the control room.

The data gathered from the Impulse Project will be further used to validate a calculation model for water collection, storage and supply (ESB-model) that is being developed within the R&D project. The model aims to serve as a decision support tool for the implementation of integrated blue-green infrastructure. It is intended to determine an optimized storage volume under given boundary conditions (water availability, water demand, climate change effects etc.) in order to secure the future water supply of green infrastructure. Furthermore, the ESB-model aims to contribute to flood prevention, in particular by determining the required retention volume for rainwater in addition to the storage volume, and at the same time is expected to limit the discharge to the sewer system in the event of heavy rainfall. It can be employed to upscale research findings and is at the center of further research.

7.3.4 Greywater Treatment

For rainwater collected from the roof of the workers' accommodation, no further treatment is required. For the treatment of light greywater from showers and washing basins, a vertical-flow constructed wetland with a total area of 5 m^2 was built and integrated into one of the containers, as can be seen in Fig. 7.2. Horizontal or vertical-flow constructed wetlands are typically filled with sand and gravel filter material and planted with reed plants (helophytes) (DWA-A 262 2017). In

Fig. 7.2 Constructed wetland at the beginning of infiltration with light greywater (left) and after three months (right). (Photos: J. Rettig)

the Impulse Project, the constructed wetland system consists of two compartments, which differ in the filter layer type: One compartment consists of 75 cm Rhine sand (0–2 mm) and the second of 75 cm lava sand (0–4 mm). In each case, a 25 cm deep layer of gravel (2–8 mm) was used as drainage. Both compartments are planted with reed.

The greywater is collected directly from shower and washing basin outlets in the workers' accommodation and routed to the greywater storage tanks. A sieve then removes coarse particles. Altogether approx. 400 L of greywater are pumped per day into the two compartments in intervals of 4 h. After percolating through the sand filter, the treated greywater is pumped into a second storage tank where it is disinfected by UV immersion emitters. During operation, the pH value, electrical conductivity and redox potential are continuously recorded in both raw and treated greywater. Treatment efficiency of relevant wastewater and irrigation water parameters—chemical oxygen demand (COD), N_{tot}, P_{tot}, NH_4-N, NO_3-N PO_4-P, salts, ions, surfactants etc.—is analysed on a regular basis. In addition, micropollutants and hygiene parameters will be investigated in order to guarantee high water quality.

Regarding greywater treatment the main research questions are: How efficient is the cleaning performance of the vertical-flow constructed wetland and how does it vary with the substrate choice and the flow rate? Is an on-demand greywater treatment feasible, in the sense that, if required, nutrients can be removed (winter) or left to remain (summer) in the irrigation water?

7.3.5 Urban Greening

Maintaining urban greenery and expanding vegetation cover in cities helps mitigate heat island effects and enhance the quality of stay in open spaces as well as in buildings (BMUB, 2017). The design process of the Impulse Project led to the integration of two types of urban greenery that are both able to tackle urgent challenges. In urban areas, planners face high competition regarding the best possible use of an urban space; therefore, multiple uses play an important role. Figure 7.2 shows the constructed wetland during start-up with greywater and after being in operation for three months. The reed rhizomes were planted in February of the same year and were continuously watered with rainwater from March to June. The transformation of the constructed wetland from a technical system to an urban green element with a dense reed cover is evident in Fig. 7.2 and highlight the multifunctionality of nature-based treatment solutions: greywater treatment, aesthetic value and intrinsic microclimate effects.

With regard to multifunctionality, the use building greening represents a complementary option for greening measures. Green roofs and facade greening are both suitable, yet the Impulse Project is only characterized by vertical green surfaces, as the statics of the building did not allow for the construction of green roofs. Facade greening and other vertical greening systems present multiple benefits for the urban microclimate. They change the level and intensity of radiation on surfaces, while having a cooling effect through evapotranspiration and, depending on the system, can insulate or shade facades, thereby generating positive effects for the inhabitants (Schmauck, 2019).

Fig. 7.3 Vertical greening of the Impulse Project Stuttgart, instant effect, due to pre-cultivation. (Photos: J. Rettig)

The Impulse Project includes three different vertical greening systems with 12 elements in total (approx. 40 m^2) in front of the building facade. Each element is 1.2 m wide and 2.0 to 2.4 m high. For all systems, the vegetation cover was pre-cultivated.

On the ground floor, there is a 40 cm deep, free-standing vertical greening element planted with ivy, geranium and lavender. On the second floor, a system consisting of a planter and a trellis was installed, which is covered with ivy and clematis. On the 3rd floor, a living wall (vertical garden) was installed and fixed to the rear part of the scaffolding. It hosts eight different plant species that are rooted in a very thin layer of substrate. While the lower system usually serves as a noise barrier and is placed on the ground, the two upper systems are intended for building integration. After all technical components were set up and extensively tested in 2020, in the course of 2021 the complete irrigation scheme will be executed: three out of the four elements per system will be irrigated with alternative water resources; for control reasons, the remaining elements will be irrigated with drinking water.

The research questions linked to the greening measures are: Is the treated greywater suitable for irrigation? Does it provide the plants with sufficient nutrients in adequate ratios? How much water do the three vertical greening systems require? How do the three systems and the constructed wetland perform with regard to the micro-climate of the environment and the facade cooling?

7.3.6 Control and Monitoring System

Four partner institutions work together to run the Impulse Project and conduct research in the open lab at a high scientific level. This task is supported by a central control unit[1] that logs flow and level data as well as water and meteorological parameters and controls all sensors and pumps including the feeding of the constructed wetland and the mixing of rainwater and greywater in the irrigation tank. The irrigation of the green modules—including watering intervals—is fully automatized. In addition, all sensors (pH value, electrical conductivity, redox potential) are monitored continuously. A weather station captures the urban meteorological situation by measuring air temperature, relative humidity, solar radiation, wind direction and wind speed. Further sensors for relative humidity, air temperature and surface temperature are used to document thermal properties of the vertical greenery and the constructed wetland as well as the container facades. On one

[1] Control unit IRRInet Ace, software ICC Pro 5.0.

hand, the data serves to evaluate the microclimatic effects, while on the other, the results are used to validate the ESB-model.

7.4 Discussion and Transfer

7.4.1 The Impulse Project—a Showcase for Building Resilience?

The evaluation and monitoring of the Impulse Project and its performance began in 2020. Preliminary results indicate that high-quality irrigation water can be obtained while exploiting synergistic effects between blue and green infrastructures, yet more data and analyses are required to evaluate the water treatment and to assess the impacts of water quality on vertical greenings. Nevertheless, some preliminary conclusions can already be drawn.

Mobilizing alternative water resources and combining them can reduce the risk of water shortage during dry and hot periods in summer. The nearly continuous production of greywater secures water supply for irrigation during dry periods. In addition, the constructed wetland has the potential to treat greywater on-demand, while microclimatic effects can be achieved during treatment due to the nature-based character of the treatment. In addition to the quantitative aspect, the water quality plays a significant role and affects the potential use and the storage dimensioning as well. Rainwater and treated greywater have potentially adequate qualities for irrigation purposes. Moreover, rainwater is well suited to dilute further alternative water resources, e.g. groundwater drainages that are, for instance, loaded with minerals to such an extent that they can be used for irrigation purposes. In particular, the use of alternative water resources reduces the stress on the drinking water supply, especially during hot and dry periods, and thus contributes to an increased resilience of urban areas.

Furthermore, there will be an increasing number of stormwater days, with short and heavy rainfall, which will have to be managed safely away from urban areas. By providing storage volumes as part of retention cisterns, peak runoff can be captured, the sewer system relieved and flood protection strengthened.

The VFCW is a multifunctional system that treats greywater on-demand and provides cooling through evapotranspiration already during treatment. Treated greywater can then be used as a continuous complementary irrigation water source for vertical greenery, thus further promoting positive microclimatic effects and enhancing urban resilience. Additionally, constructed wetlands can be incorporated into the urban landscape design and offer aesthetic value, which, to some extent, may overcome the disputes concerning scarce urban space.

The implementation of vertical greening with pre-cultivated systems is a great asset that creates a positive micro climatic impact just after implementation. First analyses confirm that the vegetation cover has lower surface temperatures and less thermal radiation than the uncovered facade. Introducing vertical green systems as an option for urban greenery helps mitigate the problem of overheating, while not further straining urban space requirements.

There are, however, limitations and potential constraints that require consideration. Both water storing and treating facilities need space that is highly disputed in urban settings. The proposed solutions of multifunctional uses are therefore only suitable under consideration of specific boundary conditions. The COVID-19 pandemic also highlighted some vulnerabilities of the concept. Due to the lockdown measures, less workers were on site and the regular flow of greywater was reduced to some extent. However, it did not affect treatment efficiency negatively, as bacteria and plants within the VFCW can cope with less water. Indeed, resting periods are beneficial in the sense of regenerating the filter through autophagy, yet this also implies less irrigation water, which could lead to short-term water shortages. Thus, this has to be considered in the planning process heightening the need for the mobilization of further alternative water resources.

Moreover, introducing vertical greening increases the vulnerability of urban greenery, as it is very much dependent on continuous irrigation. Only if irrigation with alternative water resources, adequate both in quality and quantity, can be secured, will gains be achieved in both sustainability and resilience towards climate change-associated effects.

Overall, the Impulse Project Stuttgart exemplifies how compact blue-green infrastructure can be successfully implemented in densely populated urban spaces, thus serving as a showcase for building resilience.

7.4.2 The Impulse Project—an Impulse for Building Resilience?

The ongoing Impulse Project will not yet present a final statement about the impacts of building resilience for future developments.

Nevertheless, it addresses issues that citizens articulated in workshops about urban green development in times of climate change, which were held within the R&D project. They emphasized the need and importance of urban greenery, especially when looking at climate change and development pressure. At the same time, they were aware of the arising conflict of interests between increased greenery and its higher demand for irrigation water—especially in times of heat and drought (Deffner et al. 2020).

The Impulse Project Stuttgart is situated in the Rosenstein district, for which a framework plan is currently developed by the city of Stuttgart. In joint workshops, the R&D project team together with urban and landscape planners discuss the options for implementing integrated blue-green infrastructure in the urban development area.

Presently, the R&D project team also discusses the transfer of the Impulse Project to a new location after the funding ends. The discussions with potential users show that not only can the implemented measure consisting of cistern, containers, nature-based treatment and vertical greening be relocated, but also the whole concept of stimulating debate about integrated blue-green infrastructure through a one on one example can be implemented elsewhere.

The temporary nature of the Impulse Project as well as the experimental setting has led to observations that may promote the discussion on building urban resilience. The need to improvise, to create mobile and temporary design options based on the specific boundary conditions found in the urban development area in the Rosenstein district was initially considered to require a single-case approach. However, transition areas, from plot size to city expansions, are not an exception in the urban fabric. Two aspects of transition areas are worth considering when talking about urban resilience. First, transition areas are well suited as test sites for novel applications and measures. Second, perceiving temporality not only as a limiting factor but as a constant property of the built environment opens up new technical and design solutions, which help support the inclusion of the users' and inhabitants' needs. Moreover, modularity increases the transferability of concepts, signifying that planners can react in a more flexible way to distinct specific boundary conditions in the urban fabric.

With regard to building resilience as a social process, further research within the R&D project will assess the conditions for knowledge integration and learning.

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References

Aehnelt, R., Kühn, M., & Schütte, I. (2006). *Lebensqualität in Klein- und Mittelstädten. Monitoring im Städtekranz Berlin-Brandenburg: Vol. 6. Regio transfer: Beiträge zur anwendungsbezogenen Stadt- und Regionalforschung*. Erkner: IRS.

Brears, R. C. (2018). *Blue and green cities. The role of blue-green infrastructure in managing urban water resources*. London: Palgrave Macmillan.

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB). (2017). *Weißbuch Stadtgrün. Grün in der Stadt—Für eine lebenswerte Zukunft.* Berlin: BMUB.

Coaffee, J., Therrien, M.-C., Chelleri, L., Henstra, D., Aldrich, D. P., Mitchell, C. L., Tsenkova, S., & Rigaud, É. (2018). Urban resilience implementation: A policy challenge and research agenda for the 21st century. *Journal of Contingencies and Crisis Management, 26*, 403–410.

Deffner, J., Matthes, G., Stein, M., & Winker, M. (2020). *Ich geh' jetzt mit anderen Augen durch die Stadt. Ergebnisse von Zukunftswerkstätten zur Wahrnehmung und Bedeutung blau-grüner Infrastrukturen in Frankfurt am Main und Stuttgart: Vol. 60. ISOE-Materialien Soziale Ökologie*. Frankfurt am Main: ISOE—Institut für sozial-ökologische Forschung.

DWA-A 262. (2017). *Grundsätze für die Bemessung von Kläranlagen mit bepflanzten und unbepflanzten Filtern zur Reinigung häuslichen und kommunalen Abwassers. DWA Regelwerk Arbeitsblatt: A 262. Herausgeber: DWA Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V*. Hennef: DWA.

European Environment Agency. (2020). *Urban adaptation in Europe: How cities and towns respond to climate change.* EEA-Report 12/2020. https://doi.org/10.2800/324620

Eisenberg, B., Well, F., & Ludwig, F. (2019). Integrierte Strategien zur Stärkung blau-grüner Infrastrukturen: Verbesserung des Stadtklimas und der Aufenthaltsqualität als Maßgabe zukunftsfähiger Stadtentwicklung. *Transforming Cities, 3*, 56–59.

Folke, Carl (2006). Resilience: The Emergence of a Perspective for Social-ecological System Analyses. In: *Global Environmental Change*, Vol. 16, 253-267.

Fuchs, S., & Thaler, T. (Eds.). (2018). *Vulnerability and resilience to natural hazards.* Cambridge: Cambridge University Press.

Hutter, G., Neubert, M., & Ortlepp, R. (Eds.). (2021). *Building resilience to natural hazards in the context of climate change—knowledge integration, implementation, and learning.* Wiesbaden: Springer.

Kim, Y., Kim, T., Park, H., & Han, M. (2015). Design method for determining rainwater tank retention volumes to control runoff from building rooftops. *KSCE Journal of Civil Engineering, 19*(6), 1585–1590. https://doi.org/doi.org/10.1007/s12205-013-0269-1

Kuckartz, U. (2006): Was Lebensqualität in Deutschland ausmacht. In U. Kuckartz & A. Rheingans-Heintze (Eds.), *Trends im Umweltbewusstsein* (pp. 82–106). Wiesbaden: VS Verlag.

Kuttler W., Oßenbrügge, J., & Halbig, G. (2017). Städte. In G. Brasseur, D. Jacob, & S. Schuck Zöller (Eds.), *Klimawandel in Deutschland: Entwicklung, Folgen, Risiken und Perspektiven* (pp. 225–234). Springer Spektrum. https://doi.org/10.1007/978-3-662-50397-3_22.

LUBW Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg. (2017). *Monitoring-Bericht zum Klimaschutzgesetz Baden-Württemberg -Teil I Klimafolgen und Anpassung*. Stuttgart: Ministerium für Umwelt.

Meinert, T., Becker, A., Bissolli, P., Daßler, J., Breidenbach, N., & Ziese, M. (2019). *Ursachen und Folgen der Trockenheit in Deutschland und Europa ab Juni 2019.* Offenbach: Deutscher Wetterdienst.

Meyer, C., Rott, U., Kolb, A., & Angstenberger, L. (2008). Decentralized rainwater management Retention cisterns for relief of a rainwater retention basin. *Wasser Abfall, 10*(6), 32–36. https://doi.org/10.1007/bf03247549.

Minke, R. (2014). Prognostizierte Auswirkungen des Klimawandels auf die Wasserversorgung in Baden-Württemberg. *Zukünftige Herausforderungen für die Wasserversorgung*, 28. Trinkwasserkolloquium der Universität Stuttgart, Schriftenreihe „Stuttgarter Berichte zur Siedlungswasserwirtschaft", Band 219.

Niehues, B. (2020). DVGW-Diskurs zum Trockenjahr 2018 -Ergebnisse und Ausblick. *Sichere Trinkwasserversorgung trotz Klimawandel* -wie resilient sind unsere Systeme und wo besteht Handlungsbedarf, 32. Trinkwasserkolloquium der Universität Stuttgart, Schriftenreihe „Stuttgarter Berichte zur Siedlungswasserwirtschaft", Band 246, 20.02.2020. https://doi.org/10.18419/opus-10799.

Schmauck, S. (2019). Dach- und Fassadenbegrünung—neue Lebensräume im Siedlungsbereich Fakten. *Argumente Und Empfehlungen. Bfn-Skripten, 538*. https://doi.org/10.19217/skr538

Well, F., & Ludwig, F. (2020). Blue-green architecture: A case study analysis considering the synergetic effects of water and vegetation. *Frontiers of Architectural Research, 9*(1), 191–202. https://doi.org/10.1016/j.foar.2019.11.001

Well, F., & Ludwig, F. (2021) forthcoming. Integrated Design Strategies for blue-green Architecture.

8 Participation for Building Urban Climate Resilience? Results from Four Cities in Germany

Torsten Grothmann and Theresa Anna Michel

8.1 Introduction

Participatory and inclusive approaches especially at the local level are encouraged by international organizations, strategies and networks for adaptation to climate change (e.g., World Bank 2011; UN-HABITAT 2011), disaster risk reduction (DRR), natural hazards management and for building urban resilience (e.g., Rockefeller Foundation and Arup 2015; UNISDR 2017), although there seems to be a shift away from valuing local community input and towards promoting technological advances in the Sendai Framework for Disaster Risk Reduction (SFDRR 2015–2030) compared to earlier international strategies for DRR (de la Poterie and Baudoin 2015).

8.1.1 Expected Effects of Participation

High expectations regarding the usefulness and effectiveness of participatory approaches exist also in the scientific literature. One effect claimed in several publications on adaptation to climate change, natural hazards management and resilience is *building capacities* by participation. Publications on climate change adaptation mention participatory approaches as potentially effective for increasing

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adaptive capacities (e.g., Engle and Lemos 2010; Hobson and Niemeyer 2011; Kirkby et al. 2018). Similarly, in natural hazards research there is an assumed connection between participation and building social capacities for dealing with natural hazards (e.g., de Voogt et al. 2019; Kuhlicke et al. 2011). In resilience research, which most often defines resilience as a capacity, participatory approaches are mentioned as effective in potentially improving community capital (McEwen et al. 2018), community resilience (Hartz-Karp and Meister 2011), societal resilience (Mees et al. 2016), urban disaster resilience (Zhang et al. 2020), urban climate resilience (Tyler and Moench 2012) and resilience of social-ecological systems (Leitch et al. 2015). Often the definition of these capacities includes knowledge capacities (sometimes referred to as human capital) and network capacities (sometimes called social capital), but several publications stress these potential links between participation and knowledge or networks more explicitly. These are presented in the following.

A potential effect of participation on *learning and knowledge* is mentioned in several publications. In the literature on adaptation or resilience to climate change several authors see a potential of participation for inducing social learning (e.g., Collins and Ison 2009; Lebel et al. 2010; Tyler and Moench 2012; Uittenbroek et al. 2019), for harnessing local knowledge as well as for stimulating knowledge integration and knowledge co-production (e.g., Armitage et al. 2011; Hegger et al. 2012; Tyler and Moench 2012; Uittenbroek et al. 2019), while some authors also stress the difficulties for integrating knowledge of the participants (e.g., of practical and scientific knowledge, see Scherhaufer and Grüneis 2014). These knowledge gains can reduce informational uncertainties and by incorporating value-based knowledge can also decrease normative uncertainties, for example by drawing out different knowledge perspectives from different stakeholders (Tyler and Moench 2012) or by prioritising specific climate change impacts and adaptation actions clarifying acceptable risks (Grothmann 2011). The focus on knowledge and knowledge integration is especially prevalent in participatory climate adaptation research for bottom-up assessments of climate risks and adaptation options (e.g., Conway et al. 2019; Cvitanovic et al. 2019). Natural hazards research names potentials of participatory approaches for knowledge gains and learning as well, for example for identifying those directly impacted by the respective hazard (Mercer 2010), for knowledge sharing (de Voogt et al. 2019), enhancing knowledge and skills (Gaillard et al. 2019), or for social learning supporting co-creation of knowledge and enhancing a collective understanding of what action is needed (Murti and Mathez-Stiefel 2019).

Closely related to the arguments of building capacities and knowledge by participation is the assumed effect on *empowerment* of participants, particularly of those that lack human or power resources. Especially publications on community-based adaptation (e.g., Kirkby et al. 2018), but also other publications on adaptation or resilience to climate change (e.g., Tyler and Moench 2012; Ziervogel 2019) name participatory approaches as suitable for empowering and emancipating vulnerable or marginalized groups. Authors from natural hazards research stress the role of participatory approaches for empowerment of those without power in a society even more (e.g., Kuhlicke et al. 2011; Pavey et al. 2007; Pelling 2007).

Whereas participatory approaches for empowerment focus on engaging specific population groups (e.g., most vulnerable or marginalized), public participation approaches or stakeholder engagement procedures, which try to involve a broad range of perspectives, are assumed to have an effect on *generating legitimacy*. Legitimacy and its link to participation (e.g., by establishing acceptance of and/or support for a decision) has been the subject of publications on climate change adaptation (Few 2007; Paavola and Adger 2006; Uittenbroek et al. 2019) and natural hazards management, particularly of flood risk governance research (Alexander et al. 2018; Mees et al. 2017).

An effect of participation claimed rather rarely in the scientific literature on climate change adaptation or natural hazards management is on *behaviour and behavioural motivations* of the participants. Sometimes this link is suggested in publications on adaptive capacities and empowerment, for example Engle and Lemos (2010, p. 6) state that participation can empower participating stakeholders "to respond effectively to climate change". Moser and Pike (2015) mention that individuals involved in public engagement processes can become behaviourally involved. The German Strategy for Adaptation to Climate Change (DAS) explicitly names participatory approaches as a means "to mobilise individual initiative" of participating actors (German Federal Cabinet 2008, p. 56). In natural hazards research, Kuhlicke et al. (2011) mention a potential impact of dialogue-oriented communication, which is an essential element of participatory approaches, on behaviour and engagement. Murti and Mathez-Stiefel (2019) see social learning, which is a participatory approach, as able to strengthen the willingness for joint action.

