Resilience Principles as a Tool for Exploring Options for Urban Resilience

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In Brief

The world is becoming increasingly urban and cities face a constant struggle with the complex environmental, social, economic, and political challenges of the 21st century. Many international organizations have argued that cities will need to become more resilient to these challenges. However, it is not particularly clear what that really means. In practice, policies often use the concept of 'resilience' as a buzzword. In this regard, resilience principles – that is, defining specific mechanisms that make a city resilient – can help clarify the concept and its applicability. Several case studies provide examples of how such principles can be used as tools to brainstorm on new solutions, how they can be used to evaluate proposed policy options and overarching urban resilience plans, and how they can be compared to stakeholders' preferences for national policy strategies. When applied in a structured way, resilience principles provide a powerful tool to move urban resilience thinking from a metaphorical talk to meaningful solutions.

Key Concepts

- Urban resilience is a versatile concept, which helps frames the arduous process of tackling the environmental, social, and economic challenges of modern cities in a positive way. However, similar to other broad concepts such as sustainability, resilience is inherently vague. Therefore it can be challenging to pinpoint what it means for local options and plans.
- Resilience principles are specific mechanisms and behaviors that make a city resilient or that help policies and practices improve that resilience. They can focus on the system, or its governance. Examples include buffering, redundancy, omnivory, system flatness, homeostasis (stabilizing feedbacks), and high flux of resources.
- Resilience principles can provide a solution to the conceptual vagueness around resilience per se. They help make the concept of 'urban resilience' more specific and translate it to practice. They can be used to design new solutions, evaluate proposed options and plans, and explore the positions of stakeholders.
- Such principles can be applied in a wider process of resilience assessment, reflecting on the situation, urban systems and components, and envisioned past, present, and future. Such assessments might include vulnerability analysis, scenario planning and integrated urban planning. Inherently, these assessments involve choices and trade-offs that should be openly explored and discussed.
- Resilience principles provide a powerful tool to make explicit how cities can improve their resilience: to help cities brainstorm on and evaluate options and plans for urban resilience in a meaningful and comprehensive way.

The focus on urban resilience has grown considerably in the past decade. From its roots in ecology and system dynamics particularly, the notion of resilience is now used in disaster management, governance research, economics, climate change adaptation, spatial planning, urban social studies and numerous other fields.[1,2] International agreements have also taken up the task of building the concept of resilience into societies' fabrics as an essential part of meeting their goals: e.g. the EU Urban Agenda, UN Habitat III, Sustainable Development Goals, UNFCC Paris Agreement, and Sendai Framework for Disaster Risk Reduction. Many cities and organizations have included resilience as a central concept in their policies and practices. For instance, regional and global city networks such as ICLEI and C40 encourage their members to build urban resilience. Similarly, the 100 Resilient Cities foundation actively stimulates and assists cities in setting up a resilience office and developing urban resilience plans: "We help cities around the world become more resilient to the physical, social, and economic challenges that are a growing part of the 21st century".[3]

Such challenges are no doubt numerous. Over half of the world's population lives in cities and these percentages keep on rising.[4] Cities are expected to meet the needs of their rising populations for housing, work, water, food, and energy, while simultaneously managing the resulting pressures. In today's interconnected world, this also means dealing with a host of other stresses and shocks emerging from local and global trends, amid complexity and uncertainty. Achieving resilience to these numerous challenges will be essential in building a good urban future. Urban resilience entails "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience"[3] and "the capacity for a system to survive, adapt, and flourish in the face of turbulent change and uncertainty".[5]

The problem: resilience, yes please – but what does it really mean?

Resilience is a grand, broad concept with positive connotations. This is helpful. It can be (and is) applied in a wide range of situations, taking a combined multi-issue and multi-level approach, tailored to local and regional needs. Its malleability means that resilience can function as a bridging concept ('boundary object'),[6] connecting the many fields, sectors, stakeholders, challenges, and interests involved in the 'urban system'. Urban resilience also provides an explicitly positive way of framing urban challenges, such as climate change, disaster management, resource management, economic and demographic issues, and other urban policy agendas.[7] Positive framing can be more effective at motivating people and more conducive to developing solutions than negative framing.[8] This helps bring a wide range of stakeholders to the table to constructively develop solutions.

