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ORIGINAL ARTICLE

Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands

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Abstract

In light of the persistent failure to reduce emissions decisively, facilitate long-term resilience against climate change and account for the connectedness of climate change with other social, environmental and economic concerns, we present a conceptual framework of capacities for transformative climate governance. Transformative climate governance enables climate mitigation and adaptation while purposefully steering societies towards low-carbon, resilient and sustainable objectives. The framework provides a systematic analytical tool for understanding and supporting the already ongoing changes of the climate governance landscape towards more experimental approaches that include multi-scale, cross-sectoral and public-private collaborations. It distinguishes between different types of capacities needed to address transformation dynamics, including responding to disturbances (stewarding capacity), phasing-out drivers of path dependency (unlocking capacity), creating and embedding novelties (transformative capacity) and coordinating multi-actor processes (orchestrating capacity). Our case study of climate governance in Rotterdam, the Netherlands, demonstrates how the framework helps to map the activities by which multiple actors create new types of conditions for transformative climate governance, assess the effectiveness of the capacities and identify capacity gaps. Transformative and orchestrating capacities in Rotterdam emerged through the creation of space and informal networks for strategic and operational innovation, which also propelled new types of governance arrangements and structures. Both capacities support stewarding and unlocking by integrating and mainstreaming different goals, connecting actors to each other for the development of solutions and mediating interests. Key challenges across capacities remain because of limited mainstreaming of long-term and integrated thinking into institutional and regulatory frameworks. As the ongoing changes in climate governance open up multiple questions about actor roles, effective governance processes, legitimacy and how effective climate governance in the context of transformations can be supported, we invite future research to apply the capacities framework to explore these questions.

Keywords Transformativeclimate governance · Governance agency · Urban governance · Governance capacity · Orchestrating capacity · Transformative capacity · Sustainability transformation · Resilience · Climate change

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Introduction

In recent years, climate change mitigation and adaptation have become reframed from singular and technical issues and domains such as emissions accounting or short-term risk reductions towards contributing to sustainability and resilience transformations (Hermwille 2016; O'Brien and Selboe 2015). The transformation perspective exemplifies climate change as part of ongoing, complex and radical change processes today's societies are experiencing at increasingly accelerated pace. Climate change is symptomatic of highly unsustainable and eroding social fabrics, which are deeply embedded in market patterns, the ways services are provided,

institutional conditions and behaviours (Meadowcroft 2009; Shaw et al. 2014). At the same time, many climate impacts are already underway and cannot be reversed, amplifying social, economic and environmental crises and vulnerabilities such as biodiversity loss and social inequalities (IPCC 2014). Especially in case of climate change beyond 2 °C, climate impacts could trigger tipping points with largely unknown consequences (Steffen et al. 2015; Russill 2015), and they could cause (sudden) limits to adaptation (Dow et al. 2013).

A crucial question is how to develop effective and equitable climate solutions while unlocking opportunities for realisingand maintaining a high quality of life within social-ecological limits (Abel et al. 2016; Pereira et al. 2015). This is especially pertinent considering the noticeably limited capacity of current climate governance systemsto decisively shift societal development towards low-carbon, sustainable and resilient futures (Abbott 2014; Howlett 2014; Jordan et al. 2015). Existing governance regimes inside and outside of the climate domain tend to be dominated by incremental decision-making, short-term policy cycles and powerful interests favouring optimisation in the short-term, thus precluding more disruptive changes in the long-term and perpetuating dangerous maladaptation (Lonsdale et al. 2015; Loorbach 2014). Among others, scholars stress that effective climate governance will encourage synergies, learning, innovation and multi-level cooperation (Termeer et al. 2017; Bulkeley 2015).

Since the mid-2000s, new types of actors, networks and mechanisms enter and shape the increasingly polycentric climate governance landscape (Jordan et al. 2015; Abbott 2017; Ostrom 2014). Actors from different backgrounds, such as business, local governments and civil society, initiate climate actions at multiple scales and form diverse multi-level and transnational collaborations like transnational city networks and self-regulating private networks (Abbott 2014). In these settings, experimentation emerged as a novel governance mode that by its open-ended and learning-based nature generates innovative agreements, policies and practical solutions (Hildén et al. 2017). These governance processes do not (only) rely on top-down authority but rather on bottom-up, decentralised actions and cross-learning (Cole 2011; van Asselt et al. 2018).