But many publications from natural hazards research discuss the link between participation and behaviour critically when participation is used by governmental agencies for the delegation of responsibility to the local (Begg 2018) and/or individual level (Begg et al. 2018) because this responsibilisation is often accompanied neither by an increasing right to participate nor with enhanced resources

(Kuhlicke et al. 2020). Mees et al. (2016) show that public authorities in several European countries use participatory approaches in flood risk management to redistribute responsibilities to its beneficiaries (see also Moon et al. 2017; Scolobig et al. 2015). This links to ongoing discussions whether it is appropriate to delegate responsibility to private actors in adaptation to climate change (Mees 2014) and in building urban resilience (Coaffee and Lee 2016; Tierney 2015).

8.1.2 Lack of Empirical Evaluations of Participatory Approaches

Despite the many claims of positive effects of participatory approaches there is a lack of empirical evaluations of these postulated effects, particularly in Germany. Only few studies have addressed the link between participation and resilience regarding natural hazards or climate change impacts empirically, detecting mainly effects on building capacities, social networks, learning and knowledge, while there are almost no studies on the behavioural effects of participatory approaches. For example, Slinger et al. (2009) identify shifts in the preferences of citizens and scientists to favour more redundancy in flood risk management measures due to their participation in a transdisciplinary workshop on flood risk management in the Netherlands. In the Netherlands as well, McEvoy et al. (2018) evaluated different planning support tools in urban adaptation workshops and found effects on the way workshops played out and the direct outcomes that were achieved (e.g., learning effects, development of a shared understanding, types of plans developed). Due to participation, Hassenforder et al. (2015) detect an improved understanding (e.g., of irrigation impacts on poverty or of available response options to sea-level rise), capacity-building, influence on decisions and on collective action in five case studies in the Mekong basin in Southeast Asia and in eastern Africa. Wood and Glik (2013) report for a participatory disaster drill “ShakeOut” for earthquake prevention in California that it has been successful in prompting individuals to talk to others about the drill itself and about earthquake safety and preparedness. McEwen et al. (2018) show that some form of ‘Learning for resilience’ actually takes place in flood action groups in urban flood risk settings in the UK. In the UK as well, Benson et al. (2016) identify that personal and group learning outcomes were evident to varying degrees in a stakeholder participation process on flood risk management, suggesting that stakeholder participation was relatively successful. Orleans Reed et al. (2013, p. 393) claim that their “shared learning approach in the Asian Cities Climate Change Resilience Network (ACCCRN) has helped to create or strengthen networks, build appreciation for complexity and uncertainty among stakeholders, provide a space for deliberating concepts such as vulnerability and resilience, and build knowledge and capacities for stakeholders to engage and represent their own interests". In Portugal, Luis et al. (2018) show that a two-workshop intervention including issues on local and regional adaptation, policies, and engagement was successful in increasing participating stakeholders' intention of engaging in processes of planning local adaptation. On the other hand, Wamsler et al. (2020) report for five Swedish municipalities that under current conditions citizen engagement often hampers sustainable outcomes for nature-based approaches for urban climate change adaptation.

In Germany, although there have been hundreds of participatory and transdisciplinary projects and activities on flood risk management, climate change adaptation and more recently also on urban resilience, there are almost no published evaluation studies on their effects. Begg (2018) assesses local stakeholder involvement in flood risk management in England, the Netherlands and also in Germany from an environmental justice perspective and finds that participation in practice generally focuses on transferring responsibility to the local level at the expense of power. Körner and Lieberum (2014) evaluated interactive online media of the KLIMZUG project nordwest2050 by means of user surveys, but only ten respondents answered this survey limiting the significance of the results. Gottschick and Ette (2014) interviewed eight members of existing participatory networks in a sub-region of the KLIMZUG-NORD project, among other things with regard to their assessments of how steadily the respective network can provide impulses for the development of the region. Based on document analyses and interviews with persons responsible for steering the participation processes, Grothmann (2020) analysed 22 participation processes at national, regional and local levels in Germany regarding participation objectives, participants included, methods used and potentials of the participation processes to motivate adaptation action. He finds that most analysed processes aimed at the integration of knowledge and that participation gaps exist with regard to the involvement of political decision-makers, municipalities (especially smaller communities), business (especially smaller companies), civil society actors and the general population (mainly of people from lower income and educational levels, with migration backgrounds, younger people and women)—potentially limiting resilience building in these groups and the legitimacy of participation results. Nevertheless, due to the lack of impact evaluations in the analysed participation processes effects of the processes (e.g., on building capacities, learning and knowledge, empowerment, behaviour or behavioural motivations of participants) could not be assessed by Grothmann (2020).

The lack of sound empirical evaluations of participation processes in natural hazards management, climate change adaptation and resilience building is a research gap that has been named by several authors (Burton and Mustelin, 2013; Grothmann 2020; Hügel and Davies 2020; Marti et al. 2020; Moser and Pike 2015; Sarzynski 2015; Tyler and Moench 2012; Wamsler 2017; Whitmarsh et al. 2013). Hence, whether the many hopes and expectations regarding participatory processes can actually be fulfilled is largely unclear from an empirical research perspective.

8.1.3 Main Research Question and Chapter Overview

Against this background, the primary objective of this chapter is to clarify which contributions participatory processes can make to building resilience. First, we present a newly developed resilience concept aimed at categorizing more specifically potential contributions of participation to building climate resilience. Second, we apply this concept to the evaluation of participatory processes on adaptation to climate change, particularly to increasing heavy rain events, in four cities in Germany. Here we focus on the impacts of participation on participants' behaviour and its determinants (e.g., collective efficacy beliefs, perceptions of responsibility for adaptation action) to answer the question whether the expectations particularly by governmental actors on facilitating private self-protective behaviour by participatory approaches are justified. In the final part of this chapter we discuss what we can learn from our results for the use and design of participatory approaches in building urban climate resilience and which research questions need to be addressed by future research.

8.2 Resilience Concept for the Evaluation of Participation Effects

Urban climate resilience has recently been defined by Feldmeyer et al. (2019, p. 3): "The climate resilience of a city depends on the ability of its sub-systems to anticipate the consequences of extreme weather and climate change, to resist the negative consequences of these events and to recover essential functions after disturbance quickly, as well as to learn from these events and to adapt to the consequences of climate change in the short and medium term, and transform in the long term" (Feldmeyer et al. 2019, p. 3). In comparison to the well-known definition by Meerow et al. (2016) this definition also includes the ability to anticipate the consequences of extreme weather and climate change and to learn from events and impairments. The definition by Feldmeyer et al. (2019) covers all three meanings of resilience—resilience as persistence, as adaptation and as transformation—differentiated by Davoudi (2018).

8.2.1 Resilience Knowledge, Action and Network

The definition by Feldmeyer et al. (2019) forms one important basis for our climate resilience concept that distinguishes three specific dimensions or criteria—resilience knowledge, action and network—on which an effect of participation can be expected. Therefore, we focus only on resilience dimensions for which a direct effect of participatory approaches might be expected considering the publications presented in the Introduction on potential effects of participatory approaches. In addition to the definition by Feldmeyer et al. (2019) we base our climate resilience concept on various concepts and results from research on resilience, climate change adaptation research, natural hazards management and environmental psychology. Of particular importance is the differentiation of knowledge capacities, motivational capacities and network capacities in the heuristic model of social capacity building for natural hazards by Kuhlicke et al. (2011; see also de Voogt et al. 2019), which is very similar to the dimensions or criteria of climate resilience in our concept:

1. *Resilience knowledge: Risk knowledge* on potential consequences of extreme weather and climate change and *action knowledge* how to resist the negative consequences, how to recover essential functions after disturbance quickly, how to learn from consequences, how to adapt to consequences in the short and medium term, and how to transform in the long term.
2. *Resilience action and its psychological determinants*: *Actions* to resist the negative consequences of extreme weather and climate change, to recover essential functions after disturbance quickly, to learn from consequences, to adapt to consequences in the short and medium term, and to transform in the long term. Furthermore, this dimension also includes *psychological determinants* of these actions such as action motivations, risk perceptions, self-efficacy beliefs, outcome efficacy beliefs, collective efficacy beliefs, injunctive norms, descriptive norms, and perceived self and governmental responsibilities.
3. *Resilience network*: trustful relationships and cooperation *within one's actor group* and *with other actor groups*, which can be used for building resilience knowledge via social learning or for realizing resilience action. For example,

citizens that connect with citizens would build a resilience network within an actor group, citizens that connect with representatives from governmental agencies would build a resilience network with another actor group.

Knowledge is given great importance in the resilience literature. Feldmeyer et al. (2019) list "Knowledge and risk competence" as an indicator of urban climate resilience. Tyler and Moench (2012, p. 315) cite the following ability as an important aspect of urban climate resilience: "ability to identify problems, anticipate, plan and prepare for a disruptive event or organizational failure, and to respond quickly in its aftermath". Many elements of our definition of resilience knowledge can be found in this description. The distinction between risk knowledge and action knowledge as sub-criteria of resilience knowledge is based primarily on the distinction between problem knowledge and action knowledge, which is widely used in environmental psychology (cf. Steg et al. 2012) and can also be found in the distinction of "Knowledge about the hazard and the risk" and "Knowledge about how to prepare for, cope with and recover from the negative impact of a hazard" in Kuhlicke et al. (2011, p. 806). The increase in resilience knowledge can also be described as cognitive learning, which is the acquisition of factual knowledge (Huitema et al. 2010).

Conceptualising *action* or behaviour as a dimension of resilience is rather the exception and only few publications (e.g., Wilson et al. 2020) make this link between action and resilience. Most authors (e.g., Feldmeyer et al. 2019; Meerow et al. 2016; Tyler and Moench 2012) conceptualize resilience as an ability or a capacity, which is potentially expressed in actions but these actions are not part of the resilience ability. Following the logic of assessments of an ability in psychological tests, which assess the level of the ability by measuring the quantity and quality of the action that builds on this ability, we also include action already implemented as a relevant dimension of our resilience concept. In their urban climate resilience concept Feldmeyer et al. (2019) include actions (e.g., citizens that engage in honorary positions) as indicators of resilience, too. Similar to "Motivational capacities" in Kuhlicke et al. (2011, p. 806) motivations to resist, to recover, to learn, to adapt, and to transform are also included in the action dimension of our resilience concept. Different from Kuhlicke et al. (2011, p. 806), who only consider "a sense of responsibility for one's own actions but also for those of other actors" in "Motivation capacities", we include further determinants of action motivation. Comprehensive empirical research on self-protective behaviour regarding natural hazards and climate change impacts (for a recent overview see van Valkengoed and Steg 2019) show that other factors such as self-efficacy and outcome efficacy beliefs (beliefs that one can do something to self-protect and that this action is effective) as well as injunctive and descriptive norms (perceptions of an action's social approval and of what the majority of people does) exert greater influences on action motivation and actions than perceptions of responsibilities. One might argue that also knowledge, which we consider as a separate dimension in our concept, is a determining factor of action motivation and action. But empirical psychological research indicates that knowledge often has only low correlations with motivation and action: Based on their meta-analyses using data from 106 empirical studies van Valkengoed and Steg (2019) find an average correlation of only 0.14 between knowledge about climate change and climate-related hazards and adaptation action. The insight that knowledge does not necessarily lead to appropriate action is also gaining ground outside of psychology (e.g., Baird et al. 2016; Schultz and Lundholm 2010). Increase in resilience action is connected to normative learning because injunctive and descriptive norms, which are considered as determinants of resilience motivation in the resilience action dimension, often need to change so that action is taken. Normative learning describes the process of moral developments, meaning the way individuals judge about right and wrong (Lebel et al. 2010, see also McFadgen and Huitema 2016).

While the action dimension has received little attention in the resilience literature, there are many references to our third dimension, resilience *network*. Tyler and Moench (2012, p. 315) name access to "social assets such as family or clan networks" as an important condition for the resilience of actors in cities. Romero-Lankao et al. (2016, p. 11) list "actor networks" and "operating community groups" as indicators of "urban population resilience" (similarly also McMillen et al. 2016 and Ziervogel et al. 2016). Hutter and Lorenz (2018) focussing on social resilience refer mainly to teams, organizations, and networks of organizations. Elmqvist et al. (2019, p. 269) name the following properties of urban systems that promote both resilience and sustainability: "Designed (intentional) diversity, redundancy and connectivity, Cross-scale systems perspective, Polycentric and collaborative governance". Biggs et al. (2012) see shared values, trust and relationships that support collective action between actors as important prerequisites for resilience and Biggs et al. (2015, pp. VIII–X) named several principles for promoting resilience by building trust and relationships between actors: "Manage connectivity", "Broaden participation" and "Promote polycentric governance systems". The importance of networking between actors is also emphasized in the literature on adaptation to climate change. For example, Baird et al. (2014, p. 51) name "relational learning, referring to an improved understanding of others' mindsets, enhanced trust and ability to cooperate" as important for climate change adaptation. There is also large overlap between our understanding of a resilience network and social capital approaches, which are often used to assess community resilience (Ntontis et al. 2019). Our differentiation of resilience networks within one's actor group and with other actor groups is derived mainly from arguments in social capital research on the importance of horizontal and vertical social capital (e.g., Adger 2003). Natural hazards research stresses the importance of networks as well, for example Kuhlicke et al. (2011, p. 806) name "Network capacities" with reference to social capital research as important for social capacity building for natural hazards. Most authors stress the positive influence of social ties and networks on resilience, climate change adaptation or natural hazards management. Babcicky and Seebauer (2017) observe also negative effects: Strong social ties can be effective during flood response and recovery but the expectation of social support can also reduce risk perception, resulting in a situation where self-protective precautionary actions become less likely to be taken by households. The increase in resilience networks can be seen as a case of relational learning, which refers to trust building and the increase in the ability to cooperate (cf. McFadgen and Huitema 2017).

The three resilience dimensions are not independent from each other. They influence each other. For example, resilience knowledge and resilience networks exert influence on resilience action. Collective resilience action can strengthen resilience networks. Furthermore, the dimensions have some conceptual overlaps. The first dimension, resilience knowledge, is one of the psychological determinants of resilience action (although probably only with minor influence). There is also an overlap between the concept of collective efficacy beliefs, considered as a psychological determinant in the action dimension, with resilience networks. Nevertheless, the differentiation of the three dimensions or criteria provides a useful heuristic for assessing the resilience of actors and increases in their resilience.

8.2.2 Focus on Actors and Dimensions Changeable by Participation

There are several definitions of urban resilience in the scientific literature, most of which understand resilience as an ability of urban systems. Our new climate resilience concept—differentiating resilience knowledge, resilience action and resilience network—focuses on abilities of individual actors as representatives from private households, governmental agencies, business or civil society organizations. Actors (individuals and collective actors such as organizations) are seen as crucial for building urban climate resilience. Tyler and Moench (2012, p. 314) argue "The capacities of social agents therefore comprise an important part of any urban climate resilience framework" and reference literature on resilience that emphasizes the close connection between resilience and the adaptive capacity of individuals and organizations (Berkes 2007; Folke et al. 2002; Gallopin 2006). Other authors go even further and put urban actors at "the heart" of urban climate resilience (Bahadur and Tanner 2014, p. 200). There is good reason for doing so because individual and collective actors do not only influence their own resilience (e.g., by their knowledge how to behave during an extreme rain event) but also—by their decisions and actions in their private and professional contexts—the resilience of grey, green and blue urban infrastructures that are also essential for urban resilience. Furthermore, they exert influence on other actors by their networks.

The main reason for developing our resilience concept was to evaluate the effects of participatory approaches on urban climate resilience. Therefore, we focused on including resilience dimensions that can probably be influenced by participation. Consequently, the concept focuses exclusively on social subsystems or dimensions of urban systems. Other urban sub-systems and their resilience such as grey, green and blue urban infrastructures are not considered in the resilience concept. They are potentially influenced by the dimensions included in the concept (e.g., by resilience knowledge of decision makers) but they cannot be directly influenced by the participatory processes. This argumentation follows the central idea of impact evaluations that only those criteria should be measured that can be influenced by the intervention used (e.g., a participatory approach). Following the same argument that only dimensions should be included for which an effect of participation can be expected, we also did not include further individual or social capacities that are relevant for actors' resilience such as their "economic capacities" (Kuhlicke et al. 2011, p. 806) or authority resources (Grothmann et al. 2013).

8.3 Evaluation of Participatory Processes on Adaptation to Climate Change in Four Cities in Germany

The main research question addressed in this empirical part of the chapter is whether participatory events on local adaptation to climate change (mainly on avoiding damage from increasing heavy rain events) conducted in four cities in Germany (Bremen, Worms, Lübeck and Kempten) had an impact on participants' resilience knowledge, action and network. Participants were mainly citizens. Organizers, who invited to participate, were local governments in the respective cities so that we present an evaluation of the effects of *government-led* *public participation.* Among the participants from the local government mostly people from governmental administration (e.g., from the local water authority) were present, the political level (e.g., the mayor or members of the city council) was underrepresented at the participatory events.

Due to the focus on *actions to resist* the negative consequences of extreme weather and climate change (e.g., how citizens can effectively flood proof their homes) mainly changes in knowledge and actions related to this resistance to negative consequences were evaluated. The other elements of resilience knowledge and action included in our resilience concept (recover essential functions after disturbance quickly, learn from consequences, adapt to consequences in the short and medium term, transform in the long term) were not aimed at in the evaluated participatory events and it was therefore also not assessed whether there were increases in these knowledge and action areas.

Professional private contractors, who have a lot of experience in designing and carrying out participation events, designed all evaluated participatory events and moderated most events. Although the specific agendas of the different participatory events varied, all events were personal (not online events), started with presentations of potential climate change impacts in the respective city (mostly regarding flooding from an increase in heavy rain events) and then presented and discussed public and private precautionary options. All events—related to the fact that the organizers were governmental actors—had as one goal to support and to increase self-protective actions of the participating citizens. Hence, one focus of the evaluation was the resilience *action* dimension. Furthermore, all participatory processes aimed at increasing participants' risk and action knowledge so that also the resilience *knowledge* effects were assessed in all participatory processes. The increase in the resilience *network* dimension was only the objective, but a secondary one, of the participatory process in the city of Bremen so that data on the participation effects on this dimension of the resilience concept were only gathered here.

The evaluation of participatory events in the city of Bremen was part of the project *BREsilient* funded by Germany's Federal Ministry of Education and Research (BMBF). In this project several participatory processes were conducted—some of them only with local business actors, others only with representatives from city administration—but here, for reasons of comparability, we only evaluate the participatory process in Blumenthaler Aue, a small area of Bremen at risk of being flooded after heavy rain events. This participatory process consisted of a systematic series of three four-hour workshops with 22 to 44 participants owning or using buildings located in the area (see Table 8.1). These people were citizens living in the area, but also representatives from organizations using

Table 8.1 Number of participants and questionnaire response rates in evaluated participatory events

	Cooperation fair Kempten (20 June 2017)	Heavy rain fair Worms (2 December 2017)	City quarter workshop Worms (28 September 2018)	City quarter workshop 1 Lübeck (18 May 2019)	City quarter workshop 2 Lübeck (14 June 2019)	City quarter workshop 1 Bremen (27 February 2019)	City quarter workshop 2 Bremen (30 April 2019)	City quarter workshop 3 Bremen (19 June 2019)
Number of participants	44	~110[a]	~20[a]	17	20	44	22	27
Number of returned questionnaires (return rates)	27 (61%)	29 (26%)	13 (65%)	6 (35%)	11 (55%)	30 (68%)	18 (82%)	21 (78%)

[a] An exact count of the participants was not possible due to the open event formats, for which no registration was necessary and where everyone could come and go as she or he wanted.

buildings in the risk prone area (e.g., kindergarten, NGOs). The main aims for the workshop series of the city governmental actors, who were also present in the workshops, were to increase awareness for heavy rain induced flooding and to co-design and prioritize precautionary actions for preventing flood damage in the area.

The evaluation of participatory events in the cities of Worms, Lübeck and Kempten, that lasted between three and six hours, was part of the project *rain//secure (Regen//Sicher)* funded by the German Environment Agency (UBA). Like the workshop series in Blumenthaler Aue in Bremen, the participatory events in Worms and Lübeck focused on actions to prevent flood damage from heavy rain events. Participants were mainly private homeowners because one of the main objectives of the participatory processes in these cities was to support and increase self-protective behaviour from flood damage, for which homeowners have much more opportunities than tenants since they are allowed to make structural changes to their buildings. Due to recent flood events in Worms the first participatory event in this city, a "heavy rain fair", had a very large number of about 110 participants. The other evaluated participation events in Worms and Lübeck were three city quarter workshops in different city quarters with less participants (see Table 8.1). The "cooperation fair" in Kempten had the aim of initiating new collaborations between different actors (e.g., of local businesses with local civil society organizations or with the city administration) for realizing cooperative actions for adaptation to climate change. Hence, in addition to a few participants that took part as individual citizens most participants took part as representatives of local businesses, civil society organisations or of the city administration. Although the "cooperation fair" in Kempten did not focus on climate change and heavy rain events as the participatory processes in the other cities it still represents an example of public participation regarding adaptation to climate change so that we included it in our sample of events chosen to evaluate the effects of public participation on resilience knowledge, action and network of the participants.

8.3.1 Methods: Questionnaires and Indicators of Resilience Increases

Evaluation instruments were mainly standardised questionnaires filled in by the participants at the end of the participatory events. These questionnaires (in German) are available online for the rain//secure project (Born et al. 2021). Filling in the questionnaires took about five minutes. For most participatory events, questionnaire completion was included in the event programmes before the official closing remarks to increase questionnaire return rates.