Urban resilience is used in a context of similar broad and positive concepts, such as sustainability and integrated urban planning. Sustainability involves enduring in the long term, which is obviously broader than resilience: it also includes resistance (e.g. classic dikes), retreat (e.g. moving out of vulnerable areas), or altering the drivers of change (e.g. reducing greenhouse gas emissions or resource use). Often, discussions on urban sustainability emphasize the latter (climate change mitigation) and those on urban climate resilience stress adaptation. Integrated urban planning is a practice that seeks to tackle multiple urban challenges in a coherent manner, instead of working from sectoral or departmental 'silos'. Sustainability and resilience could be increased through both non-integrated and integrated approaches, but integrated planning helps reduce negative side-effects and promotes synergies.

The flip-side of such a broad concept is that the notion of resilience can be rather vague. Policymakers and stakeholders may 'feel' that urban resilience is important, but may be unsure about what it really means. Worse, they may think they understand it intuitively, and move straight on to developing and implementing options that they believe will enhance it. This can generate policy risks. Firstly, stakeholders may have diverse intuitive understandings and framings of what resilience means in practice.[9] Such diversity can lead to resilience policies that tackle the problems only partly, and only for specific groups of people or regions. When stakeholders employ a multitude of frames (and have sufficient power to contribute to the debate), it could also lead to a 'dialogue of the deaf'. Actors may appear to agree on building a comprehensive agenda to make the city more resilient, but in practice have very different unspoken ideas on what, who, where, when, why and how this should be done. In turn, this may result in a stalemate. Ultimately, due to its vagueness, resilience may remain confined to a metaphorical, ad-hoc sense, thus remaining an empty buzzword. Several authors have indeed observed that in practice, resilience is often used as a catch-all term for future-proofing, without specifying what it really means and how solutions will contribute to reaching this goal.[10,11] In turn, that may result in apparent solutions that do not really tackle the challenge.

Resilience principles: some background

If it is to be useful, urban resilience must be operationalized. What makes a system resilient? And how can solutions help achieve this? The definitions of urban resilience offer only few clues. The literature on social-ecological resilience provides mores specific characteristics, such as capacity to absorb disturbances, the ability to self-organize and self-reorganize, and the ability to build capacity for learning and adaptation.[12] Resilience is about absorbing disturbances and coping with them dynamically and adaptively. This distinguishes resilience-based approaches from traditional 'predict-and-prevent' approaches,[13] which are focused on keeping disturbances out of the system altogether, for instance by building every higher levees.

Many recent studies on urban resilience have investigated how cities respond under pressure, and why they are or aren't resilient. These have resulted in lists (some ad-hoc, some more systematic) of traits, attributes, actions, and behaviors that underpin resilience. Such 'resilience principles'[14-17] describe specific mechanisms that make a system resilient or that help policies and practices enhance that resilience. They can focus on the 'system to be governed' (e.g. system structure, system dynamics) as well as the 'governance system'.[18] Classic examples of system-oriented principles include: redundancy, omnivory, buffering, flatness, homeostasis, high flux.[19] The first three focus on absorbing disturbances, the others on quick responses, recovery, self-(re)organization, and learning.[15] An example of a governance-oriented set: adopt a systems approach, look at beyond-design events; build according to the 'remain functioning'-principle; increase recovery capacity through social and financial capital; remain resilient into the future.[20] Various principles are suggested in the literature, often related but with different phrasing or emphases. See Wilk,[21] for an inventory and comparison. Table 1 shows a number of sets used in this paper. Table 2 provides descriptions and examples. Whether focused on the system or governance & practices (or both), resilience principles can give the otherwise nebulous concept of urban resilience a firmer footing. By making things more concrete, they provide policymakers with guidance on how to design options that can enhance urban resilience, as well as a way to evaluate whether/how proposed solutions actually contribute to this goal.

Set:	**Classic system dynamics set** Source:[18]	**Community resilience set** Source:[24]	**Systems & governance set** Source:[21,22]
Cases:	A: Climate resilience, unembanked Rotterdam.[14,31] B: Regional resilience, Venen-Vechtstreek.[15,28]	C: Community disaster resilience, Rotterdam-New York.[24]	D: Climate resilience, Rotterdam-London.[21] E: Water resilience, Rotterdam.[22]
Principles:	1. Redundancy 2. Omnivory 3. Buffering 4. Flatness 5. Homeostasis 6. High flux Added for urban resilience:[14] 7. Preparedness & planning 8. Compartmentalization 9. Flexible planning/design	1. Communication 2. Education & training 3. Good governance 4. Access to resources 5. Public awareness 6. Strong urban identity 7. Participation	1. Anticipation & foresight 2. Preparedness & planning 3. Homeostasis 4. Robustness & buffering 5. Diversity 6. Redundancy 7. Flatness 8. High flux 9. Learning 10. Flexibility
Why this set?	Generic set based on complex adaptive systems (which cities are). Strong theoretical basis, but easy to relate to adaptation options. Successfully applied to climate adaptation.[14,15,32,33]	Synthesis set based on literature on how communities cope with disasters (focus on social rather than systemic aspects).	Synthesis set based on multiple urban resilience literatures (disasters, economy, ecology, governance). Included subcriteria.[21,22]

Source: author

Table 1 – Example sets of resilience principles, as applied in case studies

Principle	Aim	Description	Examples
Redundancy	Absorbing disturbances	The system contains overlapping functions (e.g. backups); if one fails, others can take over.	Creating multiple supply routes for energy, water, etc. Building access at multiple levels. Backup power generators.
Omnivory	Absorbing disturbances, recovery, reorganization	Diversification of the resources and means that a specific function depends on or can mobilize in the event of a disturbance.	Diversified and distributed power generation (multiple sources, locations). Diversified transportation options (rail, road, water). Multifunctional buildings and spaces. Diversified sources of income.
Buffering	Absorbing disturbances	Essential capacities are over-dimensioned such that critical thresholds are less likely to be crossed.	Key utilities and infrastructures (water, energy, food, sewage/drainage, ICT) can cope with more demand than they typically need to. Low elevation spaces with non-essential functions (parks, squares, retention ponds, etc.) can buffer rainwater until the drainage system can catch up.
Flatness	Quick response, self-organization	The system and organizations should have few hierarchical levels and not be top-heavy. Overly hierarchical systems with no formal local/'on the ground' capacity to decide and act, are too slow to respond to surprise and implement non-standard local responses.	Enabling local populations to self-respond to disturbances (self-sufficiency, self-regulation, self-organization). Increasing public participation in local decision-making. Limiting the management layers between the people observing potential problems and the people making decisions.
Homeostasis	Quick response, self-organization, learning	Multiple feedback loops counteract disturbances and stabilize the system.	Early warning systems. Flexible urban planning approaches and infrastructures. Improving clarity of responsibilities.
High flux	Quick response, recovery, reorganization	Fast rate of movement of resources through the system ensures quick mobilization of these resources to cope with shocks and changes.	Reducing planning horizons. Flexible, easy-to-modify land uses in potentially vulnerable areas. Insurance schemes, emergency funds and supplies, or innovation funds that can be easily and quickly accessed.

Source: endnotes 14,15 and 33

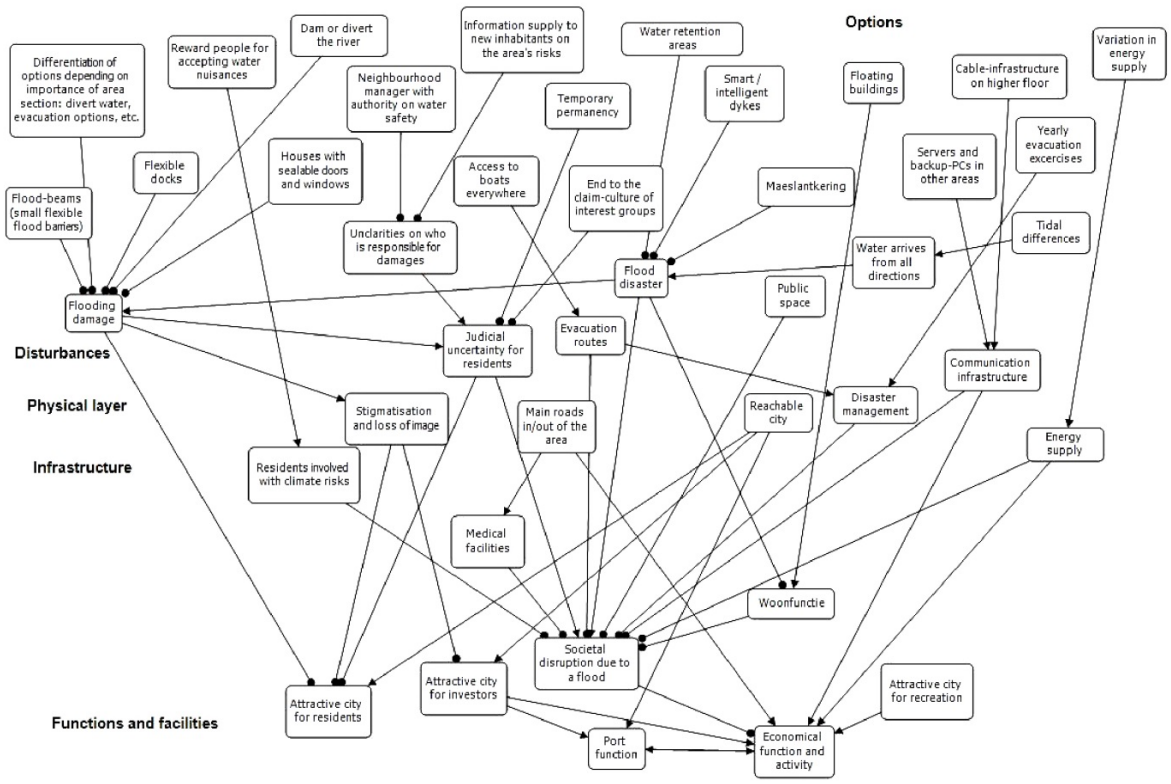
Table 2 – Descriptions of classic resilience principles and example urban options

Using resilience principles to design options

The first practical use for resilience principles is to give decision-makers handholds on how to design solutions. When you know what attributes make a city resilient, you could design options that target and enhance specifically those attributes, thereby also improving overall resilience. We've applied this approach in a study on resilience to climate change in Rotterdam's unembanked areas (Case A).[14]

Case background. Rotterdam is a major port city and economic center in the Rhine-Meuse-Scheldt river delta. Its old port districts, elevation +2.5-5m and unembanked, experience regular flooding, up to twice per year. Much of the area is being redeveloped to residential, commercial and office functions. Local decision-makers invited us to help them explore what a resilience approach, at that time a new concept in urban planning, could entail.

First, we explored the current situation in the area, its history, development plans, local practices, and social, economic, environmental challenges, particularly climate change-related. We used scientific literature, policy and stakeholder documents, and interviews. Sea level rise, particularly combined with storm surges, and enduring heat & drought were the most important stresses.[14] These could cause property damage, societal disruption, and loss of image. In a workshop, policymakers, stakeholders and experts jointly built a 'group model' of the area (Figure 1). They inventoried and prioritized the 'components': relevant physical conditions, usage functions, facilities & services, and infrastructure, and used the model to explore potential climate impacts.



Source: see endnote 31
Figure 1 – Group model of Rotterdam's unembanked urban areas

Option design. Second, we designed options to counter the climate-related pressures (shocks and stresses) on the area. We used six classic system dynamics principles (Table 1). An initial

challenge was that these are rather technical and jargon-heavy. We jointly discussed the basic notion of each principle, their meaning for urban climate resilience and provided examples. This successfully made the principles understandable and usable.

Adaptation options were designed for each resilience principle, tailored to the group model and impacts inventoried. *Redundancy*, involves having multiple copies of something; if one fails, the others can still be used. For example, having a backup copy of your computer files. In Rotterdam, it could involve having multiple roads into and out of the area, multiple services connections (energy, drinking water, etc.), backup crisis centers, and multiple access levels in buildings so that if the first floor is flooded, people can exit from another floor. *Omnivory* involves having multiple different ways (rather than copies) of obtaining your needs. In biology, omnivores (eating both plants and meat) have better food security, compared to more picky eaters. Options could involve diversifying energy sources by implementing small scale energy generation or energy/heat storage. Buildings could be designed for multiple functions, so that they can temporally house functions from flooded areas (short term) or change functions to cope with long term changes. *Buffering* involves over-dimensioning the capacity of a system, so that it can absorb disturbances to some extent. 'Water squares' could function as public square during normal operations, and temporally store and gradually release rainwater during downpours. Arterial roads (used for evacuation) could be elevated, so they remain functioning during floods. Buildings could house essential functions on higher levels, while leaving ground floors for functions that can be temporarily disrupted. Areas that are climate-risk prone should be planned with functions that are less vulnerable or can be changed rapidly. *Flatness* holds that systems and organizations that are 'top-heavy' and hierarchical (many levels of middle management; long chains of command) can be too slow or inflexible to respond to rapid changes. In flatter systems, early warning systems reach decision-makers faster and the people 'on the ground' could have authority and capacity to quickly develop solutions. This could involve improving self-reliance and self-organization of local residents. Another option was assigning neighborhood directors with formal authority on water safety. Municipal policymaking should also be made more participatory and flexible, so that local concerns filter through in policies more easily. *Homeostasis* is the property of a system to actively keep a variable constant through feedback mechanisms. For instance, the human body keeps core temperature roughly constant through sweating and shivering. Early warning and smart response mechanisms could provide foresight. Spatial planning could help reduce impacts, e.g. planning roads for fast removal of flood water, wind corridors for cooling during heat waves. Floating/amphibious houses, flexible docks and infrastructure, and flexible flood defenses can actively cope with disturbances. Counter-expertise should be actively solicited, providing feedback that reduces blind-spots in plans. *High flux* means that resources (funds, information, space, building materials, etc.) can move rapidly in the system, ensuring their fast mobilization to cope with disturbances. Residents should have rapid access to materials for post-flood recovery or for citizen initiatives to improve the area. Participants also suggested reducing the planning horizons for buildings (e.g. replacing houses after 30 rather than 50 years). This involves high costs, but some suggested that cradle-to-cradle/reusability or modular building could reduce these. Implementing a good early warning system for floods, disasters, extreme weather for officials, stakeholders, and citizens was less controversial.

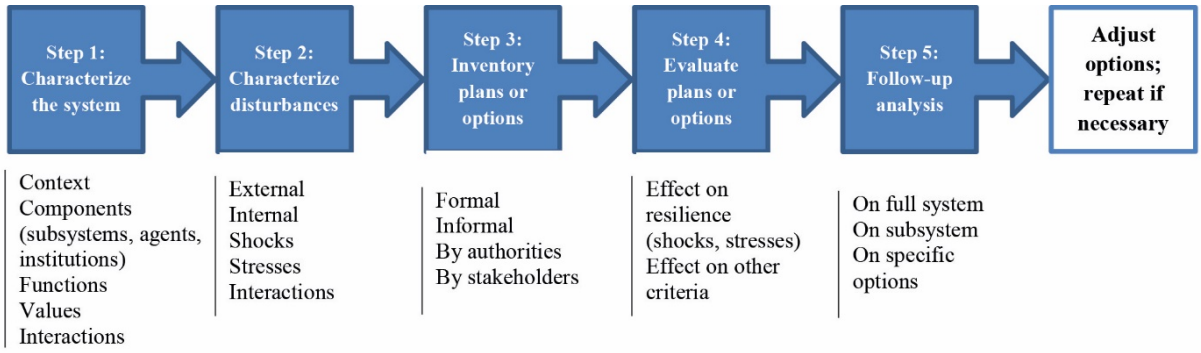
It is important to further reflect on the resulting list of options. Do they cover all principles sufficiently? Are they enough to enhance the resilience of the key functions and to meet the municipality's goals? Furthermore, it is important to check for biases in the options: do they cover all relevant aspects? E.g. regarding sectors (water, energy, housing, etc.), option types

(technical, financial, social, etc.), and long/short term resilience. It was particularly helpful to have a wide range of people involved, with different disciplinary and professional backgrounds. Additionally, it was important to specify the goals and functions in the area beforehand. This led to a more targeted and complete option design, interpretation, and evaluation. The resilience principles allowed participants to brainstorm on potential solutions for urban resilience in a structured way.

Using resilience principles to evaluate options & plans

While resilience principles were useful in designing new solutions, we wondered whether we could do the opposite as well: evaluate proposed solutions. By comparing options and plans to resilience principles, we could perhaps explore how these might impact resilience.

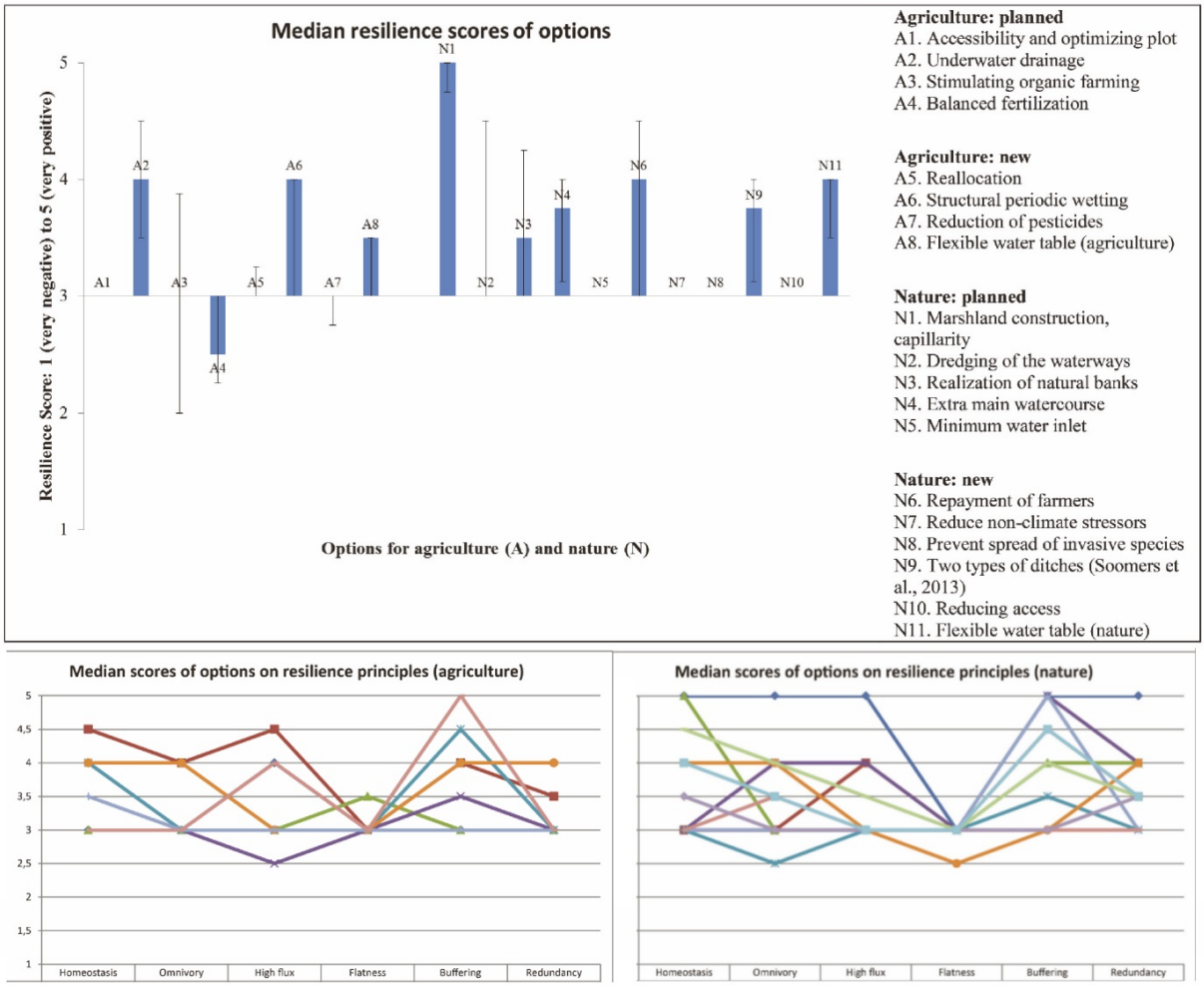
Evaluating options. We conducted a first case study (B) in the Venen-Vechtstreek. This is a relatively sparsely populated area of meadows, lakes and streams, surrounded by the Randstad (literally 'rim city'); the interconnected metropolitan areas of the largest Dutch cities, including Rotterdam, Amsterdam, The Hague and Utrecht. It is used as a buffer against urban sprawl, as well as for nature, agriculture and recreation. Stakeholders and authorities developed a joint management plan ('area covenant'), describing key development goals and solutions. We designed an approach (Figure 2) to assessing the covenant's impact on resilience to climate change and investigated using interviews and a workshop.[15]



Source: see endnote 15
Figure 2 – Resilience Assessment of options and plans

The focus was on evaluating options from the management plan on their impacts on resilience, as well as a secondary list of resilience-focused options. In a workshop, experts and stakeholders scored options on each principle on a five-point scale (large negative to large positive impact on resilience). See Figure 3. One relatively surprising result was that there was no appreciable difference in overall resilience scores between the general and the resilience-based sets. Based on the separate principles and participants' argumentation, we found that the generic options often were broad, holistic solutions that positively impacted multiple principles. The resilience-specific options, on the other hand, had a positive impact on one or two principles and neutral impact on others. Particularly, the construction of a network of marshland capillaries, linking larger waterways and nature areas was rated highly positive on all principles but one. Several options had negative impacts. Some principles were better represented than others. Buffering and homeostasis were well-covered, but flatness was completely neglected. We subjected the solutions to a wider multi-criteria analysis as well, scoring them on cost, feasibility, urgency, co-benefits, and level of no-regret. This led to some time constraints (we had to prioritize options, and couldn't score all),

but also provided useful information. In the end, we were somewhat critical of simply averaging the six resilience principles into an overall resilience score. This distinguished primarily between broad and narrowly targeted solutions, and it involves compensating bad scores on one principle with positive scores on others. While relevant, such scores shouldn't be taken at face value. However, the scores on separate resilience principles provided a wealth of information. Particularly, they helped uncover which aspects of resilience were well-covered and which aspects were blind spots that could benefit from additional targeted solutions.



Source: see endnote 15

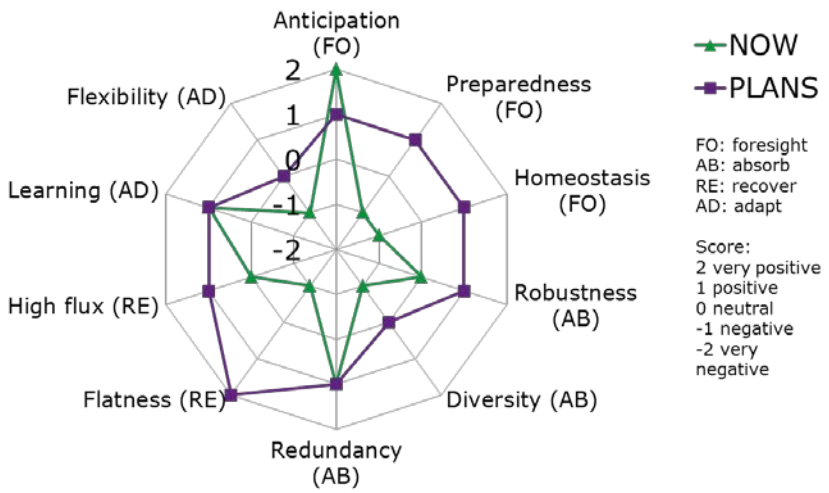
Figure 3 – Impact of management options on resilience in the Venen-Vechtstreek

Evaluating plans. We also applied this approach to evaluating full plans. While less detailed, it can account for interaction between options and help evaluate large packages of options (too time-consuming to do option-by-option) or early stage plans (few concrete options). The goal for such an exercise is to explore which directions the plans are taking: what is the focus, what are the blind spots, and is that what you intended? We applied this in three case studies (C- E), using two sets of resilience principles. Both sets were further specified into sub-principles. Target city was Rotterdam, with New York and London for comparison. Source material included interviews, document analysis and a workshop.

We evaluated the current situation and the effect of Rotterdam's urban resilience plans, regarding water-related issues.[22] The evaluation focused on diagnosis per principle, and

didn't include an average/final score. However, we also grouped our core set of principles for Case D and E into four categories of principles with similar purposes: foresight & preparedness, absorbing disturbances, recovery from disturbances, or adaptability & change.[23] For diagnostic purposes, this provides extra information: if all principles in a category score low, this could signal danger. We used 10 resilience principles (Table 1), each with 3-6 sub-principles. We used the full set of sub-principles only in the desktop research. For the workshop we wrote short narratives on what we meant with each core principle in the study's context, using the sub-principles. The results showed several things of note (Figure 4). Rotterdam's current focus was strongly on anticipation. The municipality has strong ties with universities, knowledge institutes, and consultancy and engineering firms, and strong internal capacity and practices for foresight and scenario planning. Learning, particularly experimentation with innovative approaches, and (engineering) redundancy were also well-covered. The resilience plans broaden things up considerably. For instance, flatness is improved through enhanced focus on citizen involvement and social issues. However, there are still some blindspots, such as flexibility and diversity.[21,22] Foresight & preparedness remains particularly strong. London, in comparison, focuses on principles related to absorbing, adapting, and particularly recovery.[21] Lacking a strong central government responsibility in flood risk management, formal safety standards, and centuries of investments in levees, much more emphasis is placed on self-sufficiency, room for autonomous change, and social networks. Case C also compared the current situation in Rotterdam and New York, using principles designed for community resilience.[24] It indicated that community resilience is not currently a focus in Rotterdam. While it has high scores ('established') on available resources (funding, economic opportunities, research), principles related to governance, urban identity, and participation scored 'in progress', and communication with citizens, community education & training, and public awareness 'marginal'. Conversely, New York has a long tradition of community focus: high scores for communication, education, and identity, although low scores on resources.[24]

In our case studies, we found resilience principles to be useful in evaluating proposed solutions on their impact on urban resilience. As several of our research participants cautioned, the goal of such tools is not to give a city a 'grade'. Rather, they provide diagnostic information on strong points and potential blind spots, that may be by choice or by accident. This information can help local decision-makers reflect on their situation, and help them find directions for developing solutions.



Source: see endnote 22

Figure 4 – Water resilience in Rotterdam

Concluding remarks

Urban resilience is a concept that can help cities prepare for the complex challenges of the 21st century. It provides a positive approach, that can attract a diversity of stakeholders to the table. However, like many grand concepts, it is inherently ambiguous. This leads to a risk that resilience initiatives might fail, or to policies that do not actually improve resilience. Resilience principles can help cities clarify what it means to 'be resilient', and consequently design more purposeful solutions for building urban resilience.

Several challenges can be observed. First, cities and stakeholders will have different framing of the urban resilience challenge: the problem, causes, moral judgements and remedies that are key.[9,25,26] These could lead to different views on the importance of specific resilience principles, the 'system under study', relevant timeframes, and practical implementation of principles into options and goals. They also have strong implications for what information and decision-tools are relevant and who should be involved in decision-making.[8] In a related study, on perspectives on urban agriculture in relation to urban resilience, we found that different stakeholders emphasized very different resilience principles, depending on their framing of the goals, problems and side-effects.[27] Second, resilience policies will likely need to make trade-offs between principles, goals, stakeholders, sectors, neighborhoods, and/or 'system components'. Third, when designing new solutions, options will need to be combined into policy packages, strategies, and implementation plans. While it is possible to assess multi-option plans (case E), careful reflection is required on, for instance, complementarity of options, multi-purpose options, and 'how much resilience is enough?'. Consequently, careful consideration and political choices are necessary.

Following an options inventory or evaluation of policy options or plans, using resilience principles, one can move towards improving and implementing resilience in urban policy and planning. Some resilience options will require further scoping and decisions on the magnitude and locations of intervention. For instance, how much buffer capacity do you want to install, for what, where and when? More detailed analyses may be required, e.g. using scenario planning methods, focused on both the vulnerabilities and future needs. A variety of tools is available, ranging from computational to participatory, regular scenarios to 'wildcards'[14] (surprise scenarios), standard scenario methods to serious gaming, robustness analysis and exploratory modeling,[28] as well as climate ateliers,[29] indicator studies,[21] and policy pathway analysis.[30] A more general key follow-up step is to broaden the perspective on what adaptation options are considered, considering the blind spots and options uncovered using resilience principles. If the goal is to improve general urban resilience, an integrated approach is advised, for instance through integrated urban planning. Options are likely to have trade-offs, negative and positive side-effects (on different policy fields, citizen groups, neighborhoods, etc.), and diverging support among stakeholders. An open inventory of these aspects, and an open debate among stakeholders is required.

Resilience principles can be used to design new solutions, evaluate existing situations and proposed options & plans, and explore positions of stakeholders. Applying resilience principles, however, is not a stand-alone exercise. It should be embedded in a wider process of resilience assessment, reflecting on the situation, urban systems and components, and envisioned past, present, and future. This process should keep in mind the assessment's users, context, people and data sources involved, alternative sets of resilience principles, and reflection on the results. We've developed several example methodologies and tools, with step-by-step guidance.[14,19,21,23] With careful design of the process in which they are applied,

resilience principles provide a powerful tool to make explicit how cities can improve their resilience, and help cities brainstorm and reflect on solutions that help build urban resilience in a meaningful and comprehensive way.

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