

**Assessing urban resilience in Rotterdam using resilience principles: Workshop report**

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2017

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## 1. Introduction

Cities worldwide are challenged by climate change and many other environmental, social and economic issues. At the same time, urban populations and capital at risk are rising. These challenges involve high levels of uncertainty, complexity and ignorance, and policymakers will need to find ways to deal with these (cf. Mathijssen et al., 2009; Wardekker et al., 2010). Resilience-based approaches, which focus on improving basic coping capacity rather than predicting and controlling threats, are particularly suited to adaptation under uncertainty (Wardekker et al., 2010). Urban resilience has indeed become a popular concept in both research and practice of urban policymaking, and many cities are looking to improve their climate resilience.

The notion of resilience is malleable and not always easy to interpret. Many aspects of a city contribute to or reduce resilience in one way or another and numerous definitions of the concept exist. Climate adaptation and urban resilience can be framed in multiple ways, linking up with the concerns of different stakeholders and citizens, and emphasising different aspects of resilience (Wardekker, 2004, 2016), as well as resulting in different adaptation strategies, governance approaches, and information needs (De Boer et al., 2009). Consequently, resilience plans could take a wide range of directions in their practical interpretation of resilience. Such choices, emphases and trade-offs in urban resilience plans are often made implicitly, and may be heavily influenced by the subconscious frames of the plans' authors. Consequently, it would be valuable to diagnose the way that urban resilience plans propose to tackle climate adaptation.

Utrecht University has recently developed a diagnostic tool for exploring urban resilience. At the centre of the diagnostic tool is an assessment framework of ten resilience principles, divided over four focal directions. Such principles describe different principal mechanisms or approaches through which a system or city can be resilient (Wardekker, 2018; Wardekker et al., 2010, 2016). They can be used to design or evaluate policy options and plans. Different groups of actors, with different frames or discourses on urban resilience, can prioritize different resilience principles (Wardekker, 2018; Cohlen, 2016). Consequently, resilience principles can be used to diagnose both strengths and weaknesses as well as the implicit choices and framing in urban resilience plans.

The diagnostic tool was tested on the resilience plans of the city of Rotterdam, with a focus on water. The study involved two MSc thesis projects (Brown, 2016; Wilk, 2016) and an assessment workshop. This report documents the results of that workshop.

Workshop organisers: Arjan Wardekker, Bettina Wilk, Valerie Brown.

Workshop participants: Arjan Wardekker, Bettina Wilk, Valerie Brown, Heleen Mees, Caroline Uittenbroek, Martin Wassen.

## 2. Workshop setup

On 30 June 2016, we convened an assessment team in a workshop to evaluate the strategic directions that the city of Rotterdam takes currently and in its Resilience Plan. The team involved seven social and natural science experts, including researchers on urban resilience, environmental governance, spatial planning, ecology, and sustainable development.

The participants evaluated Rotterdam’s resilience based on policy documents and data collected by two MSc research students (Brown, 2016; Wilk, 2016): 30 interviews with policymakers, experts and stakeholders in the city and region, and observations made during a six month research internship. The other participants also contributed research experience in Rotterdam from earlier studies.

The workshop (section 2.1. Workshop protocol) started with an introduction to the workshop’s topic and an introduction to the assessment framework that was to be used. After these, demarcations were set on the topic, geographic boundaries, and specific plans that were to be evaluated. Furthermore, we made explicit how the scoring should be interpreted and how we interpreted and defined resilience. The evaluation itself consisted of a baseline scoring (how resilient is Rotterdam currently, on specific resilience principles?) and an adaptation assessment (how will resilience plans impact resilience, on specific resilience principles?). In the workshop protocol, we planned to do these consecutively: baseline for all principles, followed by adaptation assessment for all principles. However, during the workshop, participants preferred to evaluate the evidence and do both baseline and adaptation assessment for one principle, and then move on to the next principle.

The assessment was conducted using a framework (section 2.2. Assessment framework) developed in Wilk (2016). The framework consists of a set of resilience principles (cf. Wardekker et al., 2010, 2016; Wardekker, 2018) covering four thematic focal directions of resilience planning: (1) planning & preparation, (2) absorbing disturbances, (3) recovering from disturbances, and (4) adaptiveness. Each principle was further operationalised into subcriteria. These were not scored separately. Instead, we developed a ‘narrative’ for each resilience principle on what that principle could mean for climate proofing in the specific situation of the case study, taking the subcriteria explicitly in mind. Baseline and adaptation assessments were scored per principle, using a five-point Likert scale (Table 1).

**Table 1. Scoring scales for baseline (top) and adaptation plans (bottom).**

--	-	0	+	++
The current situation is <u>very weak</u> regarding principle.  There are <i>key weaknesses on most aspects, no strengths</i> . Opportunities may be missed.	The current situation is <u>weak</u> regarding principle.  Either <i>overall weak</i> or mix of weaknesses and strengths that is still largely unfavourable.	The current situation is <u>neutral</u> regarding principle.  Mix of strengths or opportunities and weaknesses, with <i>overall neutral or unclear effect</i> .	The current situation is <u>strong</u> regarding principle.  Either <i>overall strong</i> or mix of weaknesses and strengths that is still largely favourable.	The current situation is <u>very strong</u> regarding principle.  There are <i>key strengths on most aspects, no weaknesses</i> and possibly valuable opportunities.

--	-	0	+	++
The adaptation plans have a <u>strongly negative</u> effect on this principle.  It has a <i>negative effect on most aspects / operationalisations, and no positive effects</i> .	The adaptation plans have a <u>negative</u> effect on this principle.  Either an <i>overall negative</i> effect, or <i>positive on some aspects / operationalisations</i> while neutral or marginally positive effect on others (total effect is still clearly negative).	The adaptation plans have <u>no or a neutral effect</u> on this principle.  Or the plans have <i>positive and negative effects</i> , e.g. positive on some aspects / operationalisations, negative on others, and the total effect is <u>unclear</u> .	The adaptation plans have an <u>positive</u> effect on this principle.  Either an <i>overall positive</i> effect, or <i>positive on some aspects / operationalisations</i> while neutral or marginally negative effect on others (total effect is still clearly positive).	The adaptation plans have a <u>strongly positive</u> effect on this principle.  It has a <i>positive effect on most aspects / operationalisations, and no negative effects</i> .