The questionnaires included indicators of effects on resilience knowledge (risk and action knowledge), resilience action (also on resilience motivation and psychological action determinants such as risk perceptions and self-efficacy beliefs) and on resilience network (within and between actor groups; only in workshop series in Bremen). The specific items used for measuring these effects on the three resilience criteria are presented in the results section. The questionnaires for the evaluation of the participatory events in the rain//secure project, which focused on detecting changes on the resilience action dimension, also included indicators of the participants' current levels in psychological determinants (e.g., risk perceptions) and current levels of action motivation to check (by correlation analyses) whether and to what degree the psychological determinants found in previous psychological research (e.g., van Valkengoed and Steg 2019) also influenced the action motivation of the participants of the evaluated events. In addition, the questionnaires included process indicators for assessing the quality of the participatory events (e.g., quality of the moderation, fairness of participation) and on gathering sociodemographic data regarding the participants. Due to the focus of this chapter on participation *effects* we only present results on the indicators of increases on resilience knowledge, action and network. The response scales for measuring the participation effects regarding the three resilience criteria were Likert scales, either measuring levels of agreement for statements on personal levels and personal increases in risk perception, self-efficacy belief, action motivation etc. due to the participatory event (six levels from "totally agree" to "do not agree at all") or measuring levels of perceived changes in one's own risk perception, self-efficacy belief, action motivation etc. (five levels from "greatly increased" to „greatly decreased"). Using these multi-level response scales allowed the use of different quantitative methods in statistical data analysis, including correlation analyses.[1]

In the evaluation, each of the various indicators of changes in a resilience criterion (e.g., indicators of changes in risk knowledge and in action knowledge for assessing changes in resilience knowledge) is considered individually in order to be able to make specific statements about which resilience indicators could be

[1] Although results of correlation analyses between participants' current levels in psychological action determinants and action motivation have to be interpreted with care when applied to small sample sizes as in the present study they provide reliable indicators of existing relations between the correlated variables.

increased by the respective participatory process. Hence, different indicator values for a resilience criterion are not aggregated in one criterion value.

Questionnaire return rates were quite high for most events (see Table 8.1) probably caused by the inclusion of a time slot for questionnaire completion in the programmes before the official closing remarks in most participatory events. Only the "heavy rain fair" in Worms and the first city quarter workshop in Lübeck had return rates lower than 50%, which reduces the probability that the questionnaire results for these events are representative. Due to the low number of only six respondents for the first workshop in one city quarter of Lübeck and allowed by the use of the same workshop design in a second workshop in another city quarter of Lübeck the survey results for these two workshops in Lübeck were combined into one data set in the evaluation.

8.3.2 Results: Changes in Resilience Knowledge, Action and Network

To clarify, the following results present measurements of *relative resilience changes* due to participation. It was not the aim of the measurement to assess absolute levels of resilience knowledge, action and network among the participants so that the following results do not present an assessment of participants' level of resilience in the four respective cities.

First, we present our results on the effectiveness of the evaluated participatory events on increasing resilience knowledge and resilience networks. Second, we show the more comprehensive results on the resilience action dimension, which was the focus of the events' evaluation in the rain//secure project.

Increases in resilience knowledge due to participation. In all participatory events in the rain//secure project the questionnaires included one question on perceived personal changes in risk knowledge (e.g., on the risks of heavy rain events) regarding the respective city. Furthermore, each questionnaire included one question on perceived personal changes in action knowledge regarding knowledge about options by which one's own household or organization can adapt to climate change or prevent flood damage. For both knowledge types we could detect average increases among the participants of all participatory events in the rain//secure project (see Table 8.2). Average increases were between 0.36 and 1.07 and therefore clearly below the maximum value of 2 ("greatly increased"). Increases were particularly high in Worms, which was recently affected by damaging heavy rain events, affecting several city quarters for the first time, so that citizens had not much experience and knowledge regarding such events and how to self-protect

Table 8.2 Reported changes in risk and action knowledge due to participation

Reported changes due to participation in …	Cooperation fair Kempten	Heavy rain fair Worms	City quarter workshop Worms	City quarter workshops Lübeck
… risk knowledge about climate change impacts/flood risks due to heavy rain events in the city area	0.36	1.07	0.75	0.43
… action knowledge about options by which one's own household or organization can adapt to climate change/prevent damage from floods due to heavy rain events	0.46	1.00	0.92	0.57

Mean values of changes expressed by the participants using the following answer scale: greatly increased = 2; slightly increased = 1; not changed = 0; slightly decreased = −1; greatly decreased = −2

from them. Therefore, they obviously learned more during the participatory events than in Kempten and Lübeck. Knowledge increases in Kempten and Lübeck were lower probably because in Kempten knowledge transfer was a secondary aim of the event and in Lübeck participants were already quite knowledgeable regarding flood risks and damage prevention measures before the workshops due to centuries of experience with river flooding in the city.

To reconfirm the low correlation between knowledge and action found in previous psychological research we calculated correlations of action motivation (for adaptation to climate change/ preventing damage from heavy rain events) with risk knowledge and with action knowledge for the participants of the events in the rain//secure project. Different from expected, we found relatively high correlations: Correlations between action motivation and risk knowledge ranged from $r = 0.26$ to $r = 0.45$. Correlations between action motivation and action knowledge ranged from $r = 0.45$ to $r = 0.75$.

In the BREsilient project, the evaluations of the three city quarter workshops in Bremen (focusing on the area Blumenthaler Aue/Beckedorfer Beeke and aiming at the same participants in all workshops) included the same indicators of perceived changes in risk knowledge about the area and action knowledge about personal options for action as in the rain//secure project, but were assessed using a level of agreement response scale (from “totally agree” to “do not agree at all”). Flood risks in the area caused by heavy rain events were presented and discussed mainly in the first city quarter workshop in Bremen whereas the second workshop mainly included presentations and discussions on options for precautionary action to avoid flood damage. Hence, increases in risk knowledge were only evaluated in the first workshop und increases in action knowledge only in the second workshop.

In the first city quarter workshop in Bremen 74% of the participants agreed to the following statement: “By participating in today’s workshop, I now understand better the dangers and damage that threaten the Blumenthaler Aue / Beckedorfer Beeke due to heavy rain and flooding.” 20% of the respondents expressed that they had this knowledge already prior to the workshop. In the second workshop 50% of the participants agreed to the statement “By participating in today’s workshop, I now understand better what options I have / my organization has for heavy rain and flood prevention at the Blumenthaler Aue / Beckedorfer Beeke.” Therefore, also the workshops in Bremen were effective in increasing risk and action knowledge, but the answers also show that several participants already possessed risk knowledge prior to the workshop.

In addition to these two indicators already used in the rain//secure project several further indicators of changes in risk and action knowledge were assessed. In the first workshop, also risk knowledge increases regarding *personal* risks were assessed. 55% of the participants agreed that “By participating in today’s workshop, I now understand better what dangers and damage my private household/my organization is threatened by from heavy rain and flooding at the Blumenthaler Aue / Beckedorfer Beeke”, but 33% reported that they already had this knowledge prior to the workshop. Furthermore, successful risk knowledge *integration* was assessed and detected: 80% of the participants agreed that “At today’s workshop we managed to jointly develop new knowledge about the dangers of heavy rain at the Blumenthaler Aue / Beckedorfer Beeke”.

At the second workshop, also indicators of increase in knowledge regarding the actions of the city administration were evaluated because flood damage can be avoided by governmental as well as by private action. 67% of the participants agreed to the statement: “By participating in today’s workshop, I now understand better which strategies and measures for heavy rain and flood prevention the Bremen administration has already implemented". 74% of the participants agreed that "By participating in today's workshop, I now understand better the possibilities and limits of government measures for heavy rain and flood prevention at the Blumenthaler Aue / Beckedorfer Beeke". Particularly action knowledge *integration* could be realized at the second workshop: 89% of the participants agreed that "At today's workshop we managed to jointly develop new knowledge about heavy rain precautions at the Blumenthaler Aue / Beckedorfer Beeke".

Hence, in the BREsilient project participation proved to be effective to increase risk and action knowledge in a broader sense. Particularly for knowledge *integration* the participatory workshops in Bremen were effective since agreement rates for statements on successful integration of risk and action knowledge were the highest among the various indicators of knowledge increases.

Increases in resilience network due to participation. Changes in networks and social relations due to participation were only assessed in the city quarter workshops series in Bremen. Only those participants that took part in all three workshops were asked in the third workshop to answer the questions on network improvements. Unfortunately, there were only six respondents that took part in the whole workshop series so that the following answers are based on a very small sample. All these participants agreed to some extent, but not fully, that "By participating in the series of workshops, my trust in the state administration of Bremen has increased" (measurement of increase in resilience network between actor groups). Five respondents agreed to some extent, but also not fully to the statement "Through my participation in the workshop series, my trust in other users of the areas at the Blumenthaler Aue / Beckedorfer Beeke has increased" (measurement of increase in resilience network within actor group).

Hence, there are some indications that also resilience networks (within and between actor groups) can be improved by participatory events. Nevertheless, the empirical basis for this statement is very small. Some further evidence on network improvements due to participation give the results on improvements in collective efficacy beliefs, which are determinants of action motivations, presented in the following section.

Increases in resilience action due to participation. Measuring effects of participation on the resilience action dimension (including effects on action motivation and psychological action determinants such as efficacy beliefs and perceptions of responsibility) was the focus of the evaluations in the rain//secure project. Hence, most results presented in the following refer to the participatory events in this project.

The first main result relates to the possibility whether a participatory event can trigger behaviour. The analysis of the actions (on adaptation to climate change or preventing damage from heavy rain events) taken by the participants prior to the participation events showed that often a high proportion of the participants (between 37 and 82%, see first row of Table 8.3) had already taken action before the events and was therefore already motivated to take action. Hence, for these participants the events could not trigger adaptation or prevention behaviour because their behaviour had already been triggered before the events.

Nevertheless, the events were effective to increase action motivation of participants but mostly only among less than half of the participants (see Table 8.3). Between 27 and 83% of the participants reported that their motivation to take action for adaptation to climate change or for preventing damage from heavy rain events had increased due to their participation in the respective events. Among these people that reported increases in motivation were also people that had taken adaptation or prevention action before the events. Hence, their motivation could

Table 8.3 Actions already taken by participants prior to the events and increases in action motivation among participants

Percentage of respondents, who reported …	Cooperation fair Kempten	Heavy rain fair Worms	City quarter workshop Worms	City quarter workshops Lübeck	City quarter workshop 1 Bremen[a]
… action for adaptation to climate change/preventing damage from heavy rain events *before* participation	82%[b]	48%	46%	65%	37%
… that their action motivation increased due to participation	27%	83%	39%	47%	Not evaluated

[a]Only the answers from the first workshop in Bremen are reported here because the workshop was the first of a workshop series including partly the same participants. Hence, only the answers of the first workshop on prevention action already taken are valid indicators of action *before* participation. [b]The very high percentage of participants reporting action before the cooperation fair is probably partly due to a misunderstanding of the word "adaptation to climate change" in the questionnaire because several answers to the open question which adaptation actions participants had already taken included climate change mitigation actions for reducing greenhouse gas emissions

be further increased by the events. The very high proportion of 83% of the participants, who reported motivation increases, in the heavy rain fair in Worms can probably be explained by the combination of recent damaging heavy rain events in the city (so that people felt the urge to do something about it) and the ability of the participatory event to increase their action knowledge (see Table 8.2) as well as their self-efficacy beliefs and perceived self-responsibility to prevent private damage from heavy rain (see Table 8.4).

Table 8.4 Reported changes in psychological determinants of action motivation due to participation

Reported changes due to participation in …	Cooperation fair Kempten	Heavy rain fair Worms	City quarter workshop Worms	City quarter workshops Lübeck
… risk perceptions of being affected by climate change impacts/heavy rain events in the city area in the coming years	0.31	0.77	**0.67**	0.43
… self-efficacy belief that one's household/organization can conduct effective actions for adaptation to climate change/preventing damage from heavy rain events	0.36	0.88	0.42	**0.50**
… collective efficacy belief that by the cooperation of governmental actors (e.g., local administration) and private actors (e.g., citizens) effective actions for adaptation to climate change/preventing damage from heavy rain events are possible	**0.57**	**1.12**	**0.67**	0.17

(continued)

Table 8.4 (continued)

Reported changes due to participation in …	Cooperation fair Kempten	Heavy rain fair Worms	City quarter workshop Worms	City quarter workshops Lübeck
… perceived self-responsibility of one's household/organization to realize actions for adaptation to climate change/preventing damage from heavy rain events	0.54	**0.93**	0.45	**0.71**
… perceived governmental responsibility to realize actions for adaptation to climate change/preventing damage from heavy rain events	**0.69**	0.75	0.50	−0.64

Mean values of changes expressed by the participants using the following answer scale: greatly increased = 2; slightly increased = 1; not changed = 0; slightly decreased = -1; greatly decreased = −2; bold: two largest increases per workshop

The participatory events were also effective in causing changes in the various measured psychological determinants of motivation and action for climate change adaptation and prevention of damage from heavy rain events, which have been evaluated only in the participatory events in the rain//secure project (see Table 8.4). Average increases were between 0.17 and 1.12. Therefore, the increases were—like the increases in resilience knowledge—very much below the maximum value of 2 ("greatly increased"). Regarding changes in these psychological determinants especially two results are of particular importance: First, the participatory events often caused the highest increases in collective efficacy beliefs that by the cooperation of governmental actors (e.g., local administration) and private actors (e.g., citizens) effective actions for adaptation to climate change or preventing damage from heavy rain events are possible. For the events in Kempten and Worms the increases in these government-citizens efficacy beliefs were among the two highest increases in psychological action determinants per participatory event (see Table 8.4). These increases can also be interpreted as indicating an increase in resilience networks between actor groups because obviously trust of the participants (mainly citizens, but also representatives from local business and NGOs) in governmental actors was built during the events. Correlation analyses showed that these collective efficacy beliefs positively influenced mainly the motivation for collective behaviour: In the cooperation fair in Kempten, which focused on planning cooperative action for adaptation to climate change, the positive correlation between participants' action motivation and their government-citizens efficacy belief was very high ($r = 0.64$). Furthermore, the collective efficacy beliefs had some, but not statistically significant influence (correlations from $r = 0.1$ to $r = 0.28$) on the motivation of individual action, which was one focus of the participatory events in Worms and Lübeck that tried to support homeowners in taking self-protective action to prevent damage from heavy rain events.

The second result that seems to be of particular importance is that most evaluated participatory events increased participants' perceived self-responsibility as well as perceived governmental responsibility for taking action (see Table 8.4). All events increased the perceived self-responsibility to realize actions for adaptation to climate change or for preventing damage from heavy rain events. Obviously, the responsibilisation of private actors, which the governmental organizers of the events were partly aiming at, had worked. Not planned by the governmental organizers, the events also increased the perceived governmental responsibility for taking action among the participants in most events. Only in Lübeck perceptions of governmental responsibility decreased. Nevertheless, correlation analyses showed that—different than we expected—the responsibilisation of governmental actors for taking action reduced the motivation of the participating citizens to take actions themselves only in Kempten ($r = -0.64$) and in Lübeck ($r = -0.54$) while in Worms the responsibilisation of governmental actors had basically no impact on participants' motivation to take action themselves (heavy rain fair: $r = -0.05$; city quarter workshop: $r = 0.01$). One probable explanation for this result is that the local governmental representatives at the participatory events in Worms explicitly stressed "the joint responsibility of the local government and the citizens" in preventing damage from heavy rain events. At the events in Kempten and in Lübeck such a "joint responsibility" was not addressed so explicitly.

8.4 Discussion

The resilience concept and the empirical way of operationalising it via standardised questionnaires proved useful, not only to assess whether the evaluated participatory events were influential for amplifying participants' resilience knowledge, resilience action and resilience network but also as a useful means for monitoring progress in the participatory process and for identifying where further efforts in building resilience among the participating actors are needed.

As a result of the questionnaire-based evaluation of the increases in participating individuals' knowledge, action and networks due to participation, our operationalisation of the resilience concept was a *personal* measurement of climate resilience increases. In this respect, the operationalisation is measuring climate resilience and climate resilience increases in individuals.

By considering individuals as representatives of certain groups of actors (general population, government, business etc.) and differentiating between these groups of actors in the survey-based evaluation (preferably by different questionnaires for these different groups to take into account different contexts and options for action in these groups), the use of the resilience concept in future research would also allow statements on group differences regarding climate resilience or resilience increases. If applied to urban resilience, this group-based analysis could also be used to make statements about three of the five dimensions of urban resilience differentiated by Feldmeyer et al. (2019). Analyses of resilience knowledge, action and networks in the general population would provide one indication—but not a comprehensive assessment—of resilience in urban *society,* analyses of government representatives provide one indication of resilience in *governance*, and analyses of business representatives would relate to the resilience of the urban *economy*. Even partial statements regarding the resilience of urban *infrastructures* and the urban *environment* appear possible if decision makers and managers responsible for urban infrastructures and the urban environment are questioned. Nevertheless, making these statements would require questioning representative samples of members of these actor groups, which is a costly assessment procedure.

Although we have used the resilience concept for analysing the effects of participation on participants' resilience, the concept is also applicable and transferrable to assessing the effects of other formats such as information, education, communication or consulting formats (e.g., websites, trainings, flyers, consultation meetings) that aim to increase climate resilience. Since the concept was developed as part of the BREsilient project related to the city of Bremen, it was developed with a focus on urban climate resilience. Nevertheless, its application is not limited to urban contexts since the dimensions it includes—resilience knowledge, action and network—probably play a role for building resilience at regional, national or even international levels.

Nevertheless, there are some *conceptual challenges* of our resilience concept. The correlations we found between action motivation and risk knowledge (correlations from r = 0.26 to r = 0.45) and action knowledge (r = 0.45 to r = 0.75) were much higher than found by van Valkengoed and Steg (2019) in their meta-analyses using data from 106 empirical studies. They found an average correlation of only 0.14 between adaptation action and knowledge about climate change and/or climate-related hazards. Knowledge indices in previous psychological research mostly related to general, sometimes even global knowledge on climate change and natural hazards. In our questionnaires we measured more specific, personally relevant knowledge: risk knowledge about climate change impacts or flood risks due to heavy rain events in the area of the city the respondents are living in; action knowledge about options by which one's own household or organization can adapt to climate change or prevent damage from floods due to heavy rain events. As our results indicate—but only based on the small sample sizes of the participants in our participatory events—the more specific and personally relevant type of knowledge we measured, particularly action knowledge, might have a stronger effect on action motivation than one might expect based on previous psychological research. Hence, such specific and personally relevant resilience knowledge might play an important role as a determinant of action motivation so that the separation of resilience knowledge as a different dimension than resilience action in our resilience concept might be questionable. Further research is needed to better understand which types of knowledge have greater and which types have smaller influence on action motivation and actual action.

Furthermore, we included motives of people (perceived norms, perceived responsibilities, preferences, attitudes, interests, goals etc.) as psychological determinants in the resilience action dimension making the number of indicators that could be considered within this dimension much bigger than in the knowledge and network dimension. One might argue that the importance of people's motives for resilience would require an additional resilience dimension in the concept. This would also improve the possibilities to consider the effects of participatory approaches on generating legitimacy (e.g., by establishing acceptance of and/or support for a decision), because generating legitimacy is often related to changes in motives so that a person moves from non-acceptance to acceptance of a decision. In our study of participation effects on resilience we have not analysed effects on legitimacy but the link between participation and legitimacy has been the subject of several publications on climate change adaptation (Few 2007; Paavola and Adger 2006; Uittenbroek et al. 2019).

In addition to these conceptual challenges several *methodological limitations* in using our resilience concept for the evaluation of participation effects on resilience need to be mentioned. The standardised questionnaires we have used for assessing resilience increases is a time efficient data gathering instrument but answers ticked by the participants might be influenced by inattention, social desirability bias or answer styles (e.g., preference for using only answers in the middle of the response scale). Most indicators of resilience increases (e.g., indicators for increases in risk knowledge, collective efficacy belief or network between actor groups) were assessed by only one question per indicator (potentially limiting the reliability of measurement) and these indicators were participants' subjective self-assessments of changes (e.g., in their knowledge) that were caused by taking part in the participatory events (potentially limiting the validity of measurement). The small numbers of participants and respondents per participatory event and assessments of effects of participatory events in only four cities in Germany restricts the derivation of robust and generalizable insights. Furthermore, effects of the evaluated participatory events on resilience knowledge, action and network of the participants might be overestimated because in no event there was a 100% questionnaire return rate and perhaps mainly the participants, who liked and subjectively profited from the events, took part in the surveys. Because indicators for resilience network increases were only assessed in one city and with a particularly small sample of only six respondents especially the results for participation effects on resilience network are very questionable. Finally, by focusing on government-led public participation and on actions to resist the negative consequences of extreme weather and climate change our empirical results only say something about this specific type of participation and this particular element of the resilience concept. The other elements of resilience knowledge and actions included in our resilience concept (recover essential functions after disturbance quickly, learn from consequences, adapt to consequences in the short and medium term, transform in the long term) were not aimed at in the evaluated participatory events and it was therefore also not assessed whether there were increases in these knowledge and action areas.

8.5 Conclusions

With due caution in view of the methodological limitations mentioned, the detected increases in resilience knowledge, resilience action and resilience networks among the participants of the analysed participatory events indicate that the contribution of participation for building (urban) resilience assumed by various authors (e.g., Leitch et al. 2015; Orleans Reed et al. 2013; Tyler and Moench 2012) and for supporting learning and knowledge, behaviour and behavioural motivations as well as networks and social capital claimed in climate change adaptation and natural hazards research (see Introduction) could actually be achieved. In other words, participation seems to be effective in stimulating learning in knowledge (mainly cognitive learning, cf. Huitema et al. 2010), in action (including normative learning, cf. Lebel et al. 2010) and in networks (which has strong links to relational learning, cf. McFadgen and Huitema 2017). Nevertheless, increases were only moderate for all resilience dimensions and could not be achieved for all participants although all participatory events were designed by professionals. Hence, the impact of participation on resilience knowledge, action and networks should not be overestimated and expectations regarding the effects of participatory approaches on resilience should stay realistic.

Increases for *resilience knowledge* could be detected for both, risk knowledge and action knowledge, in all participatory events. Increases in resilience knowledge were particularly high in Worms, which was recently affected by damaging heavy rain events, affecting several city quarters for the first time. Probably these damages motivated people to attend the participatory events (the first event was visited by about 110 people) and to learn how damage in the future could be avoided. Hence, the chances for building resilience knowledge by a participatory event are always dependent on the existing knowledge and the learning motivation of the participants. One particular strength of participatory approaches with regard to knowledge appears to be the support of knowledge integration and social learning, as shown in the Bremen case: Agreements rates for statements on successful integration of risk and action knowledge were the highest among the various indicators of knowledge increases.

