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How boundary objects facilitate local climate adaptation networks: the cases of Amsterdam Rainproof and Water Sensitive Rotterdam

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New networks of public and private parties co-produce urban climate adaptation measures, for which different viewpoints and interests have to be bridged. While previous research has focused on individuals and organizations as intermediaries, little attention has been paid to boundary objects: conceptual or material objects that help to bridge competing values. This article aims to understand how local climate adaptation networks co-develop boundary objects and how they benefit the development of adaptation measures by conducting a qualitative case study comparison of two front-running Dutch networks: Amsterdam Rainproof and Water Sensitive Rotterdam. The conceptualization of a “water-sensitive city” attracted multiple stakeholders (professionals from different disciplines, communities, businesses), while material objects, such as interactive 3D-models, addressed information needs. The objects contributed to adaptation measures by convening stakeholders, translating viewpoints and initiating collaborations. The limited diversity in the networks suggests that, rather than enabling participatory decision-making, the networks are instrumentally used by water authorities.

Keywords: boundary objects; climate adaptation; collaboration; governance networks; urban water management

1. Introduction

Local governments across the world aim to create more climate-sensitive cities, since climate change impacts have become most visible in urban areas. Urban climate adaptation used to be a field driven by public water authorities that were responsible for urban drainage systems (Brown, Ashley, and Farrelly 2011). As these systems are increasingly considered inadequate or too costly to expand (Dai, Wörner, and van Rijswijk 2018), climate adaptation measures are being taken on public and private land, which requires close collaborations between local authorities (water authorities, municipalities) and landowners (e.g. housing associations, the real estate sector, individual property owners). Examples include the construction of green roofs, permeable paving, and water-sensitive urban designs. As a result, urban climate adaptation has

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become a joint responsibility of public and private stakeholders (Mees *et al.* 2014; Dąbrowski 2018).

The delivery of urban climate adaptation therefore takes place in networks, where each stakeholder brings his or her own resources to the table (e.g. expertise, social networks and finances). Resources in these networks are dispersed among stakeholders (Johns 2019; Zuniga-Teran *et al.* 2020). This requires crossing organizational and disciplinary boundaries (Van Broekhoven and Boons 2022) and connecting different institutional logics (Franco-Torres, Rogers, and Ugarelli 2020). Hence, we see a rise of local climate adaptation networks, in which different actors, and their differing viewpoints and social worlds, are brought together (Cash *et al.* 2003; Moss 2009; Kivimaa *et al.* 2019).

Urban climate adaptation networks have been studied extensively, both locally and translocally (Anguelovski and Carmin 2011; Bulkeley 2015; Karhinen *et al.* 2021). These studies focused on how professionals – operating as boundary spanners – can connect different organizations and domains (Moss 2009; Dąbrowski 2018; Van Broekhoven and Boons 2022). Besides people and organizations, *objects* can also help to cross boundaries (Star and Griesemer 1989). These boundary objects can be either tangible artifacts, such as a map or a tool, or conceptual ideas, such as a shared narrative. So far, urban climate adaptation research has paid little attention to the role of boundary objects in networks that aim to create climate-adaptive cities. As previous research has identified the hurdles of implementing urban climate adaptation (Johns 2019), we expect that our perspective will help to understand how competing logics and values between public and private stakeholders can be bridged through the joint development of boundary objects in the field of urban climate adaptation (Karhinen *et al.* 2021).

Consequently, we aim *to understand how networks for urban climate adaptation develop boundary objects and how these objects benefit the development of urban climate adaptation measures*. We will look specifically at two internationally renowned networks in the Netherlands – Amsterdam Rainproof and Water Sensitive Rotterdam – that are frontrunners in making climate adaptation measures a joint responsibility of public and private parties (Arcadis 2016; Dai, Wörner, and van Rijswick 2018). Since the Dutch have a traditionally strong public sector in water management (OECD 2014), we can examine closely how boundary objects are developed in order to make the shift toward more shared responsibilities.

The structure of the paper is as follows. The second section presents the theoretical framework based on the concept of boundary objects. The third section introduces the case studies – Amsterdam Rainproof and Water Sensitive Rotterdam – and elaborates on the data collection and analysis. The fourth section presents the results of the two case studies. The article wraps up with a concluding section.

2. Boundary objects as enablers for joint action

2.1. Co-producing social order and knowledge through boundary objects

The concept of boundary objects was originally coined by Star and Griesemer (1989), who argued that networks of actors mutually develop boundary objects “which both inhabit several social worlds and satisfy the informational requirements of each of them” (393; see also Star 2010). These actors acknowledge that their interdependencies require collaboration, which they expect to be beneficial in meeting individual interests

(Guston 2001). As Guston (2001) argues, boundary work leads to the co-production of social order and knowledge, which could clash with established interests of individual actors. Co-production can be defined as “an iterative and collaborative process involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future” (Norström *et al.* 2020, 183). In this process, boundary objects may be strategically established by local governments with single goals in mind that promote a social order that favors established interests (Spee and Jarzabkowski 2009). Yet, this order may be contested by others (Levina and Vaast 2005). Establishing boundary objects is therefore not a value-neutral activity, but in many cases a strategic, political activity that reveals power struggles between public and private actors (Moss 2009). Overall, boundary objects can be valuable vehicles for the co-production of social order and knowledge, but they need to be continuously approved and legitimized by participants from the different domains in order to be effective (Star 2010).

2.2. *Boundary objects untangled*

Boundary objects are defined by three characteristics (Star 2010; Steger *et al.* 2018). The first and most referred to characteristic is interpretive flexibility: a boundary object should be malleable enough to appeal to a broad audience, while simultaneously concrete enough to be useful (Star 2010). Only then can a boundary object facilitate communication between different social worlds. The concept of boundary objects originates from the science-policy interface, in which the social worlds of science and policy have developed their own ways of working that need to be overcome for successful collaborations (Shackley and Wynne 1996; Cash *et al.* 2003). Second, the boundary object has to “address an information need arising from work processes” (Steger *et al.* 2018, 154). The information need emerges from the interdependencies between actors (Guston 2001) and could, for example, include the organization of data (Star and Griesemer 1989). Boundary objects, then, facilitate the co-production of knowledge and organizational systems between actors (Star 2010). Third, boundary objects are able to move back and forth between different social worlds (Steger *et al.* 2018). Each world may be driven by a different logic and may tailor the object to its specific context, yet the object needs to be able to transcend the individual domains (Franco-Torres, Rogers, and Ugarelli 2020).

Boundary objects can take many forms. In the typology of Star and Griesemer (1989), boundary objects can be both *material* (a tool or a shared infrastructure, such as a repository) and *conceptual* (a frame or a concept, such as an abstract ideal type). Consequently, boundary objects are both “product and process”; they can be used in a specific way (materialising into an infrastructure), or remain an attractive idea that can bring stakeholders together (residing at a conceptual level) (Steger *et al.* 2018: 154-155).

Material boundary objects refer to tangible artifacts and joint work practices. Typically, organizations have their own frameworks and routines, which may be difficult to match with each other. The development of a joint process or tool can help in exchanging knowledge and developing actions, leading to standardized practices. Many of these examples concern the establishment of a common platform, model or map in order to support the alignment of different information systems. These objects can exist on different levels. To illustrate, previous research has shown how the IPCC-reports have led to an improved understanding between scientists and policymakers

(Hoppe, Wesselink, and Cairns 2013). Accordingly, the IPCC reports have standardized knowledge between these domains. On a more local scale, Dewulf *et al.* (2013) discuss how a collaborative modeling exercise in the upper Guadina River in Spain can facilitate dialogue and interaction among a group of stakeholders by creating a shared frame of reference.

In contrast, conceptual boundary objects typically embody a certain vagueness, which can be valuable to appeal to a wide variety of actors and to build coalitions (Brand and Jax 2007). Rather than looking at the products, conceptual boundary objects become visible in a distinct, shared vocabulary that helps to facilitate knowledge exchange and convene stakeholders (Carlile 2002). In the field of urban climate adaptation, the dominant language is often described as technically driven, sectoral and managerial (Brown, Ashley, and Farrelly 2011). Such a language may not be appealing to other stakeholders to contribute to climate adaptation measures. Consequently, boundary objects have to embody a different frame that can better relate to a broader array of stakeholders, for instance by positioning climate adaptation as an opportunity for urban development rather than a threat (Ashley, Gersonius, and Horton 2020). This opportunity-led frame enables stakeholders to link their ambitions (e.g. regarding recreation, ecological restoration, or economic development) with climate adaptation. In a similar vein, parties may want to join new urban networks that position themes such as ‘resilience’ and ‘greening the city’ as hip and innovative (Zuniga-Teran *et al.* 2020). This labeling may offer opportunities for parties to acquire resources or to position themselves as frontrunners. This can be seen in networks that operate either locally (e.g. Toronto Climate Action Network, Climate Ready Boston; Anguelovski and Carmin 2011; Karhinen *et al.* 2021), or translocally (e.g. C40 Cities and the Resilient Cities Network; Bulkeley 2015).

2.3. Functions of a boundary object

Boundary objects can fulfill four functions (Cash *et al.* 2003; Tribbia and Moser 2008). Firstly, boundary objects have a *convening* function, “bringing stakeholder parties together for face-to-face contact to foster trust-building and mutual understanding, which is the foundation of effective information production, transfer and ultimate use” (Tribbia and Moser 2008, 317). In order to appeal to a wide range of stakeholders, the boundary object needs to develop a distinct identity that is malleable enough to attract different actors, but still brings people together around a particular theme or issue (Star and Griesemer 1989). Second, boundary objects help in the *translation* of viewpoints, expertise and resources. These elements need to be comprehensible for the actors involved, so translation requires dialogue (Tribbia and Moser 2008). In other words, boundary objects support sensemaking between stakeholders and create a shared context of action. The third function of a boundary object entails *collaboration*. According to Carlile (2002), boundary objects should provide concrete means for individuals. Dialogue, which boundary objects can facilitate, enables effective working relationships and co-production. It can help to exchange and generate knowledge and experiences, but it can also provide resources for developing actions and apply the form of generated knowledge (Carlile 2002). Fourth, collaborating can also take the form of *mediation* to manage tradeoffs between different stakeholders (Cash *et al.* 2003).

Altogether, boundary objects contribute to the four functions of boundary objects (i.e. convening, translating, collaborating, mediating), which are visualized in Figure 1.

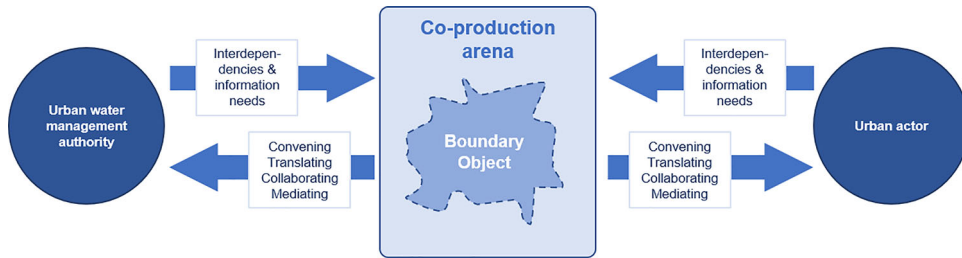


Figure 1. The co-production of social order and knowledge through boundary objects.

3. Methodology

3.1. A Case study approach

Case study research is useful to acquire in-depth, context-specific knowledge about new phenomena (Yin 2003). Because urban climate adaptation is increasingly considered a joint responsibility of public and private stakeholders (Mees *et al.* 2014; Dąbrowski 2018), we expect that urban climate adaptation provides an excellent case for examining boundary objects. New local climate adaptation networks aim to bring together these stakeholders and their underlying logics (Franco-Torres, Rogers, and Ugarelli 2020). The Netherlands is one of the countries where local climate adaptation networks are getting a foothold, often initiated by local water utilities or municipalities. The Netherlands is considered an international frontrunner of water management (OECD 2014) because it is located in a low-lying delta region and has a long-standing history of ‘fighting the water’ (Restemeyer, van den Brink, and Woltjer 2017).

In new local climate adaptation networks, urban water managers aim to stimulate and facilitate urban actors (e.g. community initiatives, real estate developers, housing associations) to take climate adaptation measures on their property. Examples include the construction of green roofs, raingardens, and water-sensitive urban designs. We look specifically at two local networks: Amsterdam Rainproof (established by local water authority *Waternet*) and Water Sensitive Rotterdam (established by the City of Rotterdam), which are positioned as creative and progressive networks that operate outside the administrative boundaries of both authorities and that connect urban stakeholders. Both cities are international frontrunners, for instance ranked first and third on the Arcadis Sustainable Cities Water Index (Arcadis 2016; Dai, Wörner, and van Rijswijk 2018), so we expect to obtain more insights from the cases (Flyvbjerg 2006). Moreover, these networks have been established since 2013, so we expect that we can trace back the evolution of boundary objects. Both cases are further introduced in section 4.

3.2. Data collection and analysis

Three sets of data were gathered in order to gather in-depth knowledge of both cases. First, the first two authors have conducted, in total 27 interviews with key stakeholders in both cities between October 2019 and January 2020, using a purposive sampling strategy. We interviewed 14 stakeholders of Amsterdam Rainproof, among which 7 were civil servants, 4 private actors and 3 community actors. We interviewed 13 stakeholders of Water Sensitive Rotterdam, among which 8 were civil servants, 2 private

actors and 3 community actors. Interviews centered on (1) how each actor was involved in the network, (2) the activities and collaborations that took place within the network, (3) how urban climate adaptation was framed (conceptual boundary objects), and (4) which instruments have been developed (material boundary objects). Interviewees were asked to reflect on the novelty of the network in contrast to regular exchanges between parties. Second, a document analysis of internal documents that the project teams developed was used to verify statements from the interviews. Third, three workshops were organized: one with the team of Amsterdam Rainproof (12 team members; 04-12-2019), one with the team of Water Sensitive Rotterdam (6 team members; 20-01-2020) and one with both teams to exchange experiences (9 team members; 10-03-2020). Together, these data allowed for triangulation, as findings from the interviews could be contrasted with aims stated in documents and discussions in the workshops. In the results section, we only use quotations from interviewees that we verified either with the documents or during the workshops.

The interview transcripts and documents were analyzed through the use of computer software Atlas.ti. A code tree was developed that consisted of the two types of boundary objects and the four functions (Figure 1). In addition, actors were grouped into three clusters (public, private and societal actors), which allowed for comparison of the different interpretations of the network, the boundary objects, and their functions. The coding was done by author 1 and 3. Author 3 coded the interdependencies, information needs and epistemic backgrounds of the individual actors. Author 1 coded the boundary objects and their functions. Discussions between the three authors ensured inter-code reliability. Both coding processes resulted in a text document with central themes derived from the textual analysis. These themes were clustered in a table leading to the eventual interpretations and conclusions as presented below.

4. Case study introduction

The results section will first discuss the performance of the networks of Amsterdam Rainproof and Water Sensitive Rotterdam. Subsequently, the conceptual and material boundary objects are discussed, as is their contribution to the performance of the network (discussed along the functions of convening, translating, collaborating and mediating; Figure 1).

4.1. Amsterdam Rainproof

Amsterdam Rainproof is a programme initiated by the local water authority Waternet in 2013, after learning lessons from heavy rainfall in Copenhagen (2011). The programme aims to create a rainproof city that is structured and designed to absorb and capture rainwater, reducing the chances of flooding and damages. Its strategy is labeled as a “network approach”; by establishing a network and developing an identity distinct from Waternet, the programme team expected that they could appeal more easily to a variety of stakeholders in Amsterdam (i.e. residents, real estate, housing associations, research institutes). Amsterdam Rainproof would be a temporary network that Waternet would reevaluate after two years, which was later extended by six years. Finances (in total 1.75 million euros) were provided by Waternet in order to establish a team of nine professionals (a combination of Waternet representatives and external consultants) that could facilitate the network. The team was based at *Pakhuis De*

Zwijger, a cultural enterprise in the center of Amsterdam that develops programmes and hosts debates about the future of cities. Being based at this enterprise, the team could emphasize its independent position from the public water authority and easily meet other local organizations working on urban development in Amsterdam.

The programme plan from 2014 formulated two main aims. First, the team aimed to prevent flood damage (driven by the urgency of peak showers) and address the need to rainproof the city. Interviewees stated how the network helped to emphasize the urgency of rainproofing the city. The fact that the local water authority and the municipality invested substantial resources into this network showed the importance to other urban stakeholders. Similarly, the team that facilitated the network could approach and continuously remind actors in the city to think about the issue of rainproofing the city. Second, the team wanted to value rainwater more positively and capture this value.

To achieve these goals, the team set up two parallel tracks funded by Waternet. An external track was dedicated to the establishment and management of a community of stakeholders. Through stakeholder analyses and inventorying stakeholders' demands, the team behind Amsterdam Rainproof tried to engage with individual stakeholders, such as entrepreneurs, universities and schools, real estate developers, and community initiatives, and mapped their needs to incorporate 'rainproof-thinking' into their ways of working. To illustrate, companies in the garden industry stated that they lacked knowledge about this topic, so the team started education workshops about rain barrels and climate-sensitive gardening. By positioning the Amsterdam Rainproof platform as independent and operating from a cultural enterprise in Amsterdam, the team could gain access to a wider pool of stakeholders. Moreover, each stakeholder was valued equally: "From the beginning, we have welcomed each initiative, while the common procedure within the local water authority is to work with a top-10 of bottlenecks."

In addition to the external track, an internal track was started, in which the local water authority tried to mainstream rainproof-thinking in policies and procedures of the City of Amsterdam. Therefore, this track is more concerned with the local water authority Waternet (which established Amsterdam Rainproof) and the City of Amsterdam. The team tried to look for ambassadors through workshops and awareness raising, as well as to create new guidelines: "It often comes down to very silly, simple things. Somewhere it should be stated that you need to do this. If people do not think it is required, they will immediately drop it." Increasingly, urban management strategies and policies now have rainproof-paragraphs in their documents in Amsterdam.

The Amsterdam Rainproof team expressed in documents the difficulties they faced when measuring the outcomes of the network. In the original programme plan (2014), output is, for instance, measured in media outreach (both traditional and social media), knowledge dissemination via the website, the start of pilots (e.g. sixty pilots in two years), and mainstreaming rainproof-thinking among civil servants, politicians, and professionals from the private sector. As mainstreaming was difficult to see already in existing regulations, stakeholders were listed by the team on an ordinal scale ranging from 'just started' to 'fully rainproof' in an evaluation report in order to operationalize mainstreaming.

Looking at the network, our coding process brought forward four social logics. The first logic is rooted in hydraulic engineering and concerns the challenge for urban water utility managers to create a robust sewage system that can withstand cloudbursts. Traditionally, this is achieved through rational decision-making that trades off risks,

costs and performance. The second logic relates to urban planning and design and is seen in how public space could be regenerated in a climate-proof way, most notably through the incorporation of blue and green infrastructure (e.g. permeable paving and raingardens). This logic emphasizes the multi-functionality of blue and green infrastructure; it can not only bring water storage benefits, but similarly recreational, ecological and economic benefits. Yet, blue and green infrastructure also comes with land-use claims, so planners have to mediate between different land-uses (e.g. aesthetics of blue-green infrastructure versus its retention capacity). The third logic relates to community groups who advocate a sustainable lifestyle. They are driven by a desire to “green” the city, for example through local renewable energy production and urban agriculture. Typically, these groups have profound environmental concerns which they aim to address in their own neighborhood. Interviewees stated that community groups need to have considerable social capital in order to make their initiatives successful. The fourth logic is more driven by social issues and concerns public health and well-being. In this logic, livability and social cohesion can be enhanced through the joint creation and maintenance of greenspaces. Both municipal departments from the social domain and neighborhood initiatives can advocate for this. These actors aim to capitalize on the social benefits of blue and green infrastructure. Altogether, the four logics represent heterogeneous actors that operate at different urban scales and inhabit different value systems, although their interests may overlap.

4.2. Water Sensitive Rotterdam

Water Sensitive Rotterdam is a programme initiated by the City of Rotterdam in 2014. It was presented as a counterpart to the innovative, large-scale water projects, for which Rotterdam is known (van der Brugge and De Graaf 2010). The central aim was to create multiple water-sensitive urban designs across the city on a smaller scale. Water Sensitive Rotterdam was presented as “a city-wide movement” facilitated by the urban water management department to link urban professionals, civil servants and residents with each other and to create adaptation measures on the neighborhood level. A fixed proportion of the annual municipal sewage budget, listed as ‘research & development’, was secured in order to finance a network of professionals that would propagate and implement small-scale projects of water-sensitive urban design in Rotterdam. The network was facilitated by a project team of six members, consisting of municipal representatives and consultants. The team was located outside the municipality, at a neighborhood organization.

The team developed two approaches for establishing the network. First, the team of Water Sensitive Rotterdam helped neighborhood projects and pilots, both existing and new ones, through seed funding. Existing initiatives were approached in order to incorporate climate adaptation measures into their projects. Interviewees stated that this process was driven from the bottom up, “in which Water Sensitive Rotterdam did not impose its goals.” Therefore, some projects that were financed contributed relatively little to climate adaptation, whereas others contributed a lot. The team behind Water Sensitive Rotterdam was initially located at a neighborhood organization (*Aktiegroep Het Oude Westen*), so it stressed its independent position from the municipality. Moreover, the platform could lean on the active network from the neighborhood organization. By creating projects in the public space, the platform became more visible, for example by creating new façade gardens. In addition, new initiatives were

facilitated by Water Sensitive Rotterdam, such as a magazine initiated by an urban design company (*Straadkrant*) that demonstrated what a climate-sensitive street could look like. Second, the team built up a city-wide community of water professionals by initiating regular events and meetings. Regular WSR Cafés were organized for actors across the city. In addition, for a smaller group of professionals who work on climate adaptation in their individual organization, a dedicated network was established in 2018 that currently consists of approximately thirty members. This network meets twice a month for coffee breaks and “get together” at a variety of locations around the city.

The team from Water Sensitive Rotterdam expresses its success in the “movement” of urban actors that has been created, liberated from municipal structures. Indicators of its success are the well-visited website and the provocative meetings it organizes. The regular events ensured that professionals convened on a structural basis. In addition, the team aimed to establish ten pilots in the Oude Westen neighborhood. Yet, within the first year, more than forty initiatives (such as community initiatives) from other neighborhoods were added to this list (Leander 2016). The events are helpful to pitch ideas and present results, so professionals can acquire new projects and community initiatives can receive support.

The logics that are present in Rotterdam are similar to those in Amsterdam: hydraulic engineering, urban planning and design, urban greening, and public health. An important fifth logic in Rotterdam entails economic development. Interviewees from the municipality highlighted that the City of Rotterdam aims to maintain its pioneering role in urban water management, which brings economic opportunities for the city and creates an attractive business environment. Developing new participatory approaches through the Water Sensitive Rotterdam platform could be one way to maintain this role.

5. Results

5.1. *Conceptual boundary objects for urban climate adaptation*

5.1.1. *Conceptual boundary objects: a positive framing of climate adaptation*

Both cities have developed new concepts for urban climate adaptation, which we will present below and link to the different actors and their social logics.

In Amsterdam, the team behind the Amsterdam Rainproof network launched the concept of ‘rainproofing the city’ in which “every drop counts”. The actors that represent the social logics have loaded this concept with different values, underscoring the interpretive flexibility. First, the field of hydraulic engineering – in particular the water utility company Waternet – has embraced the notion of ‘rainproofing the city’ as it is presented as a joint responsibility for all parties in Amsterdam, yet one that comes with opportunities for urban development. A team member explains: “We were really looking for that positive note; we did not want to present a doom scenario. It was all about connecting interests.” By doing so, Waternet hoped that ‘rainproof’-thinking would become mainstream among all urban actors: as the website stated, “do what you have to do, but do it rainproof”.

Consequently, the conceptual boundary object was targeted at linking the logic of hydraulic engineering with the other logics. For the urban water managers, the engineers stressed the urgency of taking actions, referring back to climate-related events, such as peak showers in Copenhagen in 2011 and in Amsterdam in 2013. They also

emphasized the tangibility of the concept, promoting small-scale, manageable interventions. Amsterdam Rainproof's credo – “every single drop counts” – echoed this thinking in order to make the platform accessible for as many stakeholders as possible. The key information need for this group was how to connect their urgency and demand to the agendas of other urban actors: how could they reach them and convince them to develop actions too? As a consequence, ‘rainproofing the city’ is operationalized by engineers into a new perspective on urban water management that allows for communicating the needs and urgency of urban climate adaptation.

Other actors could translate ‘rainproofing the city’ to the redevelopment of public spaces, neighborhoods or private properties. Urban planners and designers saw possibilities for creating a more livable, blue-green public space that is also aesthetically pleasing. At the same time, the limited available space also creates new dilemmas. As an interviewee recalls, urban designers already had difficulty accommodating different traffic modes in the redesign of streets in the historical Amsterdam-Zuid neighborhood (car lanes, cycle paths and sidewalks). Providing space for water storage or run-off further complicated the matter. Communities and businesses promoting a greener and more sustainable city often perceived Amsterdam Rainproof as an element of sustainable urban development and were looking for hands-on knowledge for taking actions. They have narrowed down the conceptual boundary object into tangible actions on how to green the city and store rainwater on your own property. Actors representing a logic on health and wellbeing argue that rainproofing neighborhoods could improve social cohesion (e.g. co-maintenance of greenspaces) and individual wellbeing (e.g. promoting walking). As a result, they started to articulate the wider socio-economic benefits of rainproofing the city.

In Rotterdam, the conceptualization of ‘a water-sensitive city’ is slightly distinct from rainproofing the city. In the interviews, hydraulic engineers presented the water-sensitive city as a new approach for urban water management. Rather than creating grand ‘eye-catching’ projects in the city, they started to pay attention to small-scale interventions in neighborhoods to get “into the veins of the city”. Interviewees argue that only then will the city become climate-proof. This does imply that engineers have to start collaborating with neighborhood actors, which is different from constructing the major works yourself. The information need this group therefore identifies is how to engage with other stakeholders in order to be able to get started in each neighborhood.

Similar to the Amsterdam case, the ‘water-sensitive city’-concept was loaded by team members with positive values. A member in Rotterdam stated: “You need to make climate adaptation cool, instead of making it scary and saying that we will all drown in a hundred years.” The framing of ‘water sensitivity’ did not emphasize the need for climate adaptation measures so much, but instead showed the opportunities to create a more livable city through those measures: “You have to make it fun in order to get started.” Therefore, the focus was put more on neighborhood improvements, through which climate adaptation measures could be taken simultaneously. Accordingly, the conceptual object aligned the logics and needs of urban water managers, and planners and designers. Furthermore, neighborhood organizations were embracing ‘water-sensitive city’ thinking, presenting it as one of the pillars of creating a green and livable city. The often-small-scale initiatives can present themselves in wider networks and frameworks, showing their impact better. Finally, actors representing economic values argued that the city will become more attractive for its residents, which could attract new companies and services to Rotterdam.

Ultimately, the ‘water-sensitive city’ concept is widened by urban actors toward an understanding that promotes principles from natural resources management and acknowledges socio-economic elements. Nevertheless, the team in Rotterdam emphasized the intrinsic motivation of urban actors: they needed to embody ‘water sensitivity’ themselves. As the co-founder of Water Sensitive Rotterdam argues, “Everybody is welcome. [...] But if you do not come, then apparently it is not your priority and you are not interested in what we stand for.” The conceptualization is presented as inclusive and open, yet this quote illustrates that actors need to acknowledge the need for adaptation measures in order to be welcomed.

5.1.2. Functions of the conceptual boundary objects

The boundary objects of ‘rainproofing the city’ and ‘water sensitivity’ performed two functions. First of all, the framing had a clear convening function in Amsterdam and Rotterdam, as the urgency for climate adaptation was underscored and the positive elements of rainproofing the city were emphasized. While Amsterdam aimed to appeal to a variety of stakeholders, Rotterdam targeted its discourse more specifically toward neighborhood organizations and entrepreneurs. For water authorities, the opportunity-driven and small-scale interventions perspective on climate adaptation helps to gain access to stakeholders who can take measures on their private land. For private stakeholders, the framing presents opportunities to link individual ambitions to climate adaptation goals.

Second, the translating function can be seen in how the urban water management perspective is linked to either urban development (Amsterdam) or neighborhood improvements (Rotterdam). Rather than looking at climate adaptation from a civil engineering point of view (urban drainage), the conceptualization positioned climate adaptation in a broader story of creating a more livable city, to which more parties could relate. The interviews demonstrated how this conceptualization of urban climate adaptation is translated from the urban water management domain to other domains. For example, designers and planners have translated the concept into new guidelines and handbooks on public space, making ‘rainproofing the city’ one of the steps in urban (re-)development processes. Communities and businesses received practical tips and tricks for the depavement of gardens and making use of rain barrels that can collect rainwater. Local businesses, such as garden centres, respond to this trend with new products and the promotion of sustainable garden solutions. Simultaneously, urban water managers learned about the broader socio-economic potential of rainproofing the city, which was used by the authorities to present adaptation measures as promising.

Third, initial collaborations were enhanced by the positive framing, as parties start to share a similar set of values and can more easily relate each other’s interests to each other. The conceptualization was complemented with resources to fund small initiatives. Stakeholders from the private sector and community initiatives value these resources (such as technical expertise or a subsidy). For example, a representative of the garden industry stated: “[The team] told us that they would conduct research for us. So we directly received a gift in the form of research.” More structural collaborations proved to be more difficult, which left some actors unsatisfied. To illustrate, the initial will to collaborate decreased among some interviewees, such as this representative from the private sector: “In the beginning I thought it was great. But at a certain moment, you have built up a network and then you know who to turn to.” The

Amsterdam Rainproof network had limited resources available to sustain the network, so collaborations quickly vanished. In Rotterdam, resources were made more available by the local government, which consequently remained the central actor in the network. Overall, the conceptual boundary object does not help to sustain collaborations over longer time periods without abundant resources.

The fourth function as distinguished in the theoretical framework – mediation – was not supported by the conceptual boundary object. Instead, mediation was actively avoided in both cities, since the teams targeted intrinsically motivated stakeholders and emphasized the opportunities and mutual interests rather than tradeoffs. As both networks were new initiatives in the city, the teams felt a strong drive to show impact and decided to work with stakeholders in the city who would not question the urgency and need for urban climate adaptation. This resulted in an overrepresentation of actors from some neighborhoods, while other neighborhoods were excluded. The way the conceptual boundary object facilitated cross-boundary working is summarized in Table 1.

5.2. Material boundary objects for urban climate adaptation

5.2.1. Material boundary objects: new modeling tools

Both teams in Amsterdam and Rotterdam have developed distinct artifacts, including logos, gadgets, small water management projects, maps and tools. In Amsterdam, the team focused on developing gadgets and tools. Team members put a lot of effort into creating a corporate identity – developing a brand – that professionals and citizens would recognize in the city, for example with a distinct logo, slogan (e.g. in Amsterdam ‘every drop counts’) and gadgets. A new website acted as a shared repository, showing a map of initiatives and practical tips and tricks for rainproofing the city. As such, the material object targeted all citizens in Amsterdam. Interviewees argued that this brought the social logics of hydraulic engineering together with those actors aspiring to a sustainable lifestyle and community groups. These latter two groups could find the hands-on information that they required. It also meant promotion of community and business activities in the Amsterdam region that concerned rainproofing the city. An engineer recalled: “the website worked really well to honour those local initiatives and, secondly, communicate our rain-proof-message.”

In addition, Amsterdam Rainproof developed two tools, the first being a 3D-model of Amsterdam showing flood-prone areas and bottlenecks after heavy rainfall. According to interviewees, the model helped to define the context for action in public spaces. The bottlenecks were identified per neighborhood, which were then presented to the city districts of the Municipality of Amsterdam. Another tool is a digital map, combining flood-prone areas with plans for urban developments. As a team member argued, “We do not only present problems, we are also here to help.” These maps connected the responsibilities and tasks of the local water authority with the responsibilities of the Municipality of Amsterdam concerning public space. As it could show the tradeoffs between, for example, retention capacity and urban developments, the 3D-model helped to bridge the logics of hydraulic engineering and urban planning and design.

In Rotterdam, the team considered the small adaptation projects in the city as artifacts; members argue that these physical interventions embody ‘water-sensitive’

Table 1. Comparison of the conceptual boundary object within the Amsterdam Rainproof and Water Sensitive Rotterdam networks.

		Amsterdam Rainproof	Water Sensitive Rotterdam
<i>Conceptual boundary object</i>		<ul style="list-style-type: none"> • Strong brand of ‘Rainproof’ that is positive and opportunity-driven, accessible and urgent • Examples: ‘every drop counts’, ‘do what you have to do, but do it rainproof’ 	<ul style="list-style-type: none"> • ‘Water-sensitive’ thinking as practice, which is positive and opportunity-driven, and targeted at the neighborhood level • Examples: ‘the water-sensitive city is creative’, ‘the city will only become better and stronger’
<i>Impact on the four functions of a boundary object</i>	1. <i>Convening</i>	Urgent and appealing (opportunity-driven)	Appealing (opportunity-driven), positioning participants as pioneers
	2. <i>Translating</i>	Creating possibilities to connect climate adaptation to wider urban development and stakeholder interests	Connecting climate adaptation to (stakeholders working on) the neighborhood level
	3. <i>Collaborating</i>	‘Accessible’ framing provides entry points for collaboration, often in pilots	‘Neighborhood perspective’ provides entry points for collaboration, often in pilots
	4. <i>Mediating</i>	Avoided, because discourse targeted intrinsically motivated stakeholders and opportunities were emphasized	Avoided, because discourse targeted intrinsically motivated stakeholders and opportunities were emphasized

thinking. Because many of these projects already existed, outsiders in particular have difficulty defining the contribution of Water Sensitive Rotterdam to these projects. For example, successful initiatives such as *Natuurlijk Spangen* (a community initiative that aims to create more greenery in the *Spangen* neighborhood) embody the holistic conceptualization, but according to interviewees just *how* Water Sensitive Rotterdam contributed to these initiatives remains difficult to define. These one-off collaborations therefore mainly benefited the relationship between the City of Rotterdam and a neighborhood initiative. The additional resources provided by the network helped to bridge the competing logics on hydraulic engineering, urban planning and livability.

Furthermore, the corporate identity that the team developed for Water Sensitive Rotterdam has been predominantly used by a small group of professionals rather than all citizens. Regular meetings, such as ‘Water Sensitive Cafes’, and the creation of the ‘Club of 36’ helped to create an active group of professionals who meet on a regular basis. The ceremonial function of these events helped to bridge the different logics (in particular engineering and urban planning and design) and the different operationalisations of a water-sensitive city. The combination of showcasing best practices and workshops helped to show what water-sensitive thinking could represent, and it helped to create a shared understanding and group spirit.

5.2.2. *Functions of the material boundary objects*

The artifacts operated as material boundary objects that could link actors with each other, which is reflected in the four functions that a boundary object can perform. First, the artifacts that the networks produced had a convening function. Because the corporate identity and the gadgets freed the networks from the governmental communication strategy, both networks received a lot of publicity. This made public and private stakeholders interested in the new networks and helped to raise awareness about climate adaptation.

Second, the translating function of the boundary objects is more clearly visible in the case of Amsterdam Rainproof, as Water Sensitive Rotterdam promoted more cultural and behavioral changes. The interactive maps that were developed smoothed contacts between the water authority Waternet and the urban development departments of the City of Amsterdam because they helped to translate viewpoints and interests. In Rotterdam, translation is mainly pursued through social learning, in which individuals of the city-wide community pass on their ideas, principles and approaches to each other.

Third, the facilitation of collaboration is stimulated through the use of tools in Amsterdam, as synergies could be identified more easily. The 3D-tools spurred discussions between different public parties (e.g. different municipal departments). The tools did not result in collaborations with private actors. In the case of Rotterdam, more emphasis was put on developing shared values within the community of practice, so artifacts were regarded as less important. Some interviewees were critical about the actual actions for urban climate adaptation. Awareness raising and developing creative solutions were considered more important in the projects than delivering climate adaptation measures.

Fourth, mediation was the least visible function in the two cases. Only the tools developed by Amsterdam Rainproof represent a mediating function, since the 3D-tool helped to mediate value interests and land-use claims. Plotting differing interests on the same map helped to overcome interests and bridge viewpoints.

In conclusion, both cities have developed material boundary objects for their networks to appeal to a large variety of stakeholders (Table 2). The gadgets and corporate identity have contributed to the convening function, and the tools of Amsterdam Rainproof also contribute to translation and collaboration with public stakeholders. Whereas Amsterdam believes in visible boundary objects to communicate with and convene stakeholders, Rotterdam aims to change people's mindsets and cultural values. Hence, developing joint processes has received more attention in Rotterdam than producing tangible artifacts.

5.3. *Comparison*

In both cases, we see the emergence of both 'hard' material boundary objects (repositories and modeling tools) and 'soft' conceptual boundary objects (a positive framing) to link stakeholders with each other and develop joint actions. Both elements complement each other and seem necessary to create a successful network.

Our case study comparison demonstrates that Amsterdam Rainproof has been developed as a distinct identity that is malleable to different audiences, while Water Sensitive Rotterdam puts more emphasis on practising 'water-sensitive' thinking by professionals. Water Sensitive Rotterdam has therefore reached a smaller, but more active group of urban actors who are practicing this thinking often on a daily basis.

Table 2. Comparison of the material boundary objects in the Amsterdam Rainproof and Water Sensitive Rotterdam networks.

		Amsterdam Rainproof	Water Sensitive Rotterdam
<i>Material boundary objects</i>		<ul style="list-style-type: none"> • Corporate identity with own principles, logo, and communication strategy targeted at citizens and professionals • Tools: interactive 3 D-maps • Repository: website, guidelines for citizens and professionals 	<ul style="list-style-type: none"> • Corporate identity with own principles and regular meetings mainly targeted at professionals • Repository: website • Neighborhood projects as embodiment of 'water- sensitive' thinking.
<i>Impact on the four functions of a boundary object</i>	1. <i>Convening</i>	Distinctive corporate identity helped to reach private actors	Innovative and fresh identity, with which local professionals could identify themselves
	2. <i>Translating</i>	Tools (interactive maps, website) lead to translation in the interactions between water authority and municipality	Tools facilitate translation in the personal interactions in the city-wide community
	3. <i>Collaborating</i>	Tools helped to relate different public interests to each other; artifacts have had less impact on collaborating with private stakeholders	Limited, because developing joint processes received more attention than producing tangible artifacts
	4. <i>Mediating</i>	Tools helped to identify conflicts between land use claims	Absent, because conflicts were evaded

The conceptual and material boundary objects mainly functioned as convening and translating vehicles, as the positive and opportunity-driven framing of climate adaptation helped to appeal to a variety of stakeholders. For instance, modeling and simulation tools showed how to connect differing land-use claims with each other. Collaboration was initially stimulated by the boundary objects, yet they failed to sustain collaboration beyond single pilots. For overcoming this, more resources (finances, expertise) are required, which the network currently is not able to attract. Nevertheless, boundary objects can foster more structural change, which is seen, for instance, in how the Amsterdam Rainproof identity has helped to put 'rainproof'-thinking into new regulations and policies. Similarly, the City of Rotterdam has adopted new urban water management principles that echo the framing of Water Sensitive Rotterdam.

The objects are presented as neutral and fresh intermediaries in the cities that bridge public and private parties' logics around the theme of climate adaptation. Yet, stakeholders with less affinity with these themes were purposefully side-stepped initially. Both teams presented themselves as inclusive and value-neutral, but our results show that actors need to embrace certain principles in order to be welcomed. Therefore, the boundary objects did not perform a mediation function. Moreover, the

other functions are limited to the actors that embrace the principles. Thus, emphasis is put on the individual responsibility of urban actors to take measures, which could position climate adaptation as an exclusionary practice to which only a small group of urban actors can relate. The ‘neutral’ identity of the boundary objects – operating in-between the government and other stakeholders – is a deliberate strategy pursued by urban water management officials. Although they present the opportunities of upgrading the city, their primary motive is addressing the urgency of climate-related risks. By not explicating this agenda, other actors may not feel they are taken seriously or may even feel manipulated.

6. Conclusions

Urban climate adaptation is increasingly delivered in collaborative networks to which boundary objects can contribute. Boundary objects can facilitate the interactions between organizations that are rooted in different spheres, because they create joint knowledge systems (Cash *et al.* 2003; Franco-Torres, Rogers, and Ugarelli 2020). This article examined how new networks of public, private and societal actors developed both material and conceptual boundary objects. We examined this specifically within the networks of Amsterdam Rainproof and Water Sensitive Rotterdam.

Our findings demonstrate that the conceptual boundary objects of “rainproofing the city” in Amsterdam and creating a “water-sensitive city” in Rotterdam can attract a city-wide network. The different social worlds involved in the networks can load this object with different values. For local governments and water utility managers, the boundary object is defined by a positive, opportunity-driven and accessible framing that is able to reach a broad array of stakeholders. Neighborhood organizations and entrepreneurs see the creation of a climate-proof city as a possibility to implement a green lifestyle, promote public health or realize an economically more viable city. Material boundary objects include tangible artifacts, such as interactive maps and tools. These objects addressed the information needs of specific actors, such as hydraulic information, water-sensitive urban design principles, or hands-on knowledge on installing rain barrels. The networks of Amsterdam Rainproof and Water Sensitive Rotterdam had something to offer for private stakeholders, such as access to financial resources, expertise and a social network. For public governments, these platforms are beneficial concerning new collaborations with private stakeholders as well as concerning inter-departmental alignment. As stakeholders’ motivations may differ, these elements have been used differently by each individual organization. This underlines the interpretive flexibility of the boundary objects (Star and Griesemer 1989) and their instrumentality for individual actors (Guston 2001).

The boundary objects have mainly contributed to convening stakeholders and translating climate adaptation measures into a language that is appealing to a wider variety of stakeholders beyond urban water managers and planners. The networks have therefore supported the co-production of knowledge (Norström *et al.* 2020): expertise on hydraulic engineering, urban design, economic development and public health was, for example, combined and applied to creating a rainproof or water-sensitive city. The boundary objects present in our case study are strong vehicles for the formation of networks, but they do not directly result in the frameworks or resources that are needed to sustain collaboration and mediate interests. Private stakeholders often participated in one-time interactions, arguing that the platforms lacked upscaling opportunities and were too much

driven by a single issue (cf. Steger *et al.* 2021). As Levina and Vaast (2005) discuss, boundary objects demand vast investments in order to keep them in use for a longer period of time and for a broader group of stakeholders. Some interviewees have therefore been critical regarding to what extent these investments pay off in terms of climate adaptation measures, since they are based on voluntary participation.

Our analysis of the functions of boundary objects shows some contradictory patterns. Our findings confirm that a risk-driven approach in urban water management has been replaced by a more positive, opportunity-driven approach (Ashley, Gersonius, and Horton 2020), in which more attention is paid to collaboration and participation (Pahl-Wostl 2020). The strong and positive framing by the local government was needed to develop a shared understanding and willingness to act (convening, translating), but the boundary object was also loaded with values focused on individual responsibility. Our cases have reached different social worlds (professionals from different disciplines, communities and businesses), yet they have primarily worked with those who are already concerned about the environment. Initiators of the networks felt a strong drive to show impact in the short term, so the boundary objects were mainly targeted at groups that were more receptive to the overarching aim of urban climate adaptation. Accordingly, the boundary objects mainly helped to strengthen ties between groups that are in favor of each other's values, although they are rooted in different social worlds. This may have excluded actors that have less affinity with climate change or sustainability in general. For example, some neighborhoods in Amsterdam and in Rotterdam are over-represented compared to others, potentially increasing spatial inequalities within the cities.

Convening a more diverse group of actors may require a more diverse resource pool and a different framing. Following Steger *et al.* (2021), we suggest a more equal partnership in which diverse actors co-define the goals of the network right from the start with a less prominent goal for urban climate adaptation. An even larger shift from urban water management goals toward urban regeneration goals or improving living conditions is likely to involve a larger heterogeneity of actors, yet urban water managers may be less likely to invest in these networks. Therefore, it is crucial to secure resources from other actors (e.g. urban planning and design) in order to allow boundary objects to travel between social worlds more easily. We expect that a more diverse resource pool will also lead to mediation, because it forces actors to define their shared interests. These contradictory patterns and dilemmas underscore the difficulty of successfully developing boundary objects that become widely used, which could be examined further in future research. For instance, some may see a thoughtful attempt to open up the hierarchical field of urban water management, while others may say that urban water managers are adopting their language in order to remain powerful (Wiering and Arts 2006; Brown, Ashley, and Farrelly 2011). The lack of diversity in both case studies suggests that urban water managers are driven by their narrowly defined mandate of creating a robust water system: they instrumentally use networks rather than use its potential for more participatory and decentralized decision-making. Future research could look more into the institutionalization of boundary objects and how they can transform the urban water management sector in the long run.

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