## 2.1. Workshop protocol

Utrecht, 30 June 2016, 13:00-17:00. Breaks as needed (assuming at least 2x15 minutes).

### 1. Introduction to the workshop – Wardekker [5-10 minutes]

- a. Joint paper – Steps of the resilience tool
- b. Setup of the full assessment (2 workshops)
- c. Setup & goal of workshop 1

### 2. Introduction to the resilience principles & framework – Wilk [5 minutes]

(Plus room to clear up any matters that are unclear, etc.) - All [5 minutes]

### 3. Establishing demarcations of the assessment - All [15 minutes]

- a. Topic? (climate resilience? flood resilience? More specific, e.g. fluvial vs. pluvial?)
- b. Geographic boundaries?
- c. Which 'adaptation plans' (e.g. only formal plans, water related, such as Water Plan 2, R'dam Resilience Strategy)?
- d. Do we score based on the assumption that the plans are executed, or do we weigh the chance that it will be executed in the scores given?
- e. Resilience of who, what, when, where, why?
- f. Are there any key trade-offs and normative choices that we can already spot? How to deal with those?

### 4. Baseline assessment [Brief reflections + interviewing, 30-40 minutes]

Due to limited time and perhaps information, it is not feasible to score Rotterdam's current climate resilience on all principles. Instead we will do a SWOT-like analysis.

Setup: Brown & Wilk give their opinion & input based on their interviews. The rest of us will then 'interview' them, to explore these topics further ("what about this, what about that...").

- a. Key climate-related threats & vulnerabilities: can we indicate any key impacts of climate change on Rotterdam and specifically vulnerable geographic areas, populations/communities, sectors, etc.? What climate-related matters should Rotterdam be aware of? – Brown could start the discussion from her experience, the rest of us can supplement & discuss further [10 minutes]
- b. Key strengths: looking at the resilience principles and their operationalisations in Bettina's framework, can we indicate any aspects that Rotterdam is currently (already) very good at? - All [10 minutes]
- c. Key weaknesses: looking at the resilience principles and their operationalisations in Bettina's framework, can we indicate any aspects that Rotterdam is currently (still) very bad at? - All [10 minutes]
- d. (We can also look at the 'opportunities', the O in SWOT, but not sure if this makes sense – up for discussion) - All [0-10 minutes]

### 5. Adaptation assessment [brief reflections + interviewing, 2.5 hours]

Setup: we will discuss the effect that current adaptation plans have on climate resilience. We will do this principle by principle. Per principle (10 principles x 15 minutes):

- a. Brief reflection, in which Wilk and Brown give their opinion on whether this principle is reflected in the adaptation plans, and to which extent these plans might improve climate resilience. [5 minutes]
- b. The rest of us will interview them, to further explore. Specifically: [5-8 minutes]
  - What could be reasons to give this principle a HIGH score?
  - What could be reasons to give this principle a LOW score?
- c. Finally, we will All discuss what score to give. Is this a principle that the adaptation plans will likely improve? We will assign the score as a group. [2-5 minutes]

## 2.2. Assessment framework

This section describes the assessment framework, divided in four focal directions, each containing two or three resilience principles plus an operationalisation into subcriteria. For a more extensive discussion, see Wilk (2016).

PHASE / POLICY DIRECTION	PRINCIPLE	OPERATIONALIZATION
<p><b>PLAN / PREPARE</b></p> <p>The capacity to plan, prepare for and anticipate known shocks and stresses. It is represented in proactive action, pre-emptive measures or preparedness activities aimed at mitigating or reducing exposure or minimizing vulnerability to particular threats.</p>	<p><b>Anticipation &amp; Foresight</b></p> <p>Planning ahead and foresight are essential tools for anticipatory adaptation. They originate from the human capacity to anticipate disturbances to a certain degree, imagine different futures and thus, consider possible outcomes and to implement preparatory interventions. In regards of climate hazards, anticipation is mainly concerned with creating relevant knowledge about disturbances, their probabilities, potential risks, impacts and resulting vulnerabilities. But the resulting knowledge should also be shared among organizations and made accessible for the wider population to create awareness.</p>	<p><b>Building knowledge about disturbance, exposure, vulnerability</b> Presence of climate projections, modelling and scenarios; performance of (flood) risk and vulnerability assessments; mapping of critical functions</p> <p><b>Monitoring of critical slow variables</b> Continuous monitoring of factors that affect sea, river, canal and polder water levels; flood risk monitoring system; evaluation of flood-protective infrastructure</p> <p><b>Information management &amp; sharing</b> Access of institutions to scientific data; tools for information storage and sharing that facilitate active knowledge dissemination across institutional boundaries</p> <p><b>Capacity to learn (from past experience)</b> Reactive learning from flooding experiences through historic track records of hazards and evaluative reports; lessons learnt improve planning and emergency response</p>
	<p><b>Preparedness &amp; Planning ahead</b></p> <p>Preparedness is strengthening a city's coping responses before a disaster occurs. Being better prepared enhances the chances of absorbing impacts and quicker recovery. Apart from building and implementing adequate emergency &amp; response management and mechanisms, this also entails providing the required resources for communities and businesses to plan and prepare for adverse events, such as the provision of adequate information, training and educational measures or the adoption of community flood plans.</p>	<p><b>Public awareness, risk communication, education &amp; training</b> Informing &amp; educating the public about flood risk, emergency procedures, evacuation routes, scripts for action; hazard awareness, (water) safety education programs &amp; response trainings</p> <p><b>Response &amp; emergency management</b> Early flood warning system; presence of emergency guidance documents; hazard mitigation, evacuation and recovery plans; shelter capacity; varied media used for emergency communication</p> <p><b>Preparedness of businesses for adverse events</b> Businesses are provided with climate scenarios and factor the impacts of climate change into their business practice (business continuity and contingency plans in place)</p>
	<p><b>Homeostasis</b></p> <p>Dynamics in a SES arise from interactions and feedbacks between fast variables responding to the conditions generated by slow variables. The strategic management of feedbacks to prevent regime shifts (caused by disasters or slow trends) is therefore crucial. One way to do that is through implementing multiple feedback loops that counteract disturbances (dampening feedback) and stabilize the system to maintain a particular SES regime.</p>	<p><b>Preservation and restoration of regulating ecosystem services</b> Policies for natural areas and ecosystem conservation are in place, additional green spaces are created along with the restoration of natural floodplains and water retention areas</p> <p><b>Integrated planning, coordination &amp; collaboration</b> Presence of bridging mechanisms that link and align strategies which can refer to the coordination of emergency plans or mainstreaming of water policies with other sectorial policies (e.g. land use, urban development)</p> <p><b>Inclusiveness &amp; equity standards</b> Supportive resources and services for vulnerable groups; legally enshrined rights and entitlements to use resources and services; equitable policy processes and outcomes of adaptation measures representing all interests at stake</p> <p><b>Clearly defined responsibilities of actors / institutions</b> Responsibilities for water and sewerage system, flood protection and prevention are clearly defined and allocated (statutory responsibilities) and all parties are aware of their roles in flood protection, response, recovery.</p> <p><b>Quick notification of disturbances</b> Flood and weather forecasting, monitoring and early warning system are present to generate timely information and a variety of communication channels is used for warnings</p>