While there is hope that these hybrid and experimental climate governance approaches manifest in new types of governance capacities, their mechanisms and effectiveness are still poorly understood (Jordan et al. 2015; Luederitz et al. 2017). For example, though experimentation is lauded for galvanising innovation and learning, how experimentation connects to ongoing policy and planning processes and how the generated novelties can be mainstreamed are less examined (Kivimaa et al. 2017; Turnheim et al. 2018). Likewise, scholars have pointed to governance processes other than experimentation, which demand further attention. This includes phasing-out existing unsustainable and high-emission practices decisively by providing disincentives or unravelling powerful actor networks (Hermwille 2017; Kivimaa and Kern 2016). Especially the distributed nature of the new climate governance landscape raises questions about how to mobilise, structure and coordinate the diverseclimate mitigation and adaptation activities towards shared, long-term sustainability and resilience goals (van Asselt et al. 2018; Abbott 2017). While most analyses of polycentric climate action focus on bottom-up, decentralised and voluntary commitments, Abbott (2017) argues that 'orchestration' as an indirect governance mode can strengthen polycentric climate governance by encouraging action, supporting capacities of weaker institutions, setting standards for reporting and facilitating knowledge exchange.

In this paper, we present a conceptual framework of capacities for transformative climate governance. We define transformative climate governance as the processes of interaction and decision-making by which multiple actors seek to address climate mitigation and adaptation while purposefully steering societies towards low-carbon, resilient and sustainable objectives. The framework distinguishes between different types of governance capacities to facilitate a systemic understanding of the diverse governance processes, mechanisms and conditions needed foraddressing climate changein the context of ongoing transformation dynamics. In particular, the framework serves to deconstruct how the governance capacities are produced by and how they manifest in the relational activities of actors. So far, lesser attention has been paid to agency, i.e. the processes and dynamics through which actors mobilise, create and change societal structures and 'accomplish' climate governance (cf. Bulkeley 2015). The agency-centred perspective enables to discern how, and by whom, the new types of governance capacities are produced, what types of conditions signify the new governance architecture and how effective the capacities are in accomplishing transformative climate governance.

After presenting the capacities framework, we illustrate how the framework helps studying empirically climate governance. We use climate governance in the city of Rotterdam, the Netherlands, as an exploratory case study and identify what types of governance activities manifest in transformative climate governance capacities. In the discussions section, we reflect on the contributions of the framework, limitations and future research directions.

Capacities framework for transformative climate governance

The central objectives of the capacities framework are to enable identifying, understanding and eventually supportingtransformative climate governance—i.e. how

governance is 'performed, fulfilled and completed in relation to different desires and objectives' (Bulkeley 2015:14). Governance alludes to interactive decision-making processes by which public and private actors define and pursue shared goals to address collective problems within their structural contexts (Betsill and Bulkeley 2006; Kooiman and Jentoft 2009). This resonates the concept of structuration (Giddens 1984): capacities for transformative climate governance are manifest in both the collective abilities of actors to mobilise, create and change societal structures and conditions, such as institutional settings, beliefs and financial resources, and in the structural conditions that are created as a result of the activities of actors (cf. Garud et al. 2007).

We identify four capacities for transformative climate governance in relation to different types of transformation dynamics (Table 1). This resonates the understanding of climate change as intrinsic part of these dynamics, and that the respective dynamics create different response needs. Transformation dynamics are visible in the path dependencies and break-down of existing regimes that fail to reduce and respond to emerging challenges and risks, the build-up of new alternatives to replace those regimes, as well as in deep uncertainties, contestation and disruption that are involved in these processes (Loorbach 2014; Patterson et al. 2016; Hölscher et al. 2017a). Governance is then not so much about controlling rather than influencing these dynamics, for example, by unsettling unsustainable regimes, enabling innovation and coping with surprise and disruption (Loorbach 2014).