Often around half of the participants had already taken *resilience action* (for adaptation to climate change or for preventing damage from heavy rain) before the events. This confirms the argument by Kaiser et al. (2011) that participatory events mainly reach motivated people because the costs for participation (time and sometimes money if costs for travel to the event location are necessary) are outweighed by the intrinsic motivation of the participants. To also reach not yet motivated people by participatory events the costs for participation need to be lowered, for example by paying expense allowances, reducing the time frame of the event or by choosing event locations close to the people that shall be involved. Also, online participatory events reduce participation costs but do often not reach specific groups (e.g., the elderly) and are probably not as suited for discourse and deliberation as personal forms of participation. Nevertheless, other instruments (e.g., information campaigns) are probably better suited for motivating people to become interested in urban resilience so that strategies, which combine participation with other instruments, seem to be a promising option for future attempts to build urban resilience.

On the other hand, the detected increases in motivation due to participation—but mostly only among less than half of the participants—confirm the categorization of participation by Mosler and Tobias (2007) as an instrument for the further *support* of behaviour, less for *triggering* or mobilising behaviour, as it is assumed in the German Strategy for Adaptation to Climate Change (DAS) that names participatory approaches in order "to mobilise individual initiative" of participating actors (German Federal Cabinet, 2008, p. 56). Since around half of the participants had already taken action before the events their behaviour had already been triggered or mobilised in the past.

The result that the effect of participation on increasing action and action motivation among the participants was limited can also be interpreted as a reassurance of the main democratic purpose of citizen participation, which is sharing power and allowing co-determination: "It is the strategy by which the have-nots join in determining how information is shared, goals and policies are set, tax resources are allocated, programs are operated, and benefits like contracts and patronage are parceled out" (Arnstein 1969, p. 216). Designing a "participatory event" *only* as a means to change participating citizens' behaviour (e.g., to conduct self-protective action against climate change impacts) would qualify as "manipulation" and therefore as "non-participation" in Arnstein's famous ladder of citizen participation (Arnstein 1969, p. 217).

The detected increases due to participation particularly in collective efficacy beliefs relating to collective actions of governmental actors together with citizens have important consequences for urban resilience governance. As yet, collective efficacy beliefs have mainly been analysed and detected within an actor group, e.g., between citizens engaging in a local sustainability initiative (van Zomeren et al. 2008). In our analyses we could detect collective efficacy beliefs between different actor groups (the group of citizens together with the group of governmental actors) and that these government-citizens efficacy beliefs could be strengthened by participatory events. This result opens up the possibility of a co-management of urban resilience between local governments and citizens and thereby specifies ideas of "modern administration" and "open government" for the urban resilience domain.

Connected to these ideas of co-management for building urban resilience is the result of increases during the participatory events in the perceived responsibility of local governmental actors as well as in perceived individual responsibilities for taking actions. Apparently participatory events in which climate change risks and adaptation options are discussed create a perceived “responsibility gap” which is filled by ascribing responsibility to governmental actors and/or to oneself. The result that in Worms the responsibilisation of governmental actors for adaptation action was not negatively related to the motivation of taking actions oneself was probably caused by the communication of the local governmental representatives at the participatory events in Worms, who spoke of a “joint responsibility of the local government and the citizens” in preventing damage from heavy rain events. This indicates that an open communication about responsibilities of the government and of the citizens can help avoiding one-sided responsibilisations. If it is possible to convincingly communicate a joint government-citizens responsibility for building urban climate resilience demotivating effects of high perceived governmental responsibility will probably be eliminated. However, there is a need for further research in order to better understand how perceived personal responsibility and perceived governmental responsibility change and in which cases the attribution of responsibility to governmental actors has a negative effect on private action.

Increases in *resilience network* due to participation were directly measured only in Bremen, where some increases could be detected. The increases in government-citizens efficacy beliefs, measured in the participatory events of the rain//secure project, can also be interpreted as an indication of an effect of participation on building trust and relations between governmental actors and citizens, which could also be interpreted as a sign of an increase in vertical social capital (cf. Adger 2003). Nevertheless, our data on network effects of participation are very limited and further research is needed when and how such effects appear.

Further research could also address (i) whether changes in resilience knowledge, resilience actions and resilience networks among the participants can lead to larger diffusion effects in which also other actors’ knowledge, actions and networks are changed and (ii) whether these changes in urban social systems can lead to changes in urban infrastructural and natural systems, for example by influencing decisions on urban grey, green and blue infrastructure.

Finally, future research is also needed regarding the questions who can be realistically reached by participatory events on urban resilience, how this relates to the legitimacy of the participation results and how participation of groups and actors that are unwilling to participate can be increased. This does not only refer to groups such as immigrants with language difficulties or people with low levels of education that often hesitate to visit public participation events. Among the local governmental representatives at the evaluated participatory events in our study mostly people from governmental administration were present, the political level (e.g., the mayor or elected members of the city council) was underrepresented.

The detected absence of political decision makers in the analysed participatory events is an experience also of many other participatory processes on adaptation to climate change. Innovative participatory formats are needed to better include these important actors in the future so that participatory processes, perhaps as part of a larger strategy for co-management of urban resilience, can build legitimacy by including democratically elected actors and have a more direct impact on political decision making.

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References

Adger, V. N. (2003). Social capital, collective action, and adaptation to climate change. *Economic Geography, 79*(4), 387–404

Alexander, M., Doorn, N., & Priest, S. (2018). Bridging the legitimacy gap—Translating theory into practical signposts for legitimate flood risk governance. *Regional Environmental Change, 18*(2), 397–408

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., & Patton, E. (2011). Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change, 21*(3), 995–1004

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners, 35*(4), 216–224

Babcicky, P., & Seebauer, S. (2017). The two faces of social capital in private flood mitigation: Opposing effects on risk perception, self-efficacy and coping capacity. *Journal of Risk Research, 20*, 1017–1037

Bahadur, A., & Tanner, T. (2014). Transformational resilience thinking: Putting people, power and politics at the heart of urban climate resilience. *Environment and Urbanization, 26*(1), 200–214

Baird, J., Plummer, R., Haug, C., & Huitema, D. (2014). Learning effects of interactive decision-making processes for climate change adaptation. *Global Environmental Change, 27*, 51–63

Baird, J., Plummer, R., Moore, M.-L., & Brandes, O. (2016). Introducing resilience practice to watershed groups: What are the learning effects? *Society & Natural Resources, 29*(10), 1214–1229. https://doi.org/10.1080/08941920.2015.1107788

Begg, C. (2018). Power, responsibility and justice: A review of local stakeholder participation in European flood risk management. *Local Environment, 23*(4), 383–397

Begg, C., Callsen, I., Kuhlicke, C., & Kelman, I. (2018). The role of local stakeholder participation in flood defence decisions in the United Kingdom and Germany. *Journal of Flood Risk Management, 11*(2), 180–190

Benson, D., Lorenzoni, I., & Cook, H. (2016). Evaluating social learning in England flood risk management: An 'individual-community interaction' perspective. *Environmental Science & Policy, 55*, 326–334

Berkes, F. (2007). Understanding uncertainty and reducing vulnerability: Lessons from resilience thinking. *Natural Hazards, 41*, 283–295. https://doi.org/10.1007/s11069-006-9036-7

Biggs, R., Schlüter, M., & Schoon, M. L. (Eds.). (2015). *Principles for building resilience: Sustaining ecosystem services in social-ecological systems*. University Press.

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G., Dakos, V., Daw, T. M., Evans, L. S., Kotschy, K., Leitch, A. M., Meek, C., Quinlan, A., Raudsepp-Hearne, C., Robards, M. D., Schoon, M. L., Schultz, L., & West, P. C. (2012). Towards principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources, 37*, 421–448

Born, M., Körner, C., Löchtefeld, S., Werg, J., & Grothmann, T. (2021). *Erprobung und Evaluierung von Kommunikationsformaten zur Stärkung privater Starkregenvorsorge – Das Projekt Regen//Sicher*. Climate Change 07/2021. Dessau: Umweltbundesamt.

Burton, P., & Mustelin, J. (2013). Planning for climate change: Is greater public participation the key to success? *Urban Policy and Research, 31*(4), 399–415

Coaffee, J., & Lee, P. (2016). *Urban resilience. Planning for risk, crisis, and uncertainty.* London: Palgrave.

Collins, K., & Ison, R. (2009). Jumping off Arnstein's ladder: Social learning as a new policy paradigm for climate change adaptation. *Environmental Policy and Governance, 19*(6), 358–373

Conway, D., Nicholls, R. J., Brown, S., Tebboth, M. G. L., Adger, W. N., Ahmad, B., Biemans, H., Crick, F., Lutz, A. F., De Campos, R. S., Said, M., Singh, C., Zaroug, M. A. H., Ludi, E., New, M., & Wester, P. (2019). The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nature Climate Change, 9*(7), 503–511

Cvitanovic, C., Howden, M., Colvin, R. M., Norström, A., Meadow, A. M., & Addison, P. F. E. (2019). Maximising the benefits of participatory climate adaptation research by understanding and managing the associated challenges and risks. *Environmental Science & Policy, 94*, 20–31

Davoudi, S. (2018). Just resilience. *City & Community, 17*(1), 3–7

de la Poterie, A. T., & Baudoin, M. A. (2015). From Yokohama to Sendai: Approaches to participation in international disaster risk reduction frameworks. *International Journal of Disaster Risk Science, 6*(2), 128–139

de Voogt, D. L., Bisschops, S., & Munaretto, S. (2019). Participatory social capacity building: Conceptualisation and experiences from pilots for flood risk mitigation in the Netherlands. *Environmental Science & Policy, 99*, 89–96

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., & Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability, 2*(4), 267–273

Engle, N. L., & Lemos, M. C. (2010). Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change, 20*(1), 4–13

Feldmeyer, D., Wilden, D., Kind, C., Kaiser, T., Goldschmidt, R., Diller, C., & Birkmann, J. (2019). Indicators for monitoring urban climate change resilience and adaptation. *Sustainability, 11*(10), 2931

Few, R., Brown, K., & Tompkins, E. L. (2007). Public participation and climate change adaptation: Avoiding the illusion of inclusion. *Climate Policy, 7*(1), 46–59

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B., & Svedin, U. (2002). *Resilience and sustainable development: Building adaptive capacity in a world of transformations.* Stockholm: Environmental Advisory Council.

Gaillard, J. C., Cadag, J. R. D., & Rampengan, M. M. (2019). People's capacities in facing hazards and disasters: An overview. *Natural Hazards, 95*(3), 863–876

Gallopin, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change, 16*, 293–303. https://doi.org/10.1016/j.gloenvcha.2006.02.004

German Federal Cabinet. (2008). *German strategy for adaptation to climate change.* The Federal Government.

Gottschick, M., & Ette, J. (2014). Etablierte Partizipationslandschaften. Hemmnis für Innovationen zur nachhaltigen regionalen Entwicklung und zur Anpassung an den Klimawandel. In A. Knierim, S. Baasch, & M. Gottschick (Eds.), *Partizipation und Klimawandel – Ansprüche, Konzepte und Umsetzung* (pp. 131–150). München: Oekom.

Grothmann, T. (2011). Governance recommendations for adaptation in European urban regions: Results from five case studies and a European expert survey. In K. Otto-Zimmermann (Ed.), *Resilient cities – Cities and adaptation to climate change – Proceedings of the global forum 2010* (pp. 167–175). Hamburg: Springer.

Grothmann, T. (2020). *Beteiligungsprozesse zur Klimaanpassung in Deutschland: Kritische Reflexion und Empfehlungen.* Dessau: Umweltbundesamt.

Grothmann, T., Grecksch, K., Winges, M., & Siebenhüner, B. (2013). Assessing institutional capacities to adapt to climate change: Integrating psychological dimensions in the Adaptive Capacity Wheel. *Natural Hazards and Earth System Sciences, 13*(12), 3369–3384

Hartz-Karp, J., & Meister, H. P. (2011). Creating resilient cities through empowered, deliberative participation. In K. Otto-Zimmermann (Ed.), *Resilient Cities.* (pp. 177–185). Springer.

Hassenforder, E., Smajgl, A., & Ward, J. (2015). Towards understanding participatory processes: Framework, application and results. *Journal of Environmental Management, 157*, 84–95

Hegger, D., Lamers, M., Van Zeijl-Rozema, A., & Dieperink, C. (2012). Conceptualising joint knowledge production in regional climate change adaptation projects: Success conditions and levers for action. *Environmental Science & Policy, 18*, 52–65

Hobson, K., & Niemeyer, S. (2011). Public responses to climate change: The role of deliberation in building capacity for adaptive action. *Global Environmental Change, 21*, 957–971

Hügel, S., & Davies, A. R. (2020). Public participation, engagement, and climate change adaptation: A review of the research literature. *Wiley Interdisciplinary Reviews: Climate Change*, e645.

Huitema, D., Cornelisse, C., & Ottow, B. (2010). Is the jury still out? Toward greater in-sight in policy learning in participatory decision processes – The case of dutch citizens' juries on water management in the Rhine Basin. *Ecology and Society, 15*(1), 16

Hutter, G., & Lorenz, D. F. (2018). Social Resilience. In S. Fuchs & T. Thaler (Eds.), *Vulnerability and resilience to natural hazards.* (pp. 190–213). Cambridge University Press.

Kaiser, F. G., Woelki, D., & Vllasaliu, L. (2011). Partizipative Interventionsmaßnahmen und partizipatives umweltpolitisches Handeln: Ausdruck intrinsischer Umweltmotivation, nicht deren Ursache. *Umweltpsychologie, 15*(2), 77–92

Kirkby, P., Williams, C., & Huq, S. (2018). Community-based adaptation (CBA): Adding conceptual clarity to the approach, and establishing its principles and challenges. *Climate and Development, 10*(7), 577–589

Körner, C., & Lieberum, A. (2014). Instrumente der Anpassungskommunikation in nord-west2050. Evaluation der Online-Medien. In K. Beese, M. Fekkak, C. Katz, C. Körner & H. Molitor (Eds.), *Anpassung an regionale Klimafolgen kommunizieren: Konzepte, Herausforderungen und Perspektiven* (pp. 393–405). München: Oekom.

Kuhlicke, C., Seebauer, S., Hudson, P., Begg, C., Bubeck, P., Dittmer, C., Grothmann, T., Heidenreich, A., Kreibich, H., Lorenz, D. F., Masson, T., Reiter, J., Thaler, T., Thieken, A. H., & Bamberg, S. (2020). The behavioral turn in flood risk management, its assumptions and potential implications. *Wiley Interdisciplinary Reviews: Water, 7*(3), e1418

Kuhlicke, C., Steinführer, A., Begg, C., Bianchizza, C., Bründl, M., Buchecker, M., De Marchi, B., Di Masso Tarditti, M., Höppner, C., Komac, B., Lemkow, L., Luther, J., McCarthy, S., Pellizzoni, L., Renn, O., Scolobig, A., Supramaniam, M., Tapsell, S., Wachinger, G., … Faulkner, H. (2011). Perspectives on social capacity building for natural hazards: Outlining an emerging field of research and practice in Europe. *Environmental Science & Policy, 14*(7), 804–814

Lebel, L., Grothmann, T., & Siebenhüner, B. (2010). The role of social learning in adaptiven-ess. Insights from water management. *International Environmental Agreements: Politics, Law and Economics 10(4)*, 333–353.

Leitch, A. M., Cundill, G., Schultz, L., & Meek, C. (2015). Principle 6 – Broaden participation. In R. Biggs, M. Schlüter, & M. L. Schoon (Eds.), *Principles for building resilience. Sustaining ecosystem services in social-ecological systems* (pp. 201–225). Cambridge: Cambridge University Press.

Luís, S., Lima, M. L., Roseta-Palma, C., Rodrigues, N., Sousa, L. P., Freitas, F., Alves, F. L., Lillebø, A. I., Parrod, C., Jolivet, V., Paramana, T., Alexandrakis, G., & Poulos, S. (2018). Psychosocial drivers for change: Understanding and promoting stakeholder engagement in local adaptation to climate change in three European Mediterranean case studies. *Journal of Environmental Management, 223*, 165–174

Marti, M., Stauffacher, M., & Wiemer, S. (2020). Anecdotal evidence is an insufficient basis for designing earthquake preparedness campaigns. *Seismological Research Letters (2020) 91*(4), 1929–1935.

McEvoy, S., van de Ven, F. H., Blind, M. W., & Slinger, J. H. (2018). Planning support tools and their effects in participatory urban adaptation workshops. *Journal of Environmental Management, 207*, 319–333

McEwen, L., Holmes, A., Quinn, N., & Cobbing, P. (2018). 'Learning for resilience': Developing community capital through flood action groups in urban flood risk settings with lower social capital. *International Journal of Disaster Risk Reduction, 27*, 329–342

McFadgen, B., & Huitema, D. (2016). Are all experiments created equal? A framework for analysis of the learning potential of policy experiments in environmental governance. *Journal of Environmental Planning and Management, 60*(10), 1765–1784

McFadgen, B., & Huitema, D. (2017). Stimulating learning through policy experimentation: a multi-case analysis of how design influences policy learning outcomes in experiments for climate adaptation. *Water, 9*(9), 648

McMillen, H., Campbell, L., Svendsen, E., & Reynolds, R. (2016). Recognizing stewardship practices as indica-tors of social resilience: In living memorials and in a community garden. *Sustainability, 8*(8), 775

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape Urban Plan., 147*, 38–49

Mees, H. (2014). *Responsible climate change adaptation: Exploring, analysing and evaluating public and private responsibilities for urban adaptation to climate change,* Doctoral dissertation, Utrecht University.

Mees, H., Crabbé, A., & Driessen, P. P. (2017). Conditions for citizen co-production in a resilient, efficient and legitimate flood risk governance arrangement. A tentative framework. *Journal of Environmental Policy & Planning, 19*(6), 827–842.

Mees, H., Crabbé, A., Alexander, M., Kaufmann, M., Bruzzone, S., Lévy, L., & Lewandowski, J. (2016). Coproducing flood risk management through citizen involvement: Insights from cross-country comparison in Europe. *Ecology and Society, 21*(3), 7

Mercer, J. (2010). Disaster risk reduction or climate change adaptation: Are we reinventing the wheel? *Journal of International Development: The Journal of the Development Studies Association, 22*(2), 247–264

Moon, J., Flannery, W., & Revez, A. (2017). Discourse and practice of participatory flood risk management in Belfast, UK. *Land Use Policy, 63*, 408–417

Moser, S. C., & Pike, C. (2015). Community engagement on adaptation: Meeting a growing capacity need. *Urban Climate, 14*, 111–115

Mosler, H.-J., & Tobias, R. (2007). Umweltpsychologische Interventionsformen Neu Gedacht. *Umweltpsychologie, 11*(1), 35–54

Murti, R., & Mathez-Stiefel, S. L. (2019). Social learning approaches for ecosystem-based disaster risk reduction. *International Journal of Disaster Risk Reduction, 33*, 433–440

Ntontis, E., Drury, J., Amlôt, R., Rubin, G. J., & Williams, R. (2019). What lies beyond social capital? The role of social psychology in building community resilience to climate change. *Traumatology, 26*(3), 253

Orleans Reed, S., Friend, R., Toan, V. C., Thinphanga, P., Sutarto, R., & Singh, D. (2013). "Shared learning" for building urban climate resilience–experiences from Asian cities. *Environment and Urbanization, 25*(2), 393–412

Paavola, J., & Adger, W. N. (2006). Fair adaptation to climate change. *Ecological Economics, 56*(4), 594–609

Pavey, J. L., Muth, A. B., Ostermeier, D., & Steiner Davis, M. (2007). Building capacity for local governance: An application of interactional theory to developing a community of interest. *Rural Sociology, 72*, 90–110

Pelling, M. (2007). Learning from others: Scope and challenges for participatory disaster risk assessment. *Disasters, 31*, 373–385

Foundation, R., & Arup, (Eds.). (2015). *City resilience framework*. London: Arup.

Romero-Lankao, P., Gnatz, D., Wilhelmi, O., & Hayden, M. (2016). Urban sustainability and resilience: From theory to practice. *Sustainability, 8*(12), 1224

Sarzynski, A. (2015). Public participation, civic capacity, and climate change adaptation in cities. *Urban Climate, 14*, 52–67. https://doi.org/10.1016/j.uclim.2015.08.002

Scherhaufer, P., & Grüneis, H. (2014). Herausforderungen und Grenzen partizipativer Projektarbeit – Zwei Beispiele aus der transdisziplinären Klimawandelanpassungsforschung und erste Lösungsansätze. *Umweltpsychologie, 18*(2), 189–210

Schultz, L., & Lundholm, C. (2010). Learning for resilience? Exploring learning opportunities in biosphere reserves. *Environmental Education Research, 16*(5–6), 645–663. https://doi.org/10.1080/13504622.2010.505442

Scolobig, A., Prior, T., Schröter, D., Jörin, J., & Patt, A. (2015). Towards people-centred approaches for effective disaster risk management: Balancing rhetoric with reality. *International Journal of Disaster Risk Reduction, 12*, 202–212

Slinger, J. H., Cuppen, M., & Marchand, M. (2009). The policy preferences of citizens, scientists and policy makers. In P. Samuels, S. Huntington, W. Allsop, and J. Harrop (Eds.), *Flood Risk Management: Research and Practice* (p. 161). London: Taylor & Francis Group.

Steg, L., Van den Berg, A. E., & De Groot, J. I. M. (2012). *Environmental psychology: An introduction.* Oxford: John Wiley & Sons.

Tierney, K. (2015). Resilience and the neoliberal project: Discourses, critiques, practices – And Katrina. *American Behavioral Scientist, 59*(10), 1327–1342

Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. *Climate and Development, 4*(4), 311–326

Uittenbroek, C. J., Mees, H. L., Hegger, D. L., & Driessen, P. P. (2019). The design of public participation: Who participates, when and how? Insights in climate adaptation planning from the Netherlands. *Journal of Environmental Planning and Management, 62*(14), 2529–2547

UN-HABITAT. (2011). Cities and Climate Change: Global Report on Human Settlements 2011. *United Nations Human Settlements Programme (UN-HABITAT)*, Nairobi, Kenya, 279 pp.

UNISDR. (2017). *How To Make Cities More Resilient. A Handbook For Local Government Leaders.* Geneva: United Nations.

van Valkengoed, A. M., & Steg, L. (2019). Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change, 9*(2), 158–163

Van Zomeren, M., Postmes, T., & Spears, R. (2008). Toward an integrative social identity model of collective action: A quantitative research synthesis of three socio-psychological perspectives. *Psychological Bulletin, 134*(4), 504

Wamsler, C. (2017). Stakeholder involvement in strategic adaptation planning: Transdisciplinarity and co-production at stake? *Environmental Science & Policy, 75*, 148–157. https://doi.org/10.1016/j.envsci.2017.03.016

Wamsler, C., Alkan-Olsson, J., Björn, H., Falck, H., Hanson, H., Oskarsson, T., Simonsson, E., & Zelmerlow, F. (2020). Beyond participation: When citizen engagement leads to undesirable outcomes for nature-based solutions and climate change adaptation. *Climatic Change, 158*(2), 235–254

Whitmarsh, L., O'Neill, S., & Lorenzoni, I. (2013). Public engagement with climate change: What do we know and where do we go from here? *International Journal of Media & Cultural Politics, 9*(1), 7–25. https://doi.org/10.1386/macp.9.1.7_1

Wilson, R. S., Herziger, A., Hamilton, M., & Brooks, J. S. (2020). From incremental to transformative adaptation in individual responses to climate-exacerbated hazards. *Nature Climate Change*, 1–9.

Wood, M. M., & Glik, D. (2013). Engaging Californians in a shared vision for resiliency: practical lessons learned from the Great California Shakeout. *The Alfred E. Alquist Seismic Safety Commission*, Sacramento.

World Bank. (2011). *Guide to Climate Change Adaptation in Cities*. Urban Development and Local Government Unit, Sustainable Development Network, The International Bank for Reconstruction and Development/The World Bank, Washington, DC, USA, 100 pp.

Zhang, Q., Hu, J., Song, X., Li, Z., Yang, K., & Sha, Y. (2020). How does social learning facilitate urban disaster resilience? A Systematic Review. *Environmental Hazards, 19*(1), 107–129

Ziervogel, G. (2019). Building transformative capacity for adaptation planning and implementation that works for the urban poor: Insights from South Africa. *Ambio, 48*(5), 494–506

Ziervogel, G., Cowen, A., & Ziniades, J. (2016). Moving from adaptive to transformative capacity: Building foundations for inclusive, thriving, and regenerative urban settlements. *Sustainability, 8*(9), 955

9 Building Resilience in the Context of Multi-Level Governance—Insights from a Living Lab in the Ruhr

Karsten Zimmermann and Dahae Lee

9.1 Resilience and Its Critics

Without a doubt the concept of resilience has almost reached the status of a new paradigm in the realm of regional planning and urban development. Resilience is an appealing idea for planning practitioners as well as for academics as the concept facilitates the re-articulation of many powerful notions such as *regional sustainable development, strategic planning* or *transformative governance*. Practical implications stretch from interventions in environmental planning, risk management to integrated regional development and territorial cohesion policies. In terms of theory, the concept of resilience borrows ideas from many fields such as complexity theory, ecology, adaptive management and social innovation and this conceptual plurality seems to be an attraction for many scholars (Folke 2006; Holling and Gunderson 2002; Hutter and Lorenz 2018).

At the same time the term resilience is used in an inflationary and sometimes ambivalent way and, as a result, recent publications discuss resilience critically (Bohland et al. 2018). This criticism is justified as resilience is running the risk of becoming a political buzzword with weak explanatory power and a lack of conceptual clarity (Jore 2020). Sceptical remarks refer to an emerging new technocracy and value-neutral functionalism in planning, machine-politics, soft sustainable development, depoliticized decision-making, and shadow neoliberalism (Davoudi et al.2018; see also Pelling 2010, p. 84). Critics further add the neglect of the social and political dimension of resilience (Duit 2016; Hutter and

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Lorenz 2018). Other issues that need discussion are the definitions of system boundaries as well as the de facto normative standards of stability and state of equilibrium: are these desired states and if so, desired by whom? This provokes references to systems theory in the social sciences (from David Easton's systems approach to the idea of autopoiesis in Niklas Luhmanns work; see Duit et al. 2010). In addition, implicit functionalist assumptions about agency, rational learning and transformative change call for a closer examination of the relationship between the social sciences and resilience studies as the latter still display their origin in natural sciences. A certain functionalism prevails in many contributions to the debate which is an unexpected result as, following Hutter, resilience is about "managing the unexpected" or even "surprise" (Hutter 2017).

In this chapter, we argue that through a stronger recognition of the social science literature on governance the concept of resilience would have more explanatory value as well as predictive quality. Still, the criticism needs to be taken into account. Peter Rogers expressed this ambivalence very well:

> "Resilience is a concept which, if used well, may help deliver a paradigm change in how an urbanization is governed in the 21st century, yet the term remains a focus of scepticism and critique for many who encounter it." (Rogers 2018, p. 125).

In fact, the concept oscillates between arguments for stability and change, persistence and transformation, path-dependence and path-breaking. In our view, it is necessary to disaggregate resilience into components in order to get a better understanding of what needs to be done when implementing it. Moreover, the normative desirability of some of the goals closely linked to the concept can be better discussed. Do we want a system (i.e. city, region or community) just to cope and adapt, or to transform and change (Hutter and Lorenz 2018, p. 197; Pelling 2010)? Disaggregation may also help with regard to a better understanding of the conceptual basis of resilience thinking. In many publications, the concept of resilience is understood in a holistic way as a capacity of a social-spatial entity. However, due to systems differentiation, a number of dimensions of resilience are accentuated in more recent contributions (Fuchs and Thaler 2018). These include social resilience (Hutter and Lorenz 2018), economic resilience in deindustrializing regions (Cowell 2015) or institutional and organizational resilience (Duit 2016; cf. Pelling 2010, p. 91). Breaking down resilience into these dimensions would help to understand better what determines the capacity of a city or region to react and cope with unexpected events.

Among different dimensions of resilience, the institutional and policy dimension is a relevant category for analysis. The concept of resilience seems to be based on assumptions of reflexive and collaborative governance for the adaptive management as well as transformation of socio-ecological systems (Feindt and Weiland 2018; Folke 2006; Pelling 2010; Voß and Bornemann 2011). Following this path, we argue that a stronger recognition of policy analysis and governance studies is desirable, offering a change in perspective for the analysis and design of resilience policies (Duit 2016). In our view, this is not least necessary against the background of recent contributions on *Over-reaction and under-reaction in climate policy* (Peters et al. 2017). Resilience is often seen as an abstract capacity of a socio-ecological system. But who implements resilience? Who adapts to what for which reason and what is an appropriate institutional response to an external challenge (Pelling 2010; Peters et al. 2017)? The following quote taken from Anderies et al. (2004, p. 1) expresses our concern quite well:

> "More recent developments in resilience theory emphasize adaptive capacity and coupled cycles of change that interact across several scales (…). These ideas are useful in a descriptive sense, but are less useful for studying designed systems. How does one design for adaptive capacity? What is the cost of adaptive capacity?"

Resilience is implemented by actors with manifest interests and action frames who act in organizational hierarchies and inter-organizational constellations (such as networks or multi-level governance arrangements). These elements constitute the complex institutional environment in which actors act and respond to external and internal impulses (Hoppe 2011). Hence, in this chapter we seek to identify some of the implications of resilience-policies for bureaucracies, network governance, policies and instruments, public management, and in particular multi-level governance. We discuss it against the background of the governance of city-regions (Scott 2019; Zimmermann 2020).

This is not an empirical paper. However, all the ideas and arguments presented are the results of a regional living lab that was implemented in the context of the ZUKUR project over a period of three years (2017–2020). The living lab "Future of the City-Region Ruhr" (Zukunft-Stadt-Region-Ruhr, ZUKUR),[1] sought to explore options for the implementation of resilience in the multi–level and multi-actor context of a polycentric post-industrial city-region. The principal question was: which kind of governance mechanisms and instruments are needed in order to improve the ability of a system to govern socio-ecological problems? The methods applied were interviews with stakeholders on the local and regional level of policy-making, group discussions, and workshops to include the wider

[1]Financed by German Federal Ministry of Education and research/BMBF, grant number 01LR1721A.

public as well as the analysis of documents. Being part of this living lab made the critical discussion of some of the core assumptions made in the literature on resilient cities possible.

The chapter is structured as follows. The first section gives a brief overview of the political science literature on resilience and reflexive governance. Based on the literature, we suggest four generic principles of resilience that need to be taken into account when designing a multi-level governance arrangement in city-regions that face the challenge of climate adaptation. These include redundancy, diversity, robustness, and connectivity. We then discuss these design principles against the background of what happened in the living lab. The conclusion takes up some of the issues raised in this introduction.

9.2 Adaptive Governance and Resilience

The lack of governance and policy implementation theory is a weak spot in the resilience literature. This is surprising as the notion of resilience is well known in political science. Policy-analysis and administrative science started using the notion of resilience in the late 1980s (Duit 2016). In principle, scholars were interested in the ability of political-administrative systems to react in situations of change and non-linear dynamics. Among this body of work is Aaron Wildawsky's book *Searching for Safety* (1988) and Christopher Hood's seminal article *A public Management for all seasons* (1991). In Germany, there is Carl Böhret's Book *Folgen. Entwurf für eine aktive Politik gegen schleichende Katastrophen* (1990) (Consequences. Suggestion for an active policy against creeping disasters, own translation).

Aaron Wildawsky's book (1988) is a contribution to the debate on natural disasters and technology risks. By referring to the unexpected consequences and unwanted side effects of technological innovations he questioned the capability to plan societal development. He contrasted the two notions of "anticipation" and "resilience" and, thereby, demonstrates the weaknesses of a governance model based on anticipation. This implies linear dynamics, clear causalities, and top-down governance with stable and reliable expectations. Resilience, in contrast, describes adaptive patterns of governance in situations with low stability of expectations and disruptive changes. One may also reconsider what Ulrich Beck wrote in his book *Risk Society* in 1986 (1992). Beck identified an emerging pattern of reflexive politics and governance in post-industrial societies (Beck 1994). Secondary effects, in his words, have become the main drivers for decision-making in politics, in particular in environmental politics. This sounds all too familiar when going through the resilience literature. As we are not able to actively steer climate change, all that remains to be done is to master secondary effects, at least if we have knowledge about them (Lung et al. 2013).

In organization science, one can also find inspirational thoughts for the implementation of adaptive governance for resilience. In their seminal book *Managing the unexpected. Sustained performance in a complex world,* Weick and Sutcliffe (2001) coined the notion of "mindfulness". Mindfulness is the capacity of high performance groups to identify even small mistakes in order to adapt to changes in complex environments. From a different angle, Christopher Hood, when writing about public management in the 1990s, mentioned resilience as one of the three core values of public administration (1991):

1. Sigma type values: Keep it lean and purposeful (effectivenes and efficiency)
2. Theta type values: Keep it honest and fair (legitimacy and good governance)
3. Lambda type values: Keep it robust and resilient (coping with extra-ordinary situations and capacity to learn)

It is obvious that the lambda type values are the relevant one for this chapter although the other values should not be neglected. In the early 1990s, Christopher Hood was unable to consider climate change and adaptation in the way we do today, nor did he define this value more precisely. Lambda type values would refer to qualities such as power of endurance, robustness, adaptivity, but also mindfulness and avoidance of competence traps (Duit 2016; Duit et al. 2010; Hutter and Lorenz 2018; Levitt and March 1988).[2] As the government is expected to function even in extreme and extraordinary situations, the sustained capacity to act even in extreme and disadvantageous situations is the core value (see the reaction to Hurricane Sandy in New York in 2012; Nevarez 2018).

Governance for resilience also evokes overlaps with reflexive governance, a long-standing theme in the literature on environmental policies and planning (Feindt and Weiland 2018; Voß and Bornemann 2011). Reflexive governance has a double meaning: first, reflexivity refers to the constant evaluation of the success and failure of existing governance arrangements. Hence, adaptation of rules, avoidance of competence traps (Levitt and March 1988, FN 2) as well

[2]Levitt and March (1988) define competence traps as the unjustified belief that behavior, that has led to success in the past, will necessarily lead to success in the future. In times of complex and dynamic systems this assumption is probably absurd.

as the avoidance of what Ostrom called panacea traps[3] are common themes in this discourse. Second, and worth considering when thinking about governance of resilience, is the capacity of "participants to gain a reflexive stance toward the construction of governance objects through operational schemes of observation and feedback mechanisms, thereby moving toward reflexivity" (Feindt and Weiland 2018, p. 665). In other words, reflexive governance also refers to the capacity to define and redefine what is governed.

Summing up this short review of the political science literature on resilience and reflexive governance, the standards for success and failure of governance of resilience are learning and reliability on the one side, paralysis, non-learning and disruption on the other. These values may be facilitated through measures that follow some generic design principles that we have taken from the literature on resilience, reflexive governance and institutional thought. These are:

- *Redundancy:* Redundancy is generated by the keeping of overcapacities and fallback positions as these enrich the options to react and offer alternatives in a situation formerly unknown (Folke et al. 2005, p. 453). Often, this is also referred to as "requisite variety" (with reference to Ashby 1956; Duit et al. 2010, pp. 365–366). Keeping and storing more ideas than needed when taking an action is also an element of redundancy. With regard to inter-organizational governance we may also think of "overlapping functions across organizational levels" (Folke et al. 2005, p. 53).
- *Diversity:* In order to avoid group think (Janis 1972), the autonomy of smaller working units should be maintained. It generates deviating positions and assessments, if necessary, and thus arrives at a multi-perspective evaluation (Folke et al. 2005). Again, this is also known in complexity theories as the requisite variety of institutional responses in complex and dynamic environments (Duit et al. 2010, pp. 365–366).
- *Robustness:* Robustness is a very technical term, often used in computer science and engineering. In principle, robustness describes the capacity of a system to keep more resources available than necessary to compensate for failures. Robustness is the ability to cope with errors during execution, keeping the basic functionality of a system even when the breakdown of some of its components occur. Defining robustness in institutional terms is, however,

[3] Ostrom defines panacea traps as the widely shared belief that simple and universal solutions work across time and in different places; a blueprint for a single type of governance solutions that work in different contexts (Ostrom 2007).

much more difficult (Anderies et al. 2004). We follow the approach of a research group of Elinor Ostrom (Anderies et al. 2004). Among others, this group suggests the monitoring of user behaviour and the state of the socio-ecological system, the possibility of graduated sanctions, existence of conflict-resolution mechanisms and a sufficient leeway to self-organize a decentralized governance arrangement (i.e. a degree of autonomy vis a vis higher governmental layers) as being the relevant elements (Anderies et al. 2004, p. 8).

- *Connectivity:* Another important factor in particular when considering the multi-level governance of a city-region is connectivity (Hutter and Lorenz 2018; Piattoni 2010, pp. 20–21). Connectivity can refer both to the type and quality of coupling between levels in the sense of multi-level governance (institutional and actor-related) or to connections of an organization with the outside world. Two dimensions seem to be relevant:
  Stability of connectivity: this describes the degree of integration of a decision and information system. Stability in terms of resilience must, according to Orton and Weick, "combine the contradictory concepts of connection and autonomy" (Orton and Weick 1990, p. 216). A minimum of integration must be given, but too close links in turn restrict the collective capacity to adapt.
  Diversity of connectivity: this not only refers to the degree of openness for new actors and knowledge, but also includes a culture of information sharing, i.e. willingness to pass on knowledge and information.

Our understanding of resilience is based on these four generic principles and we seek to discuss them in the context of organizational environments and inter-organizational fields.

9.3 Institutional Environment: City Regions and Multi-level Governance

Although much of the literature on resilience is about cities, it is obvious that climate change adaptation does not stop at the borders of municipalities but requires the coordination of a range of actors in a city-region in order to avoid particularism and fragmentation (Rosan 2016). However, outlooks at the success of city-region governance are, at best, sceptical due to unsolved issues of distribution of resources and collective governance (Jonas 2012; Zimmermann 2020). As highlighted by Scott (2019, p. 16), at least in the majority of city-regions, urban governments have "At the best of times, (…) limited tools and resources at their disposal for confronting internal problems and failures, but in the case of complex, overgrown city regions, weaknesses of overall social management are especially severe. This challenge is exacerbated by the persistent tendency to balkanization of municipal government in probably the vast majority of city-regions, not only as a legacy problem, but also as an effect of the oftenhaphazard lateral expansion of the urban periphery where adjacent municipalities are simply absorbed into the widening geographic orbit of the city-region."

Problems of metropolitan development can be tackled in various institutional environments. Many public tasks can be organized in different ways such as single purpose associations, inter-municipal cooperation, interventions of upper tier governments, contracts, or multi-purpose organizations and in some cases these governance forms may even overlap. Even the more successful metropolitan governance arrangements such as Stuttgart or Portland can't serve as role models with regard to general design principles (Rosan 2016; Sager 2006). Scott highlights that "an approximate template is occasionally detectable in the more successful efforts that have pushed in this direction, namely—and in sharp contradistinction to any unitary arrangement—a conglomerate structure made up of loose hierarchical relationships complemented by assorted cross-cutting organizations wherever these can significantly enhance operational effectiveness. There is no compelling reason, moreover, why a well-designed structure of this type could not also enhance the democratic assets of the city-region." (Scott 2019, p. 17).

While this is often discussed against the background of administrative solutions such as amalgamations or collaborative inter-municipal governance, the generic principles of resilience discussed above call for solutions that reach beyond the sphere of public administration. Especially against the background of cross-organizational learning and social innovation, the mobilization of social commitment and socially embedded knowledge seems to be of utmost importance. Hence, resilience seems to require a decentralized approach. Since the issue is one of eventual affectedness, those groups potentially affected in the cities and districts are called to assert their claims.

At the same time, the capacity to react, adapt and transform depends on administrative capacities and competences that are shared between different levels and units of government. Although a decentralized approach with a focus on the capacities and interests of local communities is a charming idea, protagonists of local self-governance tend to ignore that cities (and city-regions) are embedded into inter-governmental fiscal and functional relationships. In terms of political and administrative decentralization, the degree of autonomy of a city may have a positive effect on the resilience of a community but, at the same time, we need to consider that towns and municipalities—not only in the case of Germany—rely heavily on fiscal and functional inter-governmental relationships—not least in the field of regional and environmental planning (Zimmermann and Heinelt 2016).

The concept of multi-level governance, which originates from European integration research, is an equally analytical and heuristically suitable concept for addressing these questions of collective capacities to act while still keeping the autonomy of units. Units of a multi-level system constantly oscillate between losses of autonomy and jointly exercised competencies and can also compete with each other, even if they are actually interlinked. Multi-level governance, being a generic concept for policy-making and decision-making in a context characterized by shared and overlapping competences and decision-making spaces, gives us some indications for the design of city-regional governance. However, the discussion on multi-level governance has also developed in many different directions. If one chooses Schmitter's definition of multi-level governance, for example, the core contents, such as the absence of exclusive policy competence, become clear:

> "Multi-level governance can be defined as an arrangement for making binding decisions that engages a multiplicity of politically independent but otherwise interdependent actors—private and public—at different levels of territorial aggregation in more-or-less continuous negotiation/deliberation/implementation, and that does not assign exclusive policy competence or assert a stable hierarchy of political authority to any of these levels" (Schmitter 2004, p. 49).

Piattoni, on the other hand, notes that this definition is not sufficiently concrete, especially for empirically oriented studies (Piattoni 2010). She therefore suggests to go beyond the definition of multi-level governance as decision-making and coordination and to see multi-level governance through the lenses of different dimensions. One of these dimensions is political mobilization and this refers to new forms of policy-making which explicitly no longer use the formal channels of parties or political-administrative interest mediation, but apply unconventional methods of political articulation and mobilization in order to make claims in the sphere of politics (Piattoni 2010, p. 18). In the context of city-regions and local self-government, this means that the potential for social and political mobilization in cities and even neighbourhoods must be included in conventional and unconventional ways of policy-making.

With regard to policy-making, i.e. the implementation of political programs, Piattoni highlights that in the context of multi-level systems, the policy-makers are no longer separated from the policy-receivers (Piattoni 2010, p. 20). The improvement of policies during the process of implementation does indeed require new formats, the design of which we do not know much about in the context of urban and regional resilience policy but it is likely that the conventional wisdom on network governance is instructive (McGuire and Agranoff 2011). Last not least multi-level governance stands for the permanent adaptation of institutions and regulations. Particularly under the influence of the two aforementioned changes in the dimensions of politics and policy, polity-making remains open to institutional changes (Piattoni 2010, p. 23). For the aspect of mobilizing potentials for resilience-related as well as interactive policy-making, these changes may refer to increased citizen participation or administrative, political or fiscal decentralization. At least hypothetically, the resilience of a city-region may increase with the extent of fiscal and administrative decentralization as this increases the overall capacity to react in a variety of ways.

9.4 City-regional Governance in the Ruhr—Prepared for Resilience?

The following sections seek to describe the institutional pitfalls and issues as well as solutions that emerged when the above-mentioned principles of resilience guide the discussion of pathways for resilient city-region governance. We followed the method of a living lab where a group of researchers and practitioners tried to develop perspectives and solution for the implementation of resilience in a city-regional context over period of 36 months. The living lab constitutes a new form of experimentalist cooperation between practice and academia, allows to test and experiment, trying to avoid the panacea trap (Ostrom 2007, FN 3), by strongly referring to the local context. However, this method does not replace empirical social research but constitutes a different method of knowledge generation.

While implementing our own living lab, we did an analysis of the institutional context, stakeholder interviews, workshops, joined writing of academics and practitioners, and group discussions in order to identify arenas and networks suitable for collaboration on different levels of planning and politics (regional, city, neighbourhood). We were looking for steering committees, working groups, working units, coordination procedures and programmes that a) deal with climate resilience at least marginally and/or b) demonstrate a responsibility or commitment for regional cooperation. Part of the governance analysis was also an examination of informal governance mechanisms. During the course of implementation of the living lab, we distinguished an organizational and inter-organizational dimension of resilience and preparedness—a perspective that is quite common in the literature on cross-organizational learning (Hutter and Lorenz 2018, p. 194). Without organisational embedding and a corresponding shift in relevancies (in the sense of framing and political priorities) at the level of the organizations being the constituent elements of multi-level governance, multi-level governance that promotes resilience cannot function. Organizational aspects refer to internal measures (teams, cross departmental steering groups, knowledge sharing but also aspects of decision-making and accountability), while inter-organizational aspects refer to networks, joined working groups or platforms.

The Ruhr region is situated in the west of Germany and covers an area of 4,400 km^2 with roughly 5.1 Mio. inhabitants. Its settlement structure is polycentric with major cities such as Duisburg, Essen, Bochum and Dortmund and a larger group of medium-sized and smaller towns that are part of the counties (in total 53). The perimeter of this city-region, recently branded as a "city of cities", is the result of the common history of steel production and coal mining. Whether this common history of steel and coal is still a source of cohesion or constitutes a basis for joined post-industrial transformation is debatable. In any case, until today, the experience of being a less favoured region facing the long and thorny structural transformation of a post-industrial region is present in public debates on all levels of policy-making. At least the density of settlements and transport infrastructures may justify to still speak of a functional city-region, partly confirmed by commuter relationships and other functional interrelationships. At the same time, the cities and towns that constitute the city-region present a growing diversity of growth and shrinkage (Dembski et al. 2019). Increased polarization is expected to be the eventual result of this ongoing transformation process.

With regard to the governance structures, the rules and regulations of German local self-government apply (Zimmermann and Heinelt 2016). The Ruhr region has not the status of a jurisdiction, i.e. it is not a county or province. Its major constituent parts in terms of local self-government are the 11 county exempt cities and the four counties. However, the city-region has a long and ongoing history of city-regional collaboration with regional planning and watershed management being the main functions that found institutional anchors. In 1899 the Prussian government created the Emschergenossenschaft (hereinafter Emscher Association), an association responsible for waste water treatment, the sewage system and flood control. Members of this (until today existing) association were the waste water producing actors: municipalities and the industry. The Emscher Association gained prominence from the late 1990s onwards as the association was responsible for the construction of a new sewage system and, in parallel the regeneration of the Emscher River, formally used for a period of more than 100 years as an open sewer for large parts of the region. This new sewage system is one of the biggest infrastructure investments currently under way in Germany. The Emscher Association made investments of in total 5.4 billion Euro until 2020 and is also involved in the management of the Emscher Landscape Park (together with the

Regional Planning Authority). As the river Emscher crosses several cities in the Ruhr, some urban and regional development projects are also part of the portfolio of the association.

The precursor of the current Regional Planning Authority was founded in 1920 as a reaction to the rapid urbanization in the industrializing region. Main responsibilities were the protection of green spaces for recreation and agricultural land use, provincial streets and rough indications for settlement planning. In the 1960s, during the post-war period, the association took over the responsibility for the statutory regional plan. However, in 1979, this competence was taken away and the association was renamed to Kommunalverband Ruhr. Functions that remained in the competence of the Kommunalverband were recreational facilities of regional relevance (regional parks), marketing and voluntary master plans. In conjunction with a political change of the state government in 2004, the planning association was strengthened again and renamed to Regionalverband Ruhr (Regional Association Ruhr, hereinafter RVR). In 2009 the competence for statutory regional planning was given back to the RVR that is now also the owner of a regional development agency under private law. In 2015 the parliament of the state of Northrhine-Westfalia passed a law that allows for sharing of competences between the Regional Association and the counties and cities. As a result, the RVR presents itself as multipurpose association that is active in collaboration with the municipalities in fields such as tourism and industrial heritage, environmental and regional planning and regional development. In addition, the direct election of the regional assembly has been introduced with the local elections in 2020. Also the state spatial plan for Northrhine-Westfalia clearly acknowledges the metropolitan region "Ruhr".

Still, metropolitan governance in the Ruhr area is complex and confusing. A databank of the RVR mentions more than 300 inter-municipal cooperations. These cooperations show different institutional formats and most of them do not cover the whole Ruhr area but only parts. This makes it difficult to evaluate the overall situation in terms of effectiveness. Without a doubt, the RVR is one of the dominant players but there are other inter-municipal associations such as the Emscher Association or the Ruhrverband (the latter being responsible for fresh water management), creating a situation of multipolar governance. Regional governance in the Ruhr is best described by the term "fragmegration" introduced by political scientist James Rosenau (1997) to find a proper description for the emerging Global Governance regime in the 1990s. Although a certain degree of integration and coordinated action can be observed, political polycentrism is still considerable (Schmidt 2013). There is more than one institution but there are many that stand next to each other with different actors, different purposes and different rules and logics for cooperation.

9.5 Bringing Resilience In?

During the implementation of the living lab, we tried to identify possible access points in the described governance arrangement that would allow to give higher political relevance to resilience measures and strategies. The interviews and analysis of documents clearly demonstrated that socio-ecological resilience is an emerging topic in the network of environmental experts and planners of the city-region Ruhr, though largely interpreted through the lens of climate change and adaptation. Due to the low ground level elevation, which is a long-term effect of intensive mining (land subsidence), the risk of floods in some parts of the Ruhr region is high. Extreme weather events tend to happen, causing damage and disruption, in particular (but not only) for the public railway system in 2007 (winter storm Kyrill) and 2014 (convective storm Ela). In fact, climate change and adaptation have been an issue for local governments in the Ruhr region for more than a decade. The impacts of climate change were also a concern during the preparation of the statutory regional plan in 2019. The regional planning authority has a dedicated unit working on climate related data that supports cross-municipal working groups of planners and environmental experts. This unit also fed in expertise and data on climate change and eventual risks in the course of the plan preparation process. Besides the formal plan approval procedure with many events and participatory procedures, working groups of municipal planners supported and moderated by the staff of the regional planning authority are a relevant building bloc of regional governance in the Ruhr, though largely being an informal instrument of exchange between experts.

In addition, the Emscher Association strengthened its role and identity as a regional think tank in the field of flood prevention and watershed management over the years. Besides its legal responsibilities and role as a technical service provider for the member municipalities and firms, the association did much in terms of raising awareness for climate change and invites municipal planners for educational purposes and knowledge sharing. With regard to instruments and mechanisms that contribute to the development of multi-level governance for climate resilience, the "Future Initiative: Water in the City of Tomorrow" should be highlighted.[4] This network, initiated, supported and organised by the Emscher

[4] https://www.wasser-in-der-stadt.de (last access 13.11.2020).

Association brings the topic of water, including heavy rainfall events and climate resilience, into plans and projects of the municipalities of the region. While on the one hand it is located at the regional level and involves the heads of planning departments of the municipalities, the initiative has created a basis with the help of contracts for the contents discussed at regional level to become relevant for action at municipal and district level as well. These contracts, to be signed by the Emscher Association and the respective municipality, include agreements for the achievement of a defined overall objective. While the municipalities commit themselves to take measures and concretise this overall objective at local level, the Emscher Association supports the municipalities financially and with expertise. The Initiative "Water in the City of Tomorrow" is an ideal starting point for the integration of climate-relevant aspects in the sense of a multi-level governance approach, preserving the autonomy of communities but still following a cross-municipal approach. The commitment certainly is the result of incentives and not of potential sanctions.

Potentially, many of the existing arenas and professional networks offer the opportunity to bring the issue of climate change adaptation and institutional resilience more strongly onto the political agenda. However, although the two regional associations (Emscher Association and RVR) as well as many local governments took their responsibilities in their respective spheres of competence, attempts to discuss and create a resilience in multi-level governance structure met some obstacles. We are referring to the generic principles mentioned above in Sect. 9.2. Certainly, it cannot be said that the experts and political decision-makers in the Ruhr region are not well connected. However, the quality in terms of redundancy, diversity, robustness, connectivity and thus the resilience of the informal relationships is questionable for the following reasons:

- The stability and diversity of connectivity is not given, which potentially limits resilience. For one, the arenas for cooperation and knowledge exchange largely gather municipal planning officers and experts, resulting in closed expert communities. Stability is sometimes hampered by change of personnel, not least because of retirement. In principle, administrative actors consider professional cooperation and exchange across municipalities to be better than cooperation and exchange in the sphere of politics. There seems to be a siginficant knowledge gap between politics and administration which restricts the creation of a shared relevance for action. The connectivity of professionals (experts) and power promoters (politicians) has increased strongly at the intermunicipal level, but communication is still uncontrolled. The coexistence of the networks of professionals and power promoters may also create disruptions and disparities in terms of priority setting (not least between smaller and bigger municipalities).

- With regard to the organizational level, it also appears that the departmental principle is reproduced in the informal arenas and thus minimizes diversity. This means that in the various arenas and working groups, experts of similar disciplinary background and of similar status meet. The workings groups of environmental officers, round of deputy mayors, or planners reproduce the silo-mentality of public administration and this hampers diversity.
- A further concern are unclarified role distributions, in particular within the group of high level decision-makers. Who is expected to take the lead and who would be considered as a competent leader in the regional arena? Is it one of the two regional organisations (the regional planning authority and/or the Emscher Association) or the biggest cities that in a way claim to be policy leaders?
- The role of network management is rather weak. The fact that there are quite a number of bodies, networks and arenas, which in part exist for several years and to some extent overlap in terms of persons and content, could prove disadvantageous. Interview partners praised the collegial exchange, but the relevance of the individual networks can hardly be weighed against each other. At least, there is a lack of strategic coordination and agreement on the overall responsibility and the policy priorities. It is not clear at all which arena is the appropriate one to discuss issues of resilience and climate change adaptation in a more strategic way. Hence, the question is whether these informal arenas are actually capable of inserting climate resilience as a new political and technical relevance or policy priority into existing structures of city-regional policy and politics. Without a doubt some of the informal arenas can function as seedbeds for innovation and sustained collaboration. However, there is no reference from the past that could show that this has already been done in other fields of action. Some municipalities showed more interest, also in conjunction with federal funding programs, others are less interested.
- Among the reasons that seem to hinder the implementation of resilience were budget problems and limited staff capacities, in particular in smaller municipalities. This is relevant for the criteria of redundancy and robustnes as these cause costs. Keeping of overcapacities and fallback positions enrich the options to react and offer alternatives when needed but in a situation of strained budgets this is almost impossible. Many municipal planners hardly have time

and resources to try new pathways next to their daily routines. Temporary funding programmes of upper-level government seem to be a pragmatic solution for this problem, but there is a lack of continuity and stability.

- Robustness is not very strong. While there is an increasing amount of knowledge about the state of the socio-ecological system and the eventual risks of climate change, the possibility of graduated sanctions and the existence of conflict-resolution mechanisms is not given.
- In addition, the degree of autonomy of German municipalities vis a vis higher governmetal layers is high but the mentioned budget problems prevent a sufficient leeway to self-organize a decentralized governance arrangement.

The last point refers to multi-level governance and the aspect of mobilization and joined policy-making in particular. The regional planning authority is not responsible for detailed spatial specifications but flood events are considered local events. Hence, the question of the appropriate level of intervention arises. In terms of mobilization, climate resilience seems to be more of a local matter. The regional living lab met difficulties to clarify that resilience is also in need of a regional perspective and, as a consequence, inter-organizational structures of knowledge sharing and decision-making. In terms of multi-level governance, this is less a problem of mobilization but of making the regional relevance plausible. This calls for intensified boundary-spanning and coupling of levels. A further obstacle was the absence of an overall binding political goal for the subject area of interest here. The absence of a quantitatively or qualitatively formulated political objective at state level gives little incentive for municipalities to become active and start collaboration with the other actors in the region. The conditions of ambiguous policy goals and a mix of symbolic and experimental policy-making may result in non-decisions—or radical change once a window of opportunity opens.

9.6 Conclusion

In this chapter, we argued that multi-level governance must, in the context of polycentric city-regions, ensure the increase of the overall organizational capacities for resilience. Despite the detailed insights described in the previous section we want to highlight some more general insights. The first one refers to epistemic stability in a situation of pluralistic network governance, the second one to environmental justice.

Uncontrolled and multipolar communication creates redundancy, shared knowledge and a variety of options. This type of connectivity increases resilience in the sense of exchange of knowledge and experience. But this can also result into a situation of contingency, i.e. where everything is possible but nothing is mandatory, with the eventual risk of doing nothing. Rob Hoppe characterized this type of networked governance as "open issue networks". These networks are pluralistic, unstable and they allow new actors to enter the network relatively easily and thus to introduce new relevancies and knowledge claims. The more open and emergent arrangements may also facilitate citizen participation as well as (competing) scientific perspectives to be recognized. However, an alternative scenario would be rapid topic and content changes as a consequence of macropolitical changes. The result is a pluralistic knowledge order and an incremental mode of problem-solving ("random-evolutionary processes"; Hoppe 2011, p. 135) that resembles a garbage-can-like problem and goal finding (Cohen et al. 1972). What is more likely, however, is the emergence of coalitions of convenience that take options for opportunistic action whenever possible (Hoppe 2011, p. 135). Expert knowledge is predominantly used by the actors to underpin their own position, which tends to harm the trustworthiness of the expertise. In normative terms, resilience in such a context implies that a range of knowledge problems needs to be solved. These problems result from:

- the uncertainty associated with climate change regarding the probability of occurrence of extreme weather events or disruptions;
- the question of which people (in which area) will be affected most;
- and the contested assessments of the situation and the evaluation of possible (or impossible) options for action (Lung et al. 2013).

The challenge is one of mobilizing expertise and resources and finding appropriate (inter-) organizational forms to share them. One suggestion that emerged in the course of the living lab was the establishment of a competence centre or regional think tank for climate resilience, equipped with sufficient organizational and financial autonomy and being responsible for data management, knowledge sharing, awareness raising, or in more theoretical terms mindfulness, preparedness, and network management. This solution may be implemented without deep institutional or organizational changes. Rather, the competence centre would bundle and support existing initiatives and facilitate joined problem-solving.

On the other hand, resilience poses a quite different challenge for multi-level governance: Climate resilience must consider that climate change adaptation will raise the issue of socio-ecological inequality as climate related harms will be distributed unevenly. Even when not investigated on household level (socio-spatial polarization) it was rather obvious that there are powerful differences between smaller municipalities und bigger cities (the latter ones determining the agenda, also in terms of non-decision-making), between those cities with higher risks and the ones less exposed to climate related risk and between those cities with severe budget problems and those in a better financial situation.

Hence, we see two essential requirements for multi-level governance, which are completely different in character. The reduction of socio-ecological inequality usually generates distribution conflicts that are the result of an unequal distribution of risks, burdens as well as resources. This is in particular relevant in a city-region with moderate economic resilience, still facing the structural change of deindustrialization (Cowell 2015). We would argue that economic resilience and social-ecological resilience constitute two different types of action frames with partly competing or even contradictory goals and rationalities. If negotiations and mediations take place, however, a well-functioning multi-level governance can formulate the rules for compensations for unequal burdens and thus ensure acceptance. The multi-level governance of the European Union provides a rich illustrative material for such rules with positive as well as negative examples. The second essential requirement is about finding and validating knowledge about the temporal and spatial distribution of climate-related risks in an inter-organizational environment. Here, the rich literature in policy analysis and organization science has much to offer.

References

Anderies, J. M., Janssen, M. A., & Ostrom E. (2004). A framework to analyze the robustness of social- ecological systems from an institutional perspective. *Ecology & Society 9*(1), 1–17. https://www.ecologyandsociety.org/vol9/iss1/art18.

Ashby, W. R. (1956). *An introduction to cybernetics*. London: Chapman & Hall.

Beck, U. (1992). *Risk society. Towards a new modernity*. London: Sage.

Beck, U. (1994). The reinvention of politics: Towards a theory of reflexive modernization. In U. Beck, A. Giddens, & S. Lash (Eds.), *Reflexive modernization.* (pp. 1–55). Cambridge: Polity Press.

Bohland, J., Davoudi, S., & Lawrence, J. (Eds.). (2018). *The resilience machine.* London: Routledge.

Böhret, C. (1990). *Folgen. Entwurf für eine aktive Politik gegen schleichende Katastrophen.* Wiesbaden: Springer.

Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A Garbage can model of organizational choice. *Administrative Science Quarterly, 17*(1), 1–25.

Cowell, M. (2015). *Dealing with deindustrialization. Adaptive resilience in American midwestern regions*. New York: Abingdon.

Davoudi, S., Lawrence, J., & Bohland, J. (2018). Anatomy of the resilience machine. In J. Bohland, S. Davoudi, & J. Lawrence (Eds.), *The resilience machine.* (pp. 19–38). Routledge.
Dembski, S., Sykes, O., Couch, C., Desjardins, X., Evers, D., Osterhage, F., Siedentop, S., & Zimmermann, K. (2019). Reurbanisation and suburbia in northwest Europe: A comparative perspective on spatial trends and policy approaches. *Progress in Planning*. https://doi.org/10.1016/j.progress.2019.100462.
Duit, A. (2016). Resilience thinking: Lessons for public administration. *Public Administration, 94*(2), 364–380.
Duit, A., Victor, G., Katarina, E., & Ebbesson, J. (2010). Introduction. governance, complexity, and resilience. *Global Environmental Change, 20*, 363–368.
Feindt, P. H., & Weiland, S. (2018). Reflexive governance: Exploring the concept and assessing its critical potential for sustainable development. Introduction to the special issue. *Journal of Environmental Policy & Planning 20*(6), 661–674.
Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change, 16*(3), 253–267.
Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of socio-ecological systems. *Annual Review of Environmental Resources, 30*, 441–473.
Fuchs, S., & Thaler, T. (Eds.). (2018). *Vulnerability and resilience to natural hazards.* Cambridge: Cambridge University Press.
Holling, C. S., & Gunderson, L. (2002). Resilience and adaptive cycles. In C. S. Holling & L. Gunderson (Eds.), *Panarchy. Understanding transformations in human and natural Systems* (pp. 25–62). Washington: Island Press.
Hood, C. (1991). A public management for all seasons. *Public Administration, 69*(1), 3–19.
Hoppe, R. (2011). *The governance of problems: Puzzling, powering and participation.* Bristol: The Policy Press.
Hutter, G. (2017). Dealing with surprise in urban regions—Some ideas and examples for planners. In S. Deppisch (Ed.), *Urban regions now & tomorrow. Between vulnerability, resilience and transformation* (pp. 145–64). Wiesbaden: Springer.
Hutter, G., & Lorenz, D. F. (2018). Social resilience. In S. Fuchs & T. Thaler (Eds.), *Vulnerability and resilience to natural hazards.* (pp. 190–213). Cambridge: Cambridge University Press.
Janis, I. L. (1972). *Victims of group think*. Boston: Houghton Mifflin.
Jonas, A. E. G. (2012). City-regionalism: Questions of distribution and politics. *Progress in Human Geography, 36*(6), 822–829.
Jore, S. H. (2020). Is resilience a good concept in terrorism research? A conceptual adequacy analysis of terrorism resilience. *Studies in Conflict & Terrorism.* https://doi.org/10.1080/1057610X.2020.1738681.
Levitt, B., & March, J. G. (1988). Organizational learning. *Annual Review of Sociology, 14*, 318–340.
Lung, T., Lavalle, C., Hiederer, R., Dosio, A., & Bouwer, L. M. (2013). A multi-hazard regional level impact assessment for Europe combining indicators of climatic and non-climatic change. *Global Environmental Change, 23*(2), 522–536. https://doi.org/10.1016/j.gloenvcha.2012.11.009.
McGuire, M., & Agranoff, R. (2011). The limitations of public management networks. *Public Administration, 89*(2), 265–284.

Nevarez, J. (2018). *Governing disaster in urban environment*. New York: Lexington Books.
Orton, J. D., & Weick, K. E. (1990). Loosely coupled systems: A reconceptualization. *The Academy of Management of Review, 15*(2), 203–223.
Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences, 104*(39), 15181–15187. https://doi.org/10.1073/pnas.0702288104
Pelling, M. (2010). *Adaptation to climate change: From resilience to transformation.* London: Routledge.
Peters, B. G., Andrew, J., & Jale, T. (2017). Over-reaction and under-reaction in climate policy: An institutional analysis. *Journal of Environmental Policy & Planning, 19*(6), 612–624. https://doi.org/10.1080/1523908X.2017.1348225.
Piattoni, S. (2010). *The theory of multi-level governance. Conceptual, empirical, and normative challenges*. Oxford: Oxford University Press.
Rogers, P. (2018). The resilient city: Where do we go from here. In J. Bohland, S. Davoudi, & J. Lawrence (Eds.), *The resilience machine.* (pp. 125–143). London: Routledge.
Rosan, C. (2016). *Governing the fragmented metropolis: Planning for regional sustainability*. Philadelphia: University of Philadelphia Press.
Rosenau, J. N. (1997). *Along the domestic-foreign frontier. Exploring governance in a turbulent world*. Cambridge: Cambridge University Press.
Sager, F. (2006). Policy coordination in the European metropolis: A meta-analysis. *West European Politics, 29*(3), 433–460.
Schmidt, M. (2013). *Regional Governance und Infrastruktur. Kooperationen in der Wasserver- und Abwasserentsorgung am Beispiel der Stadtregionen Frankfurt/M, Berlin und Ruhr*. Detmold: Rohn Verlag.
Schmitter, P. (2004). Neo-functionalism. In A. Wiener & T. Diez (Eds.), *European integration theory.* (pp. 45–74). Oxford: Oxford University Press.
Scott, A. J. (2019). City-regions reconsidered. *Environment & Planning A: Economy and Space, 51*(3), 554–580. https://doi.org/10.1177/0308518X19831591.
Voß, J. P., & Bornemann, B. (2011). The politics of reflexive governance: Challenges for designing adaptive management and transition management. *Ecology & Society 16*(2), 1–9. https://www.ecologyandsociety.org/vol16/iss2/art9/.
Weick, K. E., & Sutcliffe, K. M. (2001). *Managing the unexpected: Assuring high performance in an age of complexity*. San Francisco: Jossey-Bass.
Wildawsky, A. (1988). *Searching for safety*. New Brunswick: Transaction Publishers.
Zimmermann, K. (2020). What is at stake for metropolitan regions and their governance institutions? In K. Zimmermann, D. Galland, & J. Harrison (Eds.), *Metropolitan regions, planning and governance.* (pp. 59–75). Cham: Springer.
Zimmermann, K., & Heinelt, H. (2016). German metropolitan policies. In A. Cole & R. Payre (Eds.), *Cities as political objects.* (pp. 156–174). Cheltenham: Elgar.

10 Project-Based Learning for Building Urban Resilience—Reflecting on Project Examples of Climate Change Adaptation in the Dresden Region

Gérard Hutter and Alfred Olfert

10.1 Introduction

The significance and relevance of the term "resilience" steadily increased during the last years of searching for strategies and measures of climate change adaptation at European, national, regional, and local level. For instance, "climate resilience" seems to become the new "Leitbild" of the German strategy for climate change adaptation (DAS) (Die Bundesregierung, 2020). Policy makers and analysts justify the reference to "resilience"—more or less explicitly—with regard to the consideration of uncertainties of climate change, its consequences, and effective strategies in the face of societal context conditions that are characterized by crisis and conflicts. One important argument to use the "resilience-word" is that the term connotes something positive, something to thrive for in the face of an uncertain future, whereas the notion of risk reduction in the context of climate change sounds less appropriate to motivate people to actually take action for climate change adaptation (e.g., Abeling et al. 2018).

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Somehow, it has become standard procedure to introduce the term "resilience" with—metaphorically speaking—a disclaimer that there are many different and partially incompatible definitions of the term in the diverse scientific literatures and related policy fields. We will not comment on this conceptual pluralism in detail (see Ansell, 2019). This chapter is based on the widely cited paper by Meerow and colleagues (2016) that conceptualizes resilience as urban resilience from a system (and also network) perspective. Urban systems are relatively permanent phenomena characterized by complex social, spatial, and temporal scales. In contrast, a single project is characterized by its design as temporary collective action. After the project duration and project goals are accomplished (or not), in a formal sense, the project is meant to disappear. How then can projects contribute to building urban resilience?

Relations between projects as temporary organizations on the one hand and permanent systems on the other attract more and more attention (Braun & Sydow, 2019; Davies, 2017; Sydow & Windeler, 2020). The climate governance literature increasingly addresses these relations between the temporary and the permanent through asking how "experiments" influence institutionalized processes of climate change adaptation (Ansell & Bartenberger, 2016; Chu, 2016, Turnheim et al. 2018). We approach such relations from a learning perspective and seek to understand how actors in research and practice learn how to build urban resilience over time, even if projects as learning opportunities are limited in time, content focus, and resources.

The chapter mainly follows a conceptual purpose. In Section 10.2, we provide the outline of a typology of project-based learning opportunities for building resilience in the context of climate change adaptation in cities and regions. The typology has two dimensions: (1) Project-based learning opportunities vary whether they refer to only some parts of an urban system or the whole urban system. (2) Opportunities vary whether they focus on adaptive capacity only or also transformative capacity. Transformations necessarily entail "deep" changes in social structures and cultural conditions of urban systems. Types of learning opportunities are consequential for how we understand learning *from* projects of climate change adaptation. Section 10.3 illustrates the heuristic value of the typology through our reflections on two projects in the Dresden region in which we were and still are involved:[1] the project REGKLAM that was accomplished in the years

[1] Below, sub-section 10.3.1 gives some more information on the methodological dimension of this chapter. For instance, we label our contribution to the edited volume as "reflections" on cases of climate change adaptation projects and not as case study *evidence* in a narrow sense (Gerring 2017).

from 2008 to 2013 and the project “HeatResilientCity (HRC)” that is accomplished in the years from 2017 to 2021. Section 10.4 concludes our argumentation through suggesting some issues for future research.

10.2 Towards a Typology of Project-Based Learning Opportunities for Building Urban Resilience

The following conceptualizes the relations between resilience, urban systems, projects, and learning efforts. All these terms are words with “messy histories” (Ansell, 2019, p. 3). Hence, it is important to clarify their meaning to some extent and to show how they are related to each other. We do this in three steps. Sub-sect. 10.2.1 introduces the concept of urban resilience (as proposed by Meerow et al. 2016 and Meerow & Newell, 2016). Among others, this concept enhances a systemic view on urban resilience and leads to the distinction between whole and partial system change. This distinction is important, because urban systems are highly complex and dynamic phenomena. It is very unlikely that any single project may “produce” deliberate systemic change. It is much more likely that a project or a series of projects are deliberately related to specific parts of an urban system. Sub-sect. 10.2.2 distinguishes between learning to increase adaptive and transformative capacity and Sub-sect. 10.2.3 introduces the outline of a typology that differentiates four types of project-based learning opportunities for building resilience in cities and regions.

10.2.1 Urban Resilience and Learning from Projects

There is an abundance of definitions of resilience (Coaffee & Lee, 2016). One can get lost in this complexity of meanings and their conceptual relations. We do not deal directly with this conceptual complexity, but adopt a specific understanding of resilience as urban resilience. Meerow and Newell (2016, p. 7) define urban resilience 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.” This definition is a good starting point to frame our argumentation:

- *Ability:* We understand urban resilience as an ability (or capacity) to deal with disturbance and change in external and internal context conditions. This understanding is rather silent on using the resilience-word for ideological and political purposes (e.g., Coaffee & Lee, 2016; Hutter & Lorenz, 2018; Kuhlicke, 2013). We do not doubt that, in the "real world", some actors may use the term "resilience" with ideological motives and/or for political tactics, but our understanding of urban resilience does not emphasize these possibilities. As said, we frame resilience as an ability of urban systems.
- *Urban systems and their differentiation:* Like resilience, the term "system" may also be understood in different ways, for instance, with regard to a specific system theory (e.g., theories of closed, open, or autopoietic systems). In this chapter, system simply means that urban resilience emerges from complex processes that relate to manifold ecological, social, and technical elements—more or less directly coupled. Systems are in most cases differentiated in sub-units (or social, socio-technical etc. sub-systems). Urban systems are phenomena of very high complexity and levels of differentiation, for instance, with regard to the scales of social action (e.g., vertically from the level of networks to single nodes within networks and horizontally with regard to diverse societal spheres like urban economy, politics, and administration).
- *Spatial and temporal scales:* Urban systems are characterized by a multitude of spatial and temporal references. For instance, it is possible to differentiate between different spatial levels and types of places as well as a multitude of temporal references (e.g., the rhythms, tempi, and durations of events and activities in urbans systems). Urban systems have histories and futures ("shadows" of the past and the future).
- *Maintenance/coping, adaptation, transformation:* Some scholars keep resilience and transformation distinct. For instance, Pelling (2011, p. 51) defines resilience in a general way as the "functional persistence in a changing environment“. From his viewpoint, resilience is restricted to changes in technology and organizational practices, whereas changes in social structures (e.g. economic and political regime changes) and cultural conditions are excluded from the notion of resilience (e.g., change in the justification of social inequality). The concept of Meerow and colleagues (2016, Meerow & Newell, 2016) is a broader one. It includes the ability to maintain and cope, to adapt, and to transform urban systems to increase adaptive capacity in the future.

To avoid misunderstandings, it is important to note (1) that the characterization of urban systems as more or less resilient is a matter of degree and of whether a statement about degree refers to coping, adaptation, or transformation. (2) Furthermore, the ability to cope, adapt, and transform urban systems needs to be demonstrated empirically, *if such empirical claims are made with regard to specific cases of urban systems* (Gerring, 2017). (3) It is also important to note that considering coping, adaptation, and transformation does not necessarily imply that such efforts are in harmony with each other. For instance, research on "regional resilience" argues that efforts of actual adaptation in the present may be in tension with efforts to ensure the adaptability of cities and regions in the future. Efforts to ensure adaptability are (to some extent) similar to initiatives of transformation (e.g., Boschma, 2015). (4) We also want to question that "to quickly transform systems" (see the citation above) is highly likely in many cases of urban systems. The notion of urban resilience (Meerow et al. 2016) is merely, as mentioned, a starting point for conceptualizing "project-based learning for urban resilience"—and now we turn to the learning part of this expression.

There are diverse definitions of learning (Easterby-Smith & Lyles, 2011). Many scholars agree that learning is present, if actors *experience reflection on and deliberate change in knowledge* on relations between the content, processes, and context conditions of action (e.g., Carroll et al. 2003; Swan et al. 2010). Different theories, models, and methods seek to differentiate between how this happens, the degree of deliberateness of change, various types of knowledge, and so forth. Learning can happen from experience in the past and anticipated "experience" in the future. Learning is a manifestation of "human agency" (Emirbayer & Mische, 1998)—so is the development and implementation of a project.

Projects are combinations of "people and other resources brought together in a temporary organization and process to achieve a specified goal. What distinguishes projects from all other organizational activities–such as manufacturing and services–is that a project is finite in duration, lasting from hours, days, or weeks to years and in some cases decades…a project organization is temporary and disposable by design. Each project brings together people and resources needed to accomplish a goal and disappears when the work is completed." (Davies, 2017, p. 2).

Projects may vary in many features (size, uniqueness, complexity, uncertainty, and ambiguity of the task, project team composition, and so forth). However, any project is established with the institutionalized expectation that project goals are to be accomplished, whether this actually happens in the end or not. Projects channel attention of multiple actors on developing, establishing, specifying, implementing, and evaluating the accomplishment of the goals of organized action—within a designed project duration. Project partners may appreciate that exactly this "temporary nature" of joint action forces them to focus on the formulation and justification of goals as well as on effective, efficient, and appropriate ways how to actually accomplish goals (Braun & Sydow, 2019).

In this chapter, it is especially important to distinguish between two forms of project-based learning (Hartmann & Dorée, 2015; Swan et al. 2010):

- Projects are learning opportunities in the sense that actors involved in projects learn how to develop and implement such collective action during the project duration ("learning *in* projects"). We largely abstract from this type of learning.
- Learning also happens before and after the beginning and the end of a project. We focus on learning after the formal completion of projects on climate change adaptation ("Learning *from* projects").

Learning agents may learn from only one project or multiple projects. Ansell and Bartenberger (2016) show that this distinction is crucial to understand "varieties of experimentalism" with regard to the provision of small contributions for solving complex problems like climate change adaptation in cities and regions, for instance, through pilot projects.

Why are projects and project-based learning efforts relevant for urban resilience? One obvious answer would be that projects are pervasive in many sectors of society and related policy fields, not only in typical project-based industries and sectors like the construction industry and advertising, but also in the "creative industries", urban development, and climate change adaptation—to name only a few (Braun & Sydow, 2019, Turnheim et al. 2018). Urban systems are also characterized by pools of projects in various sectors and urban areas. Projects need not necessarily be explicitly designed for building resilience, but many do by influencing structures, resources and capabilities of agents and institutions. Projects directed towards specific goals other than resilience may be relevant contributions for building resilience.

10.2.2 Learning from Projects to Increase Adaptive and Transformative Capacity

Given that projects, even large ones (see below REGKLAM), are goal-driven temporary collective actions of a set of project partners of limited scale and scope, it is questionable that they intentionally and strongly influence urban systems. However, project intentions may vary. To further understand the relations between project-based learning on the one hand and urban resilience on the other, we need to consider that project goals can be very different with regard to building resilience. The following mentions two options: Agents may seek to increase the adaptive capacity of an urban system. They may also try to initiate and establish more radical changes in urban systems:

- *Learning from projects to increase the adaptive capacity of and in urban systems:* Over time, urban systems are characterized by specific social structures (e.g., network structures and "structural holes", urban power relations), cultures (e.g., values, norms, cognitive structures), and practices. Actors involved in social-ecological and social-technical networks act to some extent—more or less explicitly—in accordance with societal institutions that encompass regulative, normative, and cognitive features (Scott, 2014). Adaptive capacity is the capacity of an urban system or sub-system to deal with current and future disturbance and change *without* fundamentally questioning existing social structures, cultures, and practices and without the intention of systemic change. For instance, knowledge-intensive organizations (like universities) may generate new knowledge on regional and local climate change, on climate change consequences, and options to deal with such changes. Within the given structural and cultural conditions of an urban system, this new knowledge diffuses into the relevant socio-ecological and socio-technical networks. The diffusion of new knowledge leads to a significant increase in adaptive capacity of an urban system or some parts of it. But it does not necessarily lead to a radical change of the system.
- *Learning from projects to increase the transformative capacity of and in urban systems:* Efforts of building resilience as transformative capacity face the challenge of realizing systemic change ("deep" structural and cultural change). This means, first and foremost, "deep" change of the *whole* urban system with regard to its constituent socio-ecological and socio-technical networks across temporal and spatial scales. This can also concern only parts of an urban system (see below Sub-sect. 10.2.3). Systemic change may be conceptualized differently with regard to the focal urban system and based on the chosen concepts and theories to define the system elements and their relations (Tödtling & Trippl, 2018; Wolfram, 2016). Furthermore, in the context of urban resilience and climate change adaptation, it is important to note that transformative capacity refers to deliberate change for increasing adaptive capacity in the future. Deliberate change encompasses efforts of overcoming limitations of current adaptive capacity and establishing innovations in social structures, cultures and practices. In contrast, researchers studying "regional resilience" are more concerned about relations between resilience, adaptation, adaptability, and regional economic growth (e.g., Boschma, 2015).

At first sight, we could assume that learning for adaptive capacity focuses only on parts of urban systems, whereas efforts of transformative capacity address issues of “deep” change at the level of the whole urban system. These are possible options. However, and at second thought, in the next sub-section we argue that the dimension of urban resilience related to whole systems and sub-units on the one hand and the dimension of efforts to increase adaptive and transformative capacity on the other stand in an orthogonal relation to each other. Hence, we can combine both dimensions to construct the typical 2×2-matrix for heuristic application in studies on building resilience (Gerring & Christenson, 2017).

10.2.3 Outline of a Typology of Project-Based Learning Opportunities

We summarize our conceptual statements through proposing the outline of a typology of project-based learning opportunities for building urban resilience. Two dimensions characterize the typology. Firstly, learning opportunities may vary with regard to whether learning agents consider interdependencies of a whole urban system (similar to actors that make policies for “Regional Innovation Systems (RIS)”, Tödtling & Trippl, 2005, 2018) or whether they focus learning efforts on a specific part of an urban system. Secondly, the purpose of project-based learning for building urban resilience may vary. Learners may follow modest ambitions to increase adaptive capacity directly without questioning social structures, cultures, and practices. If they are ambitious and willing to move out of their “comfort zone”, they may deliberately face the “tough issues” of increasing transformative capacity for more adaptive capacity in the mid- to long-term future. Table 10.1 summarizes these conceptual possibilities.

Given highly complex urban systems, a single project will often only provide a small contribution to solve big problems. Weick (1984) suggests that big problems require also small solutions (“small wins”), because appreciating such wins facilitates focused collective action to actually change the world. He recommends to think from big problems to small solutions. At present, in climate change adaptation research, it´s the other way round. Many pilot projects on climate change governance provide small contributions to urban systems. Now, there is the question how to move “beyond experiments” and how to establish intended “deep” change of urban systems (Turnheim et al. 2018). We propose that the typology of project-based learning opportunities considers both directions of thinking—from big to small and the other way round. The following briefly describes each type in turn:

Table 10.1 Outline of a typology of project-based learning opportunities for building urban resilience

		Dimension 2: Purpose of learning	
		Learning for adaptive capacity	Learning for transformative capacity
Dimension 1: System reference of learning	Urban sub-system	Type 1 “Staying in the comfort zone”	Type 3 “Strategic positioning of change in sub-systems”
	Urban system	Type 2 “Expanding the agenda of climate change adaptation”	Type 4 “Addressing tough issues for system-wide change”

- *Type 1 “Staying in the comfort zone”:* Learning is deliberate change in knowledge. Deliberation is easier to understand, to plan and to implement, if learning agents remain in their comfort zone. Learning opportunities arise out of establishing a focus on well- specified small contributions to big problems. Hence, also in the face of climate change adaptation and the challenges of building resilience, learning agents should not be ashamed of focusing on only parts of urban systems and adaptative capacity. Exploiting learning opportunities of type 1 is necessary, but not sufficient for building urban resilience.
- *Type 2 “Expanding the agenda of climate change adaptation:* Learning agents are able to move out of their comfort zone without necessarily questioning deep social structures, cultures, and practices. They may seek to expand the agenda of learning to build adaptive capacity in the context of climate change adaptation of whole urban systems. Below in Sect. 10.3, we encounter such a project-based effort through considering the example of the project REGKLAM. Project partners (mainly from science as well as representatives from state and local administrations and business organizations) tried to develop a comprehensive agenda for climate change adaptation in the Dresden region. They formulated an adaptation program (without intensive reference to the notion of urban resilience). The example shows that project partners had difficulties to establish a strategic focus to develop the adaptation program and that the contribution of the program to actual change in the Dresden region is questionable. Hence, even if learning agents stay within existing social structures, cultures, and practices, project outcomes may be uncertain.

- *Type 3 "Strategic positioning of change in sub-systems":* Van Buuren and Loorbach (2009) argue that project-based learning efforts in line with types 1 and 2 will be "conservative" and limited to delivering specific problem solutions that can be directly *exploited* in existing social structures and cultures. As regards the uncertainties of climate change and its consequences, especially related to extreme events like low-probability floods and heat waves, such "play within the rules of the game" (or such stay within the regime, to use the terminology of "sustainable transitions research", Köhler et al. 2019) may be not enough. Learning agents that consider opportunities of type 3 seek to establish transformation-oriented or transformative projects to increase the odds of "deep" structural and cultural change in urban systems. However, they do not attempt to change the whole system. They define a selective focus for increasing transformative capacity. For instance, they may attempt to consider what actions are possible and effective in case of anticipated low-probability and high-impact events in the context of climate change (e.g., a heat wave with extreme duration). Learning opportunities of type 3 combine the benefits of specification through strategic *positioning* of change with the ambition to *move out of the comfort zone* through initiating and establishing transformative change.
- *Type 4 "Addressing tough issues for system-wide change":* Learning agents that attempt to establish transformative change of whole urban systems face manifold tough issues. This is so for many reasons. For instance, systemic change may lead to conflicts and power plays between established actors on the one hand and "newcomers" that seek to change current practices of whole urban systems on the other. Furthermore, deliberate systemic change may be difficult to accomplish because of fragmentation between system elements in cities and regions (e.g., "fragmented metropolitan regions", Tödtling & Trippl, 2005, p. 1209; see also Zimmermann & Lee in this volume). On the level of whole urban systems, we furthermore need to consider not only single projects, sets of projects, and project networks, but whole "project ecologies" (Davies, 2017). If many organizations are involved in many projects, then the concept of a "project ecology" applies (Grabher & Ibert, 2010). Hence, one single project may indirectly contribute to building urban resilience through change in project ecologies and this, of course, also holds for multiple projects (Ansell & Bartenberger, 2016). Actors interested in learning of type 4 may work out the implications of learning through referring to the so-called "Multi-Level Perspective (MLP)" that addresses the relations between niche activities, socio-technical regimes and socio-technical landscape developments (e.g., Köhler et al. 2019).

Proposing the outline of a typology makes sense, if types are analytically distinct (Gerring & Christenson, 2017). However, this is only the conceptualization of the chapter. In the “real world”, these analytically proposed typical learning opportunities are not necessarily mutually exclusive. We also do not argue that actors involved in urban systems often face all learning opportunities in their daily practices. To consider the “healthy” difference between concept and “reality” (Weick & Westley, 1996), the following reports on two projects examples of climate change adaptation in the Dresden region. This will inform us about the heuristic value of the typology of project-based learning opportunities for building urban resilience.

10.3 Projects on Climate Change Adaptation—Examples in the Dresden region

10.3.1 Methodological Note

This chapter focuses on conceptual statements about project-based learning for building urban resilience in the context of climate change adaptation. Statements are justified primarily through referring to the relevant literatures on project management and learning as well as urban resilience and climate change governance (e.g., Braun & Sydow, 2019; Meerow & Newell, 2016, Turnheim et al. 2018). We believe that perception without conception is blind and that conception without perception is empty (Van de Ven, 2007). Therefore, this section reports our perceptions of project examples of climate change adaptation in the urban region of Dresden.

We were both intensively involved in project development and implementation from start to finish, which holds especially for the first example, the project REGKLAM. Our involvement in the two project examples implies some research opportunities and risks. The involvement enables us to reflect on project examples that we know in detail (e.g., Hutter, 2014; Hutter & Bohnefeld, 2013; Hutter & Otto, 2017; Olfert et al. 2014; Schünemann et al. 2020). However, reflecting on our own project involvement, we may be inclined to “present things better than they actually were”. We could be tempted to present success cases and to downplay failures and shortcomings (Ansell & Bartenberger, 2016). Furthermore, our suggestions about the examples may reflect some unconscious selection bias that we are unable to articulate in this chapter. We hope that relating conceptual arguments with the ex-post analysis of the project examples helps to avoid an unjustified bias in this chapter. We label our suggestions on the examples as “reflections”, because the following cannot count as case study evidence in a narrow sense (Gerring, 2017). The analysis may count as retrospective "sensemaking" (Weick, 1995) of our project involvement.

Some methodological considerations why the two project examples are worth referring to in this chapter are in order (Gerring, 2017, p. 41):

- The first example mentions a completed project in the Dresden region that was large in terms of people involved and resources used (based on funds of federal government). One could expect that a large project on climate change adaptation has a strong effect on urban systems. In contrast to this expectation, our reflections suggest that project size and duration per se are not decisive for deliberate change in urban systems and this should hold also for building resilience in the face of climate change. Of course, size and duration may matter with regard to other issues of urban systems. From the example REGKLAM we learn that building urban resilience based on "project pools" is more important than following a narrow focus on a single project.
- The second project example is deliberately related to the first example. Some actors involved in REGKLAM developed with partners from another German city, the city of Erfurt, the project "HeatResilientCity (HRC)". One could expect from such related project variety that, due to partial stability in the actor constellation, partners were and still are engaged in inter-project learning. Our reflections suggest that such inter-project learning actually happened.

Both examples point to the argument that project-based learning for building urban resilience in the context of climate change adaptation becomes salient with regard to the pool of projects in urban systems. Learning from and ex-post evaluations of single projects may still be beneficial, but they are less prominent in our argumentation.

10.3.2 The Project REGKLAM: Do Large Projects Always have Strong Effects?

REGKLAM[2] was a large project of both scientists and practitioners on climate change adaptation in the Dresden region with an overall budget over 10 Mio. EUR and a project duration of five years (from the year 2008 to the year 2013). The context conditions, processes, and contents of REGKLAM are complex and any

[2]"Regionales Klimaanpassungsprogramm für die Modellregion Dresden" can be translated as "Regional climate change adaptation program for the model region Dresden".

single study cannot do this project “justice” in every respect. However, in what follows, we want to suggest that this project example aptly illustrates two points of our argumentation:

- The probability is in many cases low that *any single* project, even a large one, leads to deliberate change of social structures and cultures in and of urban systems. In retrospection as well as in anticipation, especially learners interested in learning from only one project have to demonstrate clearly the conditions for deliberate change that actually happens with regard to deep structures, cultures, and practices (Goertz & Mahoney, 2012). To address deliberate change as building urban resilience in the context of climate change adaptation, it seems plausible to argue that the focus should be on the “pool” of adaptation projects related to an urban system (Ansell & Bartenberger, 2016). We therefore look at two project examples while being fully aware of these two being but a choice of a larger array of related projects and discourses in the region.
- Project partners of REGKLAM focused on planned (or programmed) climate change adaptation to provide a contribution mainly to increase the adaptative capacity of the Dresden region. Partners did not intend to question existing social structures and cultures and actually did not do so during project duration. They were occupied with accomplishing the project goals as laid out in the initial proposal of REGKLAM. Obviously, starting conditions of the formal project duration were of high importance for the whole project implementation.

The following briefly elaborates on these points with regard to project development and implementation: Formally, in the year 2008, federal government established the German strategy for climate change adaptation (“Deutsche Anpassungsstrategie an den Klimawandel (DAS)”) (Die Bundesregierung, 2008). In this policy context, the Federal Ministry for Education and Research (BMBF) announced the strategy- and network-oriented funding program KLIMZUG on climate change adaptation in regions and cities (already in the year 2007). Somehow “naturally”, scientists and practitioners already involved in climate change adaptation with specific expertise and responsibility in the Dresden region developed a project proposal called “Regionales Klimaanpassungsprogramm für die Modellregion Dresden (REGKLAM)”.

The proposal mentions three main goals of the joint project of scientists and practitioners (“Verbundvorhaben”): (1) developing and testing a so-called “Integrated Regional Climate Change Adaptation Program”, (2) implementing strategic projects in line with the program and (3) consolidating network relations between partners in the Dresden region that are already involved in and/or important for climate change adaptation at local and regional level. The "Free State of Saxony / Freistaat Sachsen" supported the project, for instance, through participation in the project organization. Furthermore, some state agencies in Saxony and local authorities were included, like the City of Dresden, as full project partners (with a specific budget and project responsibility). Over the time span of five years, REGKLAM included many important actors in science and practice in the Dresden region. However, citizens and politicians as well as organizations of the civil society participated only at the margins, for instance, in the context of public events organized by the project team of REGKLAM.

To ensure project activities in accordance with the REGKLAM proposal and to generate the proposed outputs for goal accomplishment, REGKLAM was implemented by a complex specific project organization and some flexible organizational as well as resource allocation elements to consider contingencies during the project duration of five years. For instance, ten percent of every project partner´s budget was allocated to "open topics" that could arise during project implementation due, for instance, to the articulation of issues important for the practitioners of climate change adaptation in REGKLAM. We think it is fair to say that project partners worked hard to accomplish the initial goal statements that justified the project in the first place and that the REGKLAM team as a whole succeeded in demonstrating this through the "production" of pre-defined outputs (Olfert et al. 2014).

Very generally, one could argue that the project REGKLAM was a typical strategy project of regional climate change adaptation in Germany characterized by the context of the years from 2000 to 2013 approximately. Resilience is no key word in the announcement of the funding program of the BMBF in the year 2007 and resilience is also no key word in the REGKLAM proposal. However, the resilience word is used approximately twenty times in a key publication on the climate change adaptation program at the end of the project (mainly with regard to water and forestry issues, see REGKLAM-Konsortium, 2013). Hence, the resilience word does not play a prominent role in REGKLAM. However, the issues of regional climate change adaptation put forth by the REGKLAM team refer in many regards to not only adapting to changes in means of climate variables and their consequences, but also in regard to structural changes of extreme values of these variables (e.g., heat waves).

A thorough document analysis in the year 2019 shows that REGKLAM project partners refer only little in their own strategy documents to the output documents of REGKLAM up to this year (Meyer, 2019). Especially the City of Dresden refers to REGKLAM outputs. Up to now, specific activities to evaluate the impact of REGKLAM on parallel processes in the Dresden region and in terms of impacts after project completion were not conducted. Unfortunately, we know only very little about the implicit impact of REGKLAM on climate change adaptation at the various spatial scales in the Dresden region (Turnheim et al. 2018, p. 227).

10.3.3 The Project HeatResilientCity (HRC): A Case of Inter-Project Learning?

HRC is significantly smaller than REGKLAM, but still a medium-sized project of both scientists and practitioners with a focus on the topic of urban heat in the two cities Dresden and Erfurt. The overall budget is approximately 3 Mio. EUR. The project HRC lasts from the year 2017 to January in the year 2021. Like REGKLAM, the project HRC is funded by the BMBF. Funding will continue after January 2021 through implementing the subsequent project HRC II. We suggest that the projects REGKLAM and HRC jointly illustrate two points of our conceptual argumentation:

- Selected REGKLAM partners developed in cooperation with partners from science and practice in Erfurt the project proposal of HRC. We see this kind of "follow up" of REGKLAM as a process of inter-project learning (at least to some extent). REGKLAM was characterized by a very broad and complex agenda of regional climate change adaptation topics. The agenda encompassed issues of adapting urban open space and built structures, and economic relations as well as policies related to health, biodiversity, agriculture and forestry. *We hypothesize that the integration capabilities of the REGKLAM partners did not match this broad agenda.* This is particularly plausible as some of the issues (such as public health) where brought up later in the process of project implementation. As a consequence, REGKLAM partners formulated a climate change adaptation program that somehow lacked a "strategic focus" (e.g., Hutter, 2014; Hutter & Bohnefeld, 2013; Hutter & Otto, 2017). HRC is clearly based on the knowledge produced and experiences made in REGKLAM and is therefore much more focused right from the beginning. Discussions aiming at joint follow up activities had started right after the completion of REGKLAM and involved a core of partners now implementing HRC. Already at this early point of time a joint focus on topics around urban heat where agreed upon. Partners followed an inter- and transdisciplinary approach to develop effective and acceptable measures for adapting to heat stress in urban areas and to investigate their effectiveness. We see this as inter-project learning, among other important conditions and processes to explain project development (network and institutional conditions, typical processes of reacting to research funding program announcements without significant change in knowledge, see Gerring & Christenson, 2017, p. 65, for an overview over "causal frameworks").

- The option of learning from multiple projects needs differentiation. Actors interested in urban resilience may learn from related as well as unrelated project variety. Ansell and Bartenberger (2016) argue that learning from unrelated variety resembles a process of "Darwinian experimentation" which requires that learning agents show, for instance, high tolerance of ambiguity and high levels of learning also from failure as well as the ability of letting go a strong interest in control of activities. In case of learning from related project variety, there is the tendency to work out some specific lessons over the course of a series of projects, for instance, to convincingly address implementation issues "on the ground" of climate change adaptation. We contend that both unrelated and related project variety are important for building urban resilience (Boschma, 2015, p. 738, proposes a similar argument for regional economic resilience).

The following briefly elaborates on these points with regard to the development of HRC (other authors in this volume report on project implementation and results in more detail): The project durations of REGKLAM and HRC show that three years passed between the two projects which is due to the two relevant BMBF program conditions. After KLIMZUG and REGKLAM, it was clear from the outset (1) that the program announcement relevant for HRC stressed the importance of "climate resilience" for urban development and (2) that projects should be smaller than the large KLIMZUG projects of the past. The (at the time potential) project partners in Dresden and Erfurt agreed that this was an opportunity to focus on such issues of climate change adaptation that were related to strong and relatively robust climate change "signals" like rising mean temperatures, a higher frequency of hot days and an increasing probability and duration of heat waves especially in urban areas. As mentioned above, we interpret this focus of HRC partially as process of inter-project learning. REGKLAM provided a robust knowledge basis which allowed to focus on a particular topic of climate change adaptation and some partners of REGKLAM had pre-selected heat as one focus topic for joint R&D activities. A core group of REGKLAM-partners organized this project-oriented agenda setting through conducting a series of planned follow-up meetings after REGKLAM had ended.

The HRC project team focuses on the effectiveness of adaptation measures to deliberately change the building stock and its usage as well as measures with regard to related green, blue, and grey infrastructures. HRC especially pays attention to the relations between the scientific analysis of the effectiveness of measures and how these measures are perceived and accepted by target groups in the relevant urban areas in the cities of Dresden and Erfurt. To generalize across the complexity of adaptation measures addressed in HRC, one could say that the project focuses on building resilience to heat stress as adaptive capacity. The agenda of HRC is not only focused with regard to the chosen climate change parameters and their consequences, especially in terms of heat stress for the people, but also with regard to intended incremental change in terms of considering a complex set of measures that stay within the existing social structures and cultures of the urban system (Westermann et al. 2021, under review). In contrast to the focused and somehow quite narrow agenda of HRC, there is high complexity of measures considered and also high complexity under which conditions these measures are applied in different urban areas in Dresden and Erfurt.

The step to move from REGKLAM to HRC with a clear focus on one topic (urban heat) and on the development of effective and acceptable measures was and still is well justified. Even without a specific evaluation study to derive this summary statement, there are several points that support this proposition:

- The background of knowledge, problem awareness, overall preparedness, the existing social networks and trust relations among partners which had cooperated in REGKLAM enabled the partners of HRC to use the project duration of three years to develop practical adaptation measures and to partially implement those measures in the "real world".
- The focus on just one main topic (urban heat) and on issues of implementation narrowed the scope of content complexity, partner relations, and of project management procedures and allowed an effective implementation of project goals. This finally resulted in the willingness and cooperation of all partners (including local practitioners) to develop the follow up project HRC II. Even an increased project complexity was brought in by including the public health topic in HRC II.
- Based on experiences made in REGKLAM with including external public health experts from another region (the university in Bielefeld), in HRC, a more integrating process was taken by involving and convincing the heavily overburdened local health authorities in Dresden to take part in HRC II and to formulate their own thematic interest in the project. Project partners of HRC still seem to be highly committed to the project and its follow-up activity of HRC II.

In sum, the two projects REGKLAM and HRC (as well as the follow-up activity of HRC II) are examples that illustrate how learning agents seek to transcend their comfort zones to address the issues of climate change adaptation in urban systems: In REGKLAM, project partners formulated a climate change adaptation program with a very broad agenda and less emphasis on implementing this agenda in the "real world" of urban systems (for instance, through strategic projects). We suggest that REGKLAM illustrates how actors in science and practice may exploit learning opportunities of type 2 "Expanding the agenda of climate change adaptation". However, REGKLAM partners did not develop a selective focus on climate change adaptation. This is perhaps not surprising, if learning agents involved in large adaptation projects move out of their comfort zone to consider high complexity of whole urban systems like the Dresden region (Healey, 2007). Based on inter-project learning, some partners of REGKLAM and actors from outside the Dresden region were subsequently able to develop a much more focused project on dealing with rising temperatures and heat stress in urban areas (the project HRC). How this relates to learning opportunities of type 1 "Staying in the comfort zone" and type 3 "Strategic positioning of change in sub-systems" needs to be discussed further. In the meantime, we wonder how processes of evaluating and learning from related projects like the two examples REGKLAM and HRC, and also from unrelated project variety, could be enhanced through future studies on building urban resilience in urban regions like Dresden and Erfurt.

10.4 Conclusion and Outlook

Similar to other policy fields and practices, climate change adaptation governance is increasingly characterized by projects at various spatial and temporal scales. We follow evolutionary thinking in expecting that projects are indispensable to increase the variety of possible adaptation solutions as well as to generate and diffuse new solutions that then become innovations for building urban resilience in the context of climate change. To understand this project variety for urban resilience and climate change adaptation, one needs to consider the literatures on project management, learning, climate change governance, and urban resilience. We tried to do so and summarized our conceptual argumentation through proposing the typical 2×2-matrix that entails two dimensions: the dimension of whole urban systems with very high complexity and sub-systems on the one hand and the dimension of learning intentions with regard to adaptive and transformative capacity on the other. We used this matrix to reflect on two project examples on climate change adaptation (the projects REGKLAM and HRC over a time span from the year 2007/2008 to the year 2021). We conclude with proposing some issues for further investigation:

- Future work on project-based learning for urban resilience may be seen as part of ongoing processes in and of "learning regions". More and more, there is work on regional development that elaborates on the policy implications of learning-oriented projects for supporting regions into desired directions of sustainable development (e.g., Köhler et al. 2019 on sustainability transitions and Tödtling & Trippl, 2018 with regard to regional innovation policies beyond "neo-liberal and traditional systemic views"). We are hopeful that conceptual and empirical work that seeks to integrate research on project management, learning, urban resilience, climate change governance, and regional climate change adaptation will lead to new policy recommendations that increase the odds of desired change in adaptative and transformative capacity in the "real world".
- Future empirical work on project-based learning for urban resilience in the context of climate change adaptation needs to take multiple levels of analysis and the complexity of process patterns for scaling up, replicating, circulating, and institutionalizing project outputs in urban systems into account (Wolfram, 2016, Turnheim et al. 2018, pp. 230–231). This will only happen if at least medium-sized projects with strategic focus on evaluation and learning, with a convincing case study design, and partners in research and practice that are willing and able to learn from projects become possible in the "real world" (Van de Ven, 2007; Gerring, 2017).

Any single project is only a small contribution to building urban resilience in the context of climate change adaptation. Given the evolution of complex project pools in urban systems, also with regard to projects on climate change adaptation in urban regions like Dresden, researchers and practitioners need to trace how project pools develop in the direction of intended change for building resilience. Therefore, in the end, we call for the co-evolution of research and practice for building urban resilience.

References

Abeling, T., Daschkeit, A., Mahrenholz, P., & Schauser, I. (2018). Resilience—A useful approach for climate adaptation? In A. Fekete & F. Fiedrich (Eds.), *Urban disaster resilience and security. Addressing risks in society* (pp. 461–471). Cham: Springer.

Ansell, C. K. (2019). Coping with conceptual pluralism: Reflections on concept formation. *Public Performance & Management Review*, 1–22

Ansell, C. K., & Bartenberger, M. (2016). Varities of experimentalism. *Ecological Economics, 130*, 64–73

Boschma, R. (2015). Towards an evolutionary perspective on regional resilience. *Regional Studies, 49*(5), 733–751

Braun, T., & Sydow, J. (2019). *Projektmanagement und temporäres Organisieren.* Stuttgart: Kohlhammer.

Carroll, J. S., Rudolph, J. W., & Hatakenaka, S. (2003). Learning from organizational experience. In M. Easterby-Smith & M. A. Lyles (Eds.), *The Blackwell handbook of organizational learning and knowledge management* (pp. 575–600). Malden: Blackwell.

Chu, E. K. (2016). The governance of climate change adaptation through urban policy experiments. *Environmental Policy and Governance, 26*, 439–451

Coaffee, J., & Lee, P. (Eds.). (2016). *Urban resilience. Planning for risk, crisis, and uncertainty*. London: Palgrave.

Davies, A. (2017). *Projects. A very short introduction.* Oxford: Oxford University Press.

Die Bundesregierung (2020). *Zweiter Fortschrittsbericht zur Deutschen Anpassungsstrategie an den Klimawandel.* o. A.

Die Bundesregierung (2008). *Deutsche Anpassungsstrategie an den Klimawandel vom Bundeskabinett am 17. Dezember 2008 beschlossen.* o. A.

Easterby-Smith, M., & Lyles, M. A. (Eds.). (2011). *Handbook of organizational learning and knowledge management*. Chichester: Wiley.

Emirbayer, M., & Mische, A. (1998). What is agency? *American Journal of Sociology, 103*(4), 962–1023

Gerring, J. (2017). *Case study research. Principles and practices.* Cambridge: Cambridge University Press.

Gerring, J., & Christenson, D. (2017). *Applied social science methodology. An introductory guide*. Cambridge: Cambridge University Press.

Goertz, G., & Mahoney, J. (2012). *A tale of two cultures. Qualitative and quantitative research in the social sciences.* Princeton and Oxford: Princeton University Press.

Grabher, G., & Ibert, O. (2010). Project ecologies: A contextual view on temporary organization. In P. W. G. Morris, J. Pinto, & J. Söderlund (Eds.), *The Oxford handbook of project management.* (pp. 175–198). Oxford: Oxford University Press.

Hartmann, A., & Dorée, A. (2015). Learning between projects: More than sending messages in bottles. *International Journal of Project Management, 33*, 341–351

Healey, P. (2007). *Urban complexity and spatial strategies. Towards a relational planning for our times*. Milton Park and New York: Routledge.

Hutter, G. (2014). Goal-oriented networks and capacity building for natural hazards—Examples in the Dresden region. *Natural Hazards and Earth System Sciences, 14*(1), 81–94

Hutter, G., & Bohnefeld, J. (2013). Vielfalt und Methode—Über den Umgang mit spannungsreichen Anforderungen beim Formulieren eines Klimaanpassungsprogramms am Beispiel REGKLAM. In A. Knierim, S. Baasch, & M. Gottschick (Eds.), *Partizipation und Klimawandel—Ansprüche, Konzepte und Umsetzung* (pp. 151–172). München: oekom.

Hutter, G., & Lorenz, D. F. (2018). Social resilience. In S. Fuchs & T. Thaler (Eds.), *Vulnerability and resilience to natural hazards* (pp. 190–213). Cambridge: Cambridge University Press.

Hutter, G., & Otto, A. (2017). Raumwissenschaft und Politikberatung—Am Beispiel von Projekten zur Klimaanpassung in Städten und Regionen. *disP—The Planning Review, 53*(4), 42–54

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An Agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation & Societal Transitions, 31*, 1–32

Kuhlicke, C. (2013). Resilience: a capacity and a myth: Findings from an in-depth case study in disaster management research. *Natural Hazards, 67*, 61–76

Meerow, S. & Newell, J. P. (2016). Urban resilience for whom, what, when, here, and why? *Urban Geography*, 1–21

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning, 147*, 38–49

Meyer, C. (2019). *Wie wirken Verbundvorhaben der Klimaanpassung in Städten und Regionen? Vorrecherche von Praxisdokumenten mit explizitem Bezug zu REGKLAM-Output.* Dresden: IÖR (unpublished manuscript).

Olfert, A., Müller, B., Bernhofer, C., Korndörfer, C., & Sommer, W. (2014). REGKLAM—Ein integriertes regionales Klimaanpassungsprogramm: das Beispiel Dresden. In H. Biebeler, H. Bardt, E. Chrischilles, M. Mahammadzadeh, & J. Striebeck (Eds.), *Wege zur Anpassung an den Klimawandel—Regionale Netzwerke, Strategien und Maßnahmen* (pp. 169–188). Köln: Institut der deutschen Wirtschaft.

Pelling, M. (2011). *Adaptation to climate change: From resilience to transformation.* London: Routledge.

REGKLAM-Konsortium (Ed.). (2013). *Integriertes Regionales Klimaanpassungsprogramm für die Region Dresden. Grundlagen, Ziele und Maßnahmen.* Berlin: Rhombos.

Schünemann, C., Olfert, A., Schiela, D., Gruhler, K., & Ortlepp, R. (2020). Mitigation and adaptation in multifamily housing: overheating and climate justice. *Buildings and Cities, 1*(1), 36–55

Scott, W. R. (2014). *Institutions and organizations. Ideas and interests.* Thousand Oaks: SAGE.

Swan, J., Scarbrough, H., & Newell, S. (2010). Why don't (or do) organizations learn from projects? *Management Learning, 41*(3), 325–344

Sydow, J., & Windeler, A. (2020). Temporary organizing and permanent contexts. *Current Sociology Monograph, 68*(4), 480–498

Tödtling, F., & Trippl, M. (2018). Regional innovation policies for new path development—Beyond neo-liberal and traditional systemic views. *European Planning Studies, 26*(9), 1779–1795

Tödtling, F., & Trippl, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy, 34*, 1203–1219

Turnheim, B., Kivimaa, P., & Berkhout, F. (2018). Experiments and beyond: An emerging agenda for climate governance innovation. In B. Turnheim, P. Kivimaa, F. Berkhout (Eds.),

Innovating climate governance. Moving beyond experiments (pp. 216–241). Cambridge: Cambridge University Press.
Van de Ven, A. H. (2007). *Engaged scholarship. A guide for organizational and social research.* Oxford: Oxford University Press.
van Buuren, A., & Loorbach, D. (2009). Policy innovation in isolation? *Public Management Review, 11*(3), 375–392
Weick, K. E. (1995). *Sensemaking in organizations.* Thousand Oaks: SAGE.
Weick, K. E. (1984). Small wins. Redefining the scale of social problems. *American Psychologist, 39*, 40–49
Weick, K. E., & Westley, F. (1996). Organizational learning: Affirming an oxymoron. In S. R. Clegg, C. Hardy, & W. R. Nord (Eds.), *Handbook of organizational studies.* (pp. 440–458). London: SAGE.
Westermann, J. R., Bolsius, J., Kunze, S., Schünemann, C., Sinning, H., Ziemann, A., Baldin, M.-L., Brüggemann, K., Brzoska, P., Ehnert, F., Goldberg, V., Großmann, L., Grunewald, K., Naumann, T., Reinfried, F., Richter, B., Spohr, G., & Ortlepp, R. (2021). Bewohner-orientierte Hitzeanpassung von Stadtquartieren. Transdisziplinäre Wissensintegration von Klimatologie, Ökologie, Gebäude- und Governanceforschung sowie Maßnahmenplanung und Umsetzung. *GAIA* (under review).
Wolfram, M. (2016). Conceptualizing urban transformative capacity: a framework for research and policy. *Cities, 51*, 121–130