**ABSORB**

The ability to withstand a disturbance, endure its impacts and cope with it to a certain extent while not being degraded by its effects or lose function. It is a function of actions taken to mitigate, better absorb impacts and enhance response capacity to an event.

**Robustness & Buffering**

The inherent strength of a city, referred to as robustness and the existence of buffering mechanisms based on over-dimensioning systems (i.e. water storage capacity) determine whether a city can endure, cope with a hazard and maintain function during adverse circumstances. Solid flood-protective infrastructure coupled with pre-emptive planning practices, such as flood-sensitive building codes and event buffering capacity can enhance the robustness of a system.

**Diversity**

Systems with many different components are more resilient than their counterparts with only a few. Diversification of resources and means can reduce a system's vulnerability by generating heterogeneous components performing different functions and thus facilitating a diversity of responses to threats. Furthermore, the prevalence of multiple ways of needs fulfillment (also called functional diversity) facilitates performing essential tasks and maintaining functions under a wider range of climate conditions and thus, enhances a system's flexibility.

**Redundancy**

Describes the presence of multiple elements or replication of components or pathways in order to have multiple instances available that perform the same function. These can fully substitute each other and therefore prevent system failure in case one component fails. From a resilience-building perspective it implies the strategic creation of systems that have multiple nodes, connected components and spare capacities that prevent failure in the face of extreme pressures or disruption, and maintain service delivery. It applies both to technological (power grid, infrastructure) as well as to social systems (large social networks that offer different problem-solving options).

**Robustness through infrastructure**  
Flood-protective installations (such as dikes, dams, levees, walls) and coastal defense structures are present which are periodically analyzed and inspected for safety

**Creating buffer capacities**  
Water excess capacity is created via overdimensioning the system, for instance by developing additional water storage, green roofs or natural floodplains

**Impact- and risk-reducing planning & planning practice**  
Property development rights are limited in flood plains, zoning instruments are applied and / or flood-conscious design and construction promoted through standards

**Functional & response diversity**  
Energy, food supply, transport options (multiple modes for transporting goods and people), land-use types and the economic landscape are diversified; in addition different flood management approaches are employed cutting across preparation, prevention, adaptation, response

**Spatial diversity of critical functions**  
Vital functions and services (financial institutions, hospitals, crisis centres, refugee centres, water pumping facilities, flood protective infrastructure) are physically distributed across the city to balance risk

**Actor & stakeholder diversity**  
Involvement of diverse administrative levels, actors and stakeholders with different backgrounds and knowledge in decision-making, planning and implementation processes which allows for different problem frames and solutions for flooding events

**Institutional diversity, multi-level governance systems and linkages**  
Governing authorities differ in size, structure and culture, there are various water governing authorities at different scales (national, regional, local) with overlapping roles so that they can take over in the case of one's failure

**Overlapping functions and roles**  
Redundancy of actors, actor groups, overlapping roles and multiple alternative connections at local to global scale through multi-level governance systems help maintain functions under adverse circumstances

**Functional redundancy in important functions and services**  
Components of the urban system are duplicated to provide substitute services when another component is disrupted (flood protective infrastructure, electricity networks, water systems, multiple routes of supply, energy, transport)

**Spare capacities & back-up resources**  
Purposely created spare capacity and back-ups for contingency situations with rising demand, such as alternative power, water and energy supplies for critical infrastructure and businesses or stocks of food, medicine, drinking water

**Compartmentalisation & Modularity**  
Mechanisms to locally contain flood impacts and prevent cascading effects are compartmentalization dikes or basing communication, transport networks, infrastructure grids and other vital functions in cities on a modular network structure

**RECOVER**

The ability to rapidly recover from an experienced disturbance, timely reorganize within desired boundaries and resume function by fostering fast response mechanisms and autonomous, self-directed (public) action.

**Flatness**

Flatness refers to a non-hierarchical way of governing a system and is a means of enhancing self-organization. The absence of a local formal competence to act on behalf of the population, as well as on lower policy levels along with lengthy decision-making and bureaucracy processes make the system inflexible and too slow to cope with changes and thus, ineffective in responses. Flatness is represented by inclusive, participatory processes that include a wide range of stakeholders, and providing the public with the power, authority and competence to respond to disturbances on their behalf.

**High Flux**

The principle of High Flux is rooted in the concept of perceiving urban processes to happen in "systems of cities", consisting of social and ecological networks with dynamic interlinkages (panarchies). High Flux represents a fast rate of movement of resources through the system that ensures a fast mobilization of these resources to quickly respond to threats and changes. This mechanism addresses rapidly by seeking ways and implementing conditions to maximize promptness in response. The underlying idea is that the faster the rate of movement of resources, the more resources are available at a given point in time to deal with disturbance.

**Institutional decentralization & autonomy**  
Independent governance units in water and flood risk management with particular domains of authority, shared responsibilities, rights and management authorities produce their own strategic goals and tailor-made policies

**Broad participation, stakeholder engagement & Inclusiveness**  
Non-governmental stakeholders contribute to problem analysis and developing solutions, through platforms of exchange, public consultation or legal provisions for participation and all interests at stake are included and equally represented to create shared ownership

**Room for autonomous change**  
Empowering the population to organize themselves, to innovate and improvise during crisis by providing them with information and having procedures that enable groups to form legal voluntary organizations, raise funds and undertake activities in relation to emerging needs

**Availability of & access to resources**  
Financial support for recovery is provided through contingency or damage compensation funds and payout of these funds or insurances is quick; supportive resources and assistance are arranged for vulnerable groups

**Social & institutional networks**  
Formal or informal cross-sector partnerships and networks between governing authorities, academia, firms and NGO and a broad web of social ties can fasten recovery by accessing resources of others

**Flexibility in response / resourcefulness**  
Citizens have the choice and options to modify behaviour and adopt alternatives strategies if required, such as modifying structures, changing physical location or temporary repurposing of resources, means and spaces

**Managing connectivity of critical sectors, infrastructure and natural habitats**  
Interconnectivities between sectors, critical functions along with potential cascading effects are identified and connections between natural habitats and water bodies are established

**ADAPT**

The flexibility to seize arising opportunities and the capacity to initiate informed, deliberate, long-term changes in the system (e.g. organizational change, new policies) in response to changing conditions in order to maintain desired functions in the future.

**Learning & Reflectivity**

Under conditions of uncertainty and unexpected changes, learning becomes pivotal for affecting actual change. It is the most important driver for strategic adjustments in part of the system and new strategies to cope with change. It depends on the capacity and willingness of organizations and individuals to apply new knowledge, adopt novel, alternatives strategies in response to changing circumstances and change set goals if a new context requires it.

**Flexibility**

Uncertainty requires flexible planning, spontaneous responses and adopting flexible elements that are apt for several scenarios to come. From an institutional perspective, flexibility in structure and processes is crucial to be operational under fast-changing conditions. Flexibility in spatial means refers to creating anticipatory physical "structural elbowroom" for future adjustments, extensions or retrofitting. Flexibility can also be perceived as a design principle for adaptation measures according to reversibility, and avoiding limitations on the range of possible future measures.

**Institutional learning capacity & reflectivity**  
Plans, strategies and policies are periodically revised and updated based on emerging information and research and continuous, participatory co-learning approaches are being applied (information networks, workshops, webinars)

**Experimentation & innovation**  
Small-scale policy experiments to test alternative approaches and designs, inform policy recommendations and explore new ways to live with climate change impacts are present and financially supported, and informal, safe space to experiment and innovate is provided

**Institutional flexibility**  
Institutions have flexible decision-making processes where a change in speed and actor composition is possible, allow for changes in goals, strategies and time horizons, and have flexible procedures and cooperation arrangements

**Flexibility in spatial planning**  
Flexible elements in spatial planning and physical interventions are applied that allow for future adjustments, retrofitting and/or extension (examples are broader dike foundations, modular elements in buildings)

**Flexibility in measures**  
Measures taken now exhibit a mixture of small-, large scale, structural and non-structural measures and do not limit the range of possible future measures; preferably they are reversible (multi-functional dikes)



## 3. Results

The results of the assessment will be discussed below, starting with the demarcations and an overview of key threats and vulnerabilities. The baseline and adaptation plans assessments are discussed per focal direction (plan/adapt, absorb, recover, adapt).

### 3.1. Demarcations

We focus on the level of the municipality, because most plans are also made for this geographic and governmental level.

We examine formal municipal plans. Other, informal plans are not taken into account, as they are difficult to inventory and assess. For example, they are difficult to prove and delineate how ambitious or effective they are, or what is really planned and what just speculation. Pilot plans connected to the municipal level are taken into account when indicated in the municipal documents.

We are evaluating the plans based on the assumption that the plans are actually implemented as described. This allows for the most solid scoring. While the plans will no doubt change in practical implementation, scoring based on the expert team's assessment of the likely practical implementation would be too speculative.

Regarding the who, what, where, when and why of resilience, several things can be observed. The discourse in the plans suggests that Rotterdam focuses on enhancing overall resilience – i.e. for everyone in the city. A broad range of topics is covered in the Resilience Plan (Municipality of Rotterdam, 2016): society, the port, clean energy, cyber, climate adaptation, infrastructure, networks, and 'anchoring' of resilience. A practical observation (cf. Brown, 2016; Wilk, 2016) is that the focus is strongly on economic aspects, particularly business, the port, and water. However, more focus seems to be paid to citizens and communities in the Resilience Plan compared to earlier plans. The '21<sup>st</sup> century' is the explicit timeframe that the Resilience Plan focuses on, however, the year 2030 is mentioned explicitly. Many older policy documents refer to 2030 (Municipality of Rotterdam, 2007; Municipality of Rotterdam et al., 2007, 2013) or 2035 (De Greef et al., 2005) as well.

Trade-offs and normative choices were not explored prior to the assessment.

Participants had some discussion on the relation between flatness and the focal direction of recovery. It could also be related to other focal directions.

### 3.2. Key vulnerabilities, strengths and weaknesses

#### **Vulnerabilities**

Key vulnerabilities and climate change impacts are related to flooding, particularly due to precipitation and cloudbursts. Heat and sea level rise are also concerns.

Potential vulnerable neighbourhoods include the polder areas (meters below sea level) and the unembanked areas, such as the old port districts that have been or are redeveloped into housing and office areas. Potential vulnerable populations include the poorer socio-economic groups, as these live in potentially vulnerable neighbourhoods, such as the areas close to the harbour.

Critical infrastructure could be vulnerable, e.g. energy and ICT infrastructure (particularly related to the port, water system, Maeslantkering storm surge barrier), transport routes inland and to Belgium.

Soil subsidence, low groundwater tables, and related rot damage to wooden foundation pilings are an issue in some areas. For instance the Schieland area has 1 cm/yr soil subsidence. This is comparable to some of the surrounding countryside, e.g. the Green Heart region experiences in some locations 12 mm/yr subsidence (Wardekker et al., 2016). Infrastructure, houses and foundations of other buildings could be at risk.

### **Strengths**

Key strengths of Rotterdam include a high level of expertise and experience in construction and infrastructure. I.e. Rotterdam is very good at building things, particularly in relation to water engineering, flood prevention, and architecture. *Robustness* through structural interventions is a major strength.

Rotterdam has a strong basis in *anticipation & foresight*, particularly through strong knowledge networks both nationally (e.g. KNMI climate scenarios, many scientists working on climate and water related issues at various universities and knowledge institutes), and specifically between Rotterdam and national knowledge programs (Knowledge for Climate, Climate Changes Spatial Planning, etc.), institutes and universities. There is strong, streamlined knowledge development.

Rotterdam has a strong tradition of *learning*. The city wants to learn from experiences (evaluation) and change policies based on that. There are numerous innovative pilot projects and programs. Links with scientists and institutes are strong, including semi-public institutes such as Deltares and STOWA. These serve as 'backup knowledge development', complementing Rotterdam's own research. Participatory learning can also be observed, e.g. collaborations at the IABR International Architecture Biennale Rotterdam led to input for Rotterdam's Water Plan. However, respondents did note that the follow-through of this learning is lacking, particularly when it comes to translating pilot projects into new policies and to this learning permeating from the inner circle of Rotterdam's adaptation specialists into a wider audience. This could result in an implementation gap.

### **Weaknesses**

Potential weaknesses include the level of *high flux*, for example the access of citizens to resources which is related to low scores on the principle of *flatness* and an identified lack of broad stakeholder engagement and inclusiveness. A website and app are available, but the ease of finding these and actual usage by citizens were questioned. Collaboration with citizens is improving however, particularly after the experiences in developing Rotterdam's water squares (e.g. the original attempt was unsuccessful, the second much better). Some discussion followed on social-institutional networks. Participants noted that collaboration in the resilience principle high flux (i.e. neighbourhood support or organized, self-directed action in the event of flooding) is different than in other focal directions. E.g. related to high flux, networks are not very good. Related to other resilience principles, these networks are much better. Good involvement can be observed in high profile projects, but low involvement in some other cases. It is highly project dependent.

Regarding *preparedness & planning ahead*, the current level of training is not good (cf. OECD, 2014). The emergency planning, response and recovery plans are also not yet adequate and public risk awareness needs to be improved.

Rotterdam has a strong tradition in implementing structural interventions. While important, the strong focus on these results in a lack of *flexibility*, due to both the inflexible nature of structural measures and the risk of these causing a 'path dependency' on using those as the primary approach to adaptation.

## Opportunities

Rotterdam is a 'new' city. It was heavily bombed and largely levelled during World War 2. Relatively few historical areas remained. This can be seen as an opportunity, as it allows for fast (re)developments.

The vicinity to the water is a threat but also an opportunity. For example, it allows for quickly discharging water from neighbourhoods.

Rotterdam is highly skilled in marketing and exporting its knowledge and experience. For instance, Rotterdam is currently actively involved in exporting its water squares to Mexico City (Ilgen, 2016).

### 3.3. Assessment: planning & preparation

#### **Box 1. Resilience narratives for planning & preparation**

##### **Anticipation & foresight**

A significant body of knowledge has been developed of past, present and future climate-related risks, including their nature and impacts on different levels. This knowledge and information is accessible to actors involved in climate adaptation and actively shared with stakeholders beyond the municipality. Infrastructure is in place to actively monitor slow variables (key underlying factors and trends in e.g. economy, society, politics, environment, etc.) and act proactively upon this information. The organisation is geared towards active learning regarding current and past disturbances.

##### **Preparedness & planning ahead**

Calamity and emergency response plans for a variety of different hazards with detailed indication of responsibilities of various actors to act and react, during and after a disturbance. A specified actor has the capacity to coordinate responses during disturbances. Both the public and businesses are aware well-informed of climate-related risks, their personal vulnerabilities and situation, their responsibilities, and sources of information they can access. All parts of the population are frequently trained in adequate disaster response for various events. Businesses have their own contingency and business continuity plans for all kinds of threats.

##### **Homeostasis**

There is a high level of integration of climate adaptation into other policy arenas, including 'hard' and 'soft' laws. Responsibilities of all key actors are clearly defined and integrated in policy and law. Policy processes are also integrative, accounting for equity and inclusiveness. Natural environmental processes that help regulate key ecosystem services are enhanced and/or recuperated. Various communication channels are in place to spread information on disturbances and inform decision-making.

#### **Anticipation & foresight**

- + There is a fair amount of research and reports by (or involving) the municipality.
- ++ Rotterdam is involved extensively in knowledge networks.
- + Rotterdam is involved extensively in exchange of best practices.
- +/- Some tools, such as stress tests and the CAS Adaptation Portal may not be specific enough for municipalities that are themselves already advanced in adaptation and foresight.
- +/- There are local impact projections, such as 3D flood simulations and related tools. These also connect with stakeholders. However, these materials mostly focus on dike breach events, not on precipitation and cloudbursts. There is a rain radar specific for Rotterdam.
- /+ The plans provide some effort on anticipation and foresight, but it is clearly not a major focus.

The assessment team rated this principle as: currently very strong (++) , the plans improve (+) these.

#### **Preparedness & planning ahead**

- Several key weaknesses lie in public awareness of climate change and water related risks, risk communication, training of citizens, and training of municipal staff. These are currently low.
- The population is currently far from prepared for climate and water related problems.
- +/- Businesses are prepared to some extent, but mostly only large businesses (SEVESO directive).
- +/- The plans seem to focus mostly on creating an accepting community and social cohesion.
- + The plans try to build in educational elements.
- + The plans exhibit a clear ambition regarding planning and preparedness.
- ++ There are several pilot projects on 'vertical evacuation' planning.
- + The plans also include cyber resilience.

The assessment team rated this principle as: currently weak (-), the plans improve (+) these.

#### **Homeostasis**

- + The responsiveness of Rotterdam and its water (crisis) management system are currently good. However, participants suggested that this is mainly due to national level policies and planning.
- The integration of climate adaptation in other policy areas (e.g. adaptation mainstreaming) has been attempted, but doesn't come off the ground. Rather, the municipality opted for a dedicated approach (Rotterdam Climate Proof), separate from the rest of the municipality. There is no real integration and mainstreaming into other policy domains.
- The clarity of responsibilities, such as the responsibility of businesses, is not really specified. Some participants suggested that the municipality might be scared to point to responsible parties.
- +/- There is a warning system for floods and safety issues (particularly through the responsible Safety Region; a collaborative regional authority), but not for cloudbursts. The latter is a difficult risk.
- +/- to – Some work has been done (and further work is planned in the plans) on the Meuse ecosystem, green roofs, pilots in the port area, etc. to enhance ecological and heat-related resilience. However, these are primarily small scale.
- + In the plans, integration of climate adaptation into other policy areas is a clear goal. The Resilience Plan takes a broad perspective on urban resilience. (as noted above, this has been tried, and participants were somewhat sceptical, but our scoring assumption was that plans are implemented as described).

The assessment team rated this principle as: currently weak (-), the plans improve (+) these.

### **3.4. Assessment: absorbing disturbances**

#### **Box 2. Resilience narratives for absorbing disturbances**

##### **Robustness & buffering**

There is sufficient capacity to buffer climate-related disturbances, preventing impacts to some extent or slowing them down. This is achieved through policy, spatial, and structural measures. Spatial planning and infrastructure have made provisions and can withstand to a certain extent the impacts that do take place.

**Diversity**

The governance system consists of various governing authorities at different scale (national, regional, local). A diverse group of actors and stakeholders (with diverse professional and scientific backgrounds) is actively involved in decision-making, planning, policy-making and implementation processes. There is continuous and frequent interaction, exchange and collaboration among the diverse stakeholders operating at the different levels. The city, its economy, and organisations are supported by a diverse spectrum of resources, sources of income, and management strategies. Key functions are strategically, spatially distributed across the area. Biodiversity is high and well cared for.

**Redundancy**

There is a high level of redundancy in key governance functions and roles, and operational management and provision of key public services and resources. Several different entities (within and among organisations) can react to disturbances; if the service of one is interrupted or hampered, there are alternatives. Vital functions have backup capacities (e.g. backup locations, equipment, stock, etc.). Critical resources (energy, water, food, etc.) can be obtained from several alternative sources, including local ones, and via multiple routes, to counter disruptions in supply chains. The potential of cascading impacts due to a disturbance have been inventoried and countered through backups or compartmentalisation of the systems involved.

**Robustness & buffering**

- There's currently heavily insufficient rainwater storage capacity.
- ++ The robustness of Rotterdam's water system is very high.
- Regarding planning, particularly spatial planning, the city is trying, but not making much progress.
- +/- Overall, this principle first appeared as a strength (section 3.2: Key vulnerabilities, strengths and weaknesses), but in hindsight it is not or only on robustness, and even the latter are mostly pilot projects, rather than mainstreamed programs or general system strengths.
- + Ideas regarding Water Sensitive and Sponge Cities are being introduced as a new concept in practice and in the plans. These ideas help make the city more robust and enhance buffer capacity. Rotterdam is making some nice efforts; better than other Dutch cities. However, compared to cities such as Basel or Stuttgart, it is still very limited.
- + Various projects are planned for green (plants/nature), blue (water storage), yellow (energy), and red (social) aspects, particularly for urban roofs.
- + Underground water storage is planned to be extended (compared to a pilot project at present).
- + The plans suggest implementation of urban wetlands.

The assessment team rated this principle as: currently neutral (0), the plans improve (+) these.

**Diversity**

- Spatial diversity of functions is low. In part, this is simply due to the fact that cities grow in an organic way, resulting in vulnerable functions sometimes being placed in vulnerable areas. E.g. flood shelters in prone areas.
- + Rotterdam has high cultural diversity.
- + Actor and stakeholder diversity are good, as are their involvement, and collaboration across institutional and organisational boundaries. This also benefits institutional diversity.
- The diversity in framing of problems, solutions, etc. (cf. De Boer et al., 2009; Wardekker, 2016, 2018) is not explicitly taken into account.

- There is limited awareness of different, and differentiation of, functions and how to improve those. Many of these are however challenging to improve from the municipal level, e.g. economic functions, energy mixes, etc.

+ There's some material on energy diversification in the Resilience Strategy, but this is more about sustainability in general.

- None of the plans discuss diversification of water management strategies.

The assessment team rated this principle as: currently weak (-), the plans have a neutral effect (0) on these. The team did indicate that this principle might be very difficult to influence by a municipality.

### **Redundancy**

+ There are redundancies in the actors involved.

- There is however limited accountability in the actor redundancies mentioned above. This leads to a risk/downside, in that actor collaborations and groups can quickly break up for various reasons.

+ Pumping capabilities can be operated both electronically and manually. Mobile backup pumps are available.

+ The system of dikes, Maeslantkering storm surge barrier, and coastal dunes provide redundant flood protection against sea level issues, storm surge and other marine flooding problems.

- Infrastructure (rail, tunnels, roads) is currently already under high pressure and therefore vulnerable and lacking somewhat in redundancy.

+ The plans examine and improve redundancy in transport routes, emergency planning, and removal of bottlenecks.

The assessment team rated this principle as: currently strong (+), the plans improve (+) these.

## 3.5. Assessment: recovering from disturbances

### **Box 3: Resilience narratives for recovering from disturbances**

#### **Flatness**

Institutions and decision-making are decentralised, with autonomous local units that have the power to make operational decisions and develop policies to counter disturbances that they encounter. The 'on the ground' decision-makers explicitly include a broad and inclusive range of stakeholders and the public. They include vulnerable and marginalised groups. These have problem ownership, are engaged, and access to information, scripts of action, tools, and capacities/education/training to take (autonomous) action. There should be explicit room for autonomous action and change by the local community.

#### **High Flux**

Stakeholders and the public can have easy and quick access to required financial, human, knowledge/information, and other resources. This is provided through their own social networks as well as institutional, regulatory and financial (e.g. insurances or recovery funds) provisions made by the authorities. There is explicit attention to equity in post-disaster resource distribution and access to resources. Decision-makers are flexible and resourceful enough to quickly respond to disturbances and switch between strategies or responses if necessary. The connectivity between various economic, social and environmental systems, including ecological and blue-green corridors, is managed: e.g. interdependencies of different sectors (e.g. water & energy) are known, and are used to stimulate resilience and quick responses to disturbances, while preventing cascading effects between systems.

## Flatness

- There are many social issues in the city that currently inhibit active social involvement and citizen empowerment.

- People/citizens generally do not know about climate change, adaptation, and the city's efforts.

+/- In some pilot projects, efforts are being made to promote flatness and local input.

+/- The Municipality of Rotterdam is highly autonomous in climate change adaptation. They may not really need to involve others. This suggests a risk of not involving other parties (point of attention).

+/- The level of power in adaptation focused departments of the Municipality is limited.

++ The Resilience Strategy and other plans strongly emphasise the need for focus on community resilience, social issues, and citizen involvement. These are embedded well within the plans. Rotterdam clearly exhibits a desire to show that they're working on the city's social issues.

The assessment team rated this principle: currently weak (-), the plans strongly improve (++) these.

## High Flux

+ There is a fast exchange of human resources, ideas, advisors, backgrounds, and reports.

- It is difficult to acquire funding; there is limited funding available. Also no solution for flood insurance.

-/0 The level of social cohesion regarding e.g. floods is low. Rotterdam is a big city, with high flux of materials, people, etc. but limited social cohesion.

+ The plans explicitly aim to improve social cohesion.

The team rated this principle as: currently neutral (0), the plans improve (+) this.

## 3.6. Assessment: adaptability

### Box 4. Resilience narratives for adaptability

#### Learning

The city, its institutions, stakeholders and citizens can learn from previous experience and new information in a reflexive, participatory way. Learning should be aimed both at coping with short-term shocks and long-term pressures. There is room for experimentation and learning by doing. Innovation is stimulated. Institutional learning capacity is explicitly developed and maintained. Learning is translated and implemented proactively into new or updated policies, improved goals, and improved institutions. The learning process is actively monitored, and the lessons learned are actively communicated and implemented. There is continuous reflection (not a single learning event, but periodic updating) on processes, activities, and the state of the system/city, including the uncertainties and ignorance regarding climate change and its local impacts.

#### Flexibility

Climate adaptation and other policies and process are flexible on all levels, in order to cope with uncertainties and surprises. The system should be able to cope with both short-term and long-term challenges, however they may change. Climate adaptation measures are flexible and can account for a wide range of impacts, should not limit the possible range of future options being taken (e.g. measures can be reversed or altered; they do not consume all available options and/or allow for a combination with other measures (e.g. no dominant, single approach)). Spatial planning is similarly flexible, allowing for changes in spatial functions and developments, that allow for expansion, reduction, and shifts in the use of space & buildings, as needs may change. Institutions and decision-making processes are also flexible, allowing for changes in the processes, participants, rules, strategies, goals, and speed of decision-making.

## Learning

- + The level of experimentation and innovation in Rotterdam is high.
- + Pilot studies are conducted, aimed at testing new ideas and concepts.
- Follow-through and upscaling of the experiments and innovation is not that good, particularly related to actual learning from pilot projects. There are challenges regarding moving pilots from Rotterdam's 'inner circle' of adaptation and resilience specialists to a wider movement. This would require institutional changes, breaking current municipal silos, both in terms of policy development and budgeting (budgets for specific plans; who pays for what?). This is difficult.
- + There is consistency in a number of the key people involved in urban climate adaptation and urban resilience building in Rotterdam. These serve as active figureheads and advocates over the long run, preserving knowledge and experiences, and improving institutional memory.
- + Plans are periodically updated, and take along new knowledge and insights during those updates.
- + New policies are being developed, and there is specific attention to policymaking under uncertainty. Much of this attention focuses on scenarios and the notion of 'embracing uncertainty' (cf. Mathijssen et al., 2008; Wardekker et al., 2010).
- + The plans are good in strategic policymaking, vision development, and profiling. The marketing quality is high, which could help other cities learn from Rotterdam's work (cf. Ilgen, 2016).
- Follow through of these new policies into actual new, comprehensive policymaking and practical applications is not strong. Plans exhibit a lot of marketing, nice images, and high-profile pilot projects, and these are carried through into policy plans and visions, but often are not well translated into concrete changes in the city. I.e. the focus seems on strategic policymaking and profiling, rather than discussing the actual needs of neighbourhoods, helping the city adapt, and implementing an actual transition in the city.
- + An 'Adaptation Monitor' is being developed to evaluate adaptation, monitor its impacts, potentially leading to double loop learning.

The assessment team rated this principle as: currently strong (+), the plans improve (+) these.

## Flexibility

- Institutional flexibility is often a challenge in large organisations, and in Rotterdam it is currently low (cf. the comments above, under Learning). There seems to be some room to shift budgets and the like for pilot projects, but these are often single, incidental cases.
- Rotterdam Climate Proof depends strongly on EU funds. Few options for actual adaptation funding.
- Little flexibility in spatial aspects. Pressure on space is high in the city.
- + There is flexibility in measures. Tailor-made adaptation options are being developed.
- A considerable amount of the budget is reserved for 'hard' adaptation options, such as dike reinforcement. In a 'multi-layered safety approach', the hard 1<sup>st</sup> layer (flood prevention) is currently being developed to be sufficient as a stand-alone option, while the other layers (damage prevention, evacuation, etc.) could consequently be seen as redundant.
- + The plans pay attention to flexible adaptation pathways.

The team rated this principle as: currently weak (-), the plans have a neutral effect (0) on these. The team did indicate that there might not be much room for implementing flexibility. However, Dutch spatial and urban planners do have a long tradition of experimenting with flexible use of space.



## 4. Discussion

Following the baseline assessment (what's the current situation) and adaptation assessment (how do adaptation and resilience plans improve or reduce the current situation), some observations can be made regarding Rotterdam's strengths, weaknesses, and implicit choices. See Figure 1 for the final scores.

Regarding the current situation, Rotterdam has a highly targeted resilience situation: (very) good at specific aspects. Particularly, the city is very strong in anticipation & foresight, through its extensive involvement in research, national knowledge networks, and national and international exchange of experiences. They are also strong in redundancy (but primarily the engineering aspects) and learning. Notable weaknesses include preparedness, homeostasis, diversity, flatness, and flexibility. The focal directions planning & preparation, absorbing disturbances, and adaptability are covered, although by a single principle each. Recovery is a point of attention.

The adaptation plans clearly take a much broader approach, covering most resilience principles. Particularly, flatness is strongly improved through a clear effort to tackle current social issues in the city, and improving community resilience and citizen involvement. Also improved are: anticipation, preparedness, homeostasis, robustness, redundancy, high flux, and learning. Diversity and flexibility are not well covered. All four focal directions are covered by the current plans, generally by multiple principles, assuming they will be successfully implemented.

Overall, a shift is observed between the current situation and the plans: from a highly targeted and perhaps somewhat top-down technocratic and engineering approach towards a broader effort that also strongly includes social aspects.

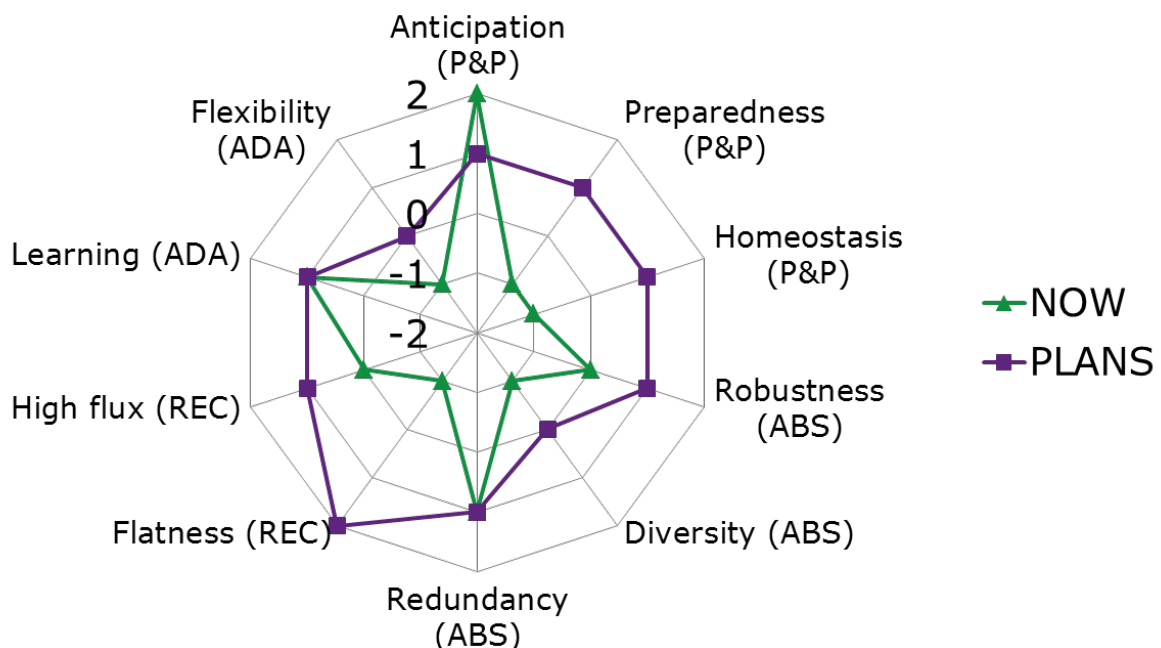


Figure 1. Diagnostic diagram of Rotterdam's baseline and planned resilience. Resilience principles cover the focal directions: planning & preparation (P&P), absorption (ABS), recovery (REC), and adaptability (ADA). The scale ranges from - (-2; very weak currently, very negative impact of plans) to ++ (+2; very strong currently, very positive impact).

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