We synthesised different scientific literatures to identify and define the capacities fortransformative climate governance, the conditions that manifest in the capacity's existence and the multi-actor activities that create the conditions. We reviewed sustainability transitions, resilience, climate governance and meta-governance literatures, because they offer complementary concepts and insights for addressing transformation dynamics (Table 1). Climate governance literature highlights different entry points to understanding and supporting mitigation and adaptation, including transformational adaptation to respond to tipping points and disruptive impacts (Kates et al. 2012; Lonsdale et al. 2015; Wise et al. 2014), experimentation to facilitate innovation (Hildén et al. 2017; Kivimaa et al. 2017) and orchestration to ensure coordination and integration (Chan et al. 2015; Abbott et al. 2015; Abbott 2017). Both sustainability transitions and resilience approaches start from models of how complex adaptive systems evolve and to what extent system change can be anticipated and dealt with in a strategic and systemic way. Sustainability transitions approaches focus on overcoming unsustainable path dependencies by developing disruptive innovations (Loorbach et al. 2015; Frantzeskaki et al. 2012; Raven et al. 2010) and regime destabilisation (Kivimaa and Kern 2016; Geels 2014). Resilience approaches largely focus on adaptive governance for dealing with emerging disturbances and risks and avoiding undesirable transformations (Chapin et al. 2010; Plummer 2013; Folke et al. 2005). They also research transformative agency for innovation and experimentation (Westley et al. 2013; Olsson et al. 2014). Finally, meta-governance literature specifies processes of coordination to facilitate goal alignment and concerted action of multiple actors and networks in fragmented governance systems (Sørensen 2006; Kooiman and Jentoft 2009; Capano et al. 2015).

Wereviewed the literatures to first define the different governance functions that need to be fulfilled to address transformation dynamics. We then identified the conditions that manifest in each capacity's existence. Finally, we identified the activities that are listed as creating these conditions and clustered them accordingly (Table 2). The full overview of the capacities conceptualisation including supporting sources is given in Supplementary Material A.

Stewarding capacity: anticipating and responding to disturbances and uncertainty

Ongoing transformation dynamics including climate change and other social-ecological changes and stresses createshort-term and long-terminstabilities, uncertainty and surprise (IPCC 2014; Wise et al. 2014; Dow et al. 2013). Resilience and climate governance scholars stress institutional, social and physical conditions enabling social-ecological systems to recognise, protect and recover from disturbances and surprisesin a manner that improves wellbeing and without experiencing radical change (Folke et al. 2005; Dietz et al. 2003; Chaffin et al. 2014). Responses include anything between short-term coping and disaster response and putting in place the conditions for longer-term adaptation and resilience (Termeer et al. 2017) while also considering underlying socio-economic vulnerabilities such as injustice (Lonsdale et al. 2015; Bahadur and Tanner 2014).

Stewarding capacity is defined as the abilities of actors to anticipate, protect and recover fromdisturbances while exploiting opportunities beneficial for sustainability. It manifests in conditions that enable proactive and flexible responses to continuous and uncertain change. Knowledge generation and integration about social-ecological system dynamics enable anticipating emergent disturbances and uncertainties and identifying available options in light of these (Chapin et al. 2010; Tàbara et al. 2017). Decentralised self-organisation and context-specific rule-making support the abilities of organisations, communities and individuals to independently and flexibly respond to changes and disturbances (Folke et al. 2005; Dietz et al. 2003; Garmestani and Benson 2013). Monitoring and continuous learning are critical conditions for facilitating a collective memory of adaptation options as well as for changing management rules in response to learning of what

Table 1 Transformative climate governance capacities and related governance concepts

Transformative climate governance capacity	Transformation dynamics addressed	Climate governance	Sustainability transitions	Resilience	Meta-governance
Stewarding: anticipating and responding to disturbances	Emergent instabilities, uncertainty and surprise	Adaptation and adaptive capacity (Brown and Westaway 2011; Gupta et al. 2010); transformative adaptation (Wise et al. 2014; Kates et al. 2012; Lonsdale et al. 2015)	–	Adaptive governance and adaptive capacity (Folke et al. 2003, 2005; Dietz et al. 2003; Plummer 2013); resilience (Chapin et al. 2010; Matyas and Pelling 2014; Garmestani and Benson 2013)	–
Unlocking: recognising and dismantling unsustainable path dependencies	Path dependencies and erosion of unsustainable regimes	Mitigation and mitigative capacity (Winkler et al. 2007; Burch and Robinson 2007); exnovation (Hermwille 2017)	Regime destabilisation (Geels 2014; Kivimaa and Kern 2016); phase-out (Loorbach 2014)	–	–
Transformative: creating and embedding novelties	Build-up of new and sustainable alternatives	Experimentation (Hoffmann 2011; Hildén et al. 2017); mainstreaming (den Exter et al. 2014)	Niche experimentation and leadership (Raven et al. 2010; Brown et al. 2013; Loorbach et al. 2015); scaling and replicating (Ehnert et al. 2018)	Experimentation and leadership (Westley et al. 2013; Moore and Westley 2011; Olsson et al. 2006; Marshall et al. 2012)	–
Orchestrating: coordinating multi-actor processes	Multi-actor processes across scales, sector and time; synergies and trade-offs; contestation and goal conflicts	Orchestration (Abbott et al. 2015; Abbott 2017; Chan et al. 2015)	Intermediation and meta-governance (Hodson and Marvin 2010; Hodson et al. 2013; Loorbach 2014; Frantzeskaki et al. 2014)	Polycentric governance (Galaz et al. 2011)	Meta-governance (Sørensen 2006; Kooiman and Jentoft 2009; Capano et al. 2015)

Table 2 The transformative climate governance capacities framework: capacities, conditions and activities for transformative climate governance

Governance capacity	Condition	Activities and supporting sources
Stewarding capacity	Generating knowledge about system dynamics	Developing systems models of feedback across scales, sectors and time
		Integrating different forms/sources of knowledge and understanding
		Identifying and communicating sources of uncertainty
	Strengthening self-organisation	Creating decentralised and nested institutions and social networks across governance scales that fit to social and ecological contexts and have multiple centres of power
		Creating open and simple institutions and rules (e.g. rules-of-thumb) that nurture diversity and redundancy to enable flexible patterns of behaviours and adaptation of rules if needed
		Ensuring inclusive dialogue and participation to enhance awareness of risks, responsibility sharing power balance among interest groups
	Monitoring and continuous learning	Iteratively evaluating how the system responds to disturbances and management
		Building a collective social memory of experience for linking past experiences with present and future, improving routines
		Systematically revisiting and questioning underlying assumptions and objectives
Unlocking capacity	Revealing unsustainable path dependency and maladaptation	Identifying sources and responsibilities for undesirable side-effects, (market, political, etc.) failures and maladaptation, monitoring trends in stressors and impacts
		Monitoring trends in stressors, vulnerability analyses, identifying areas with higher/increasing risks and how changes affect different needs and interests
	Undermining vested interests and incentive structures	Withdrawing support for regime technologies, structures and practices
		Adjusting legal rights and responsibilities to create (dis)incentives and control policies
		Breaking up existing actor networks, replacement of key actors
		Divesting in human and financial capital that underlie regime structures
	Breaking open resistance to change	Fostering political willingness and public awareness for change
		Developing and strengthening (political) counter-movements and support networks
Transformative capacity	Enabling novelty creation	Developing, testing and experimenting with new paradigms, practices, processes
		Providing protected and informal spaces to nurture innovation
		Supporting and creating informal and heterogeneous (shadow) networks that develop and test innovation and experiments
	Increasing visibility of novelty	Creating forging alliances and advocacy networks
		Creating internal support within an organisation through political leadership
		Providing inspiration through communicating future visions and showcasing innovation
	Anchoring novelty in context	Anticipating and recognising opportunities for change and crises
		Aligning strategic, organisational, institutional and implementation processes and structures with the novelty, e.g. in overarching policy documents and operational checklists
		Learning from tested solutions and practices
		Providing resources (e.g. manpower, skills, finances) to wider practical implementation
Orchestrating capacity	Strategic alignment	Defining a shared, long-term and integrative strategic direction and reference points for governance (shared goals, vision, narrative)
		Enlisting and engaging heterogeneous actor groups to create ownership over strategic direction and steer action in line with goals
		Linking strategic direction to ongoing processes
	Mediating across scales and sectors	Recognising, brokering and integrating resources (financial, knowledge, human, etc.) and goals
		Creating formal and informal convening spaces to exchange knowledge and resources and manage conflicts
		Setting up formal and informal connection nodes, communication channels and facilitating information platforms to optimise interactions and link formal and informal processes
	Creating opportunity contexts	Providing institutional designs for synergies and action in line with goals (e.g. financial incentives, regulations, taxation, recognition, shaming)
		Assisting actors and networks in implementing actions in line with goals (e.g. financing, guidance, technical assistance)
		Determining (normative) action mandates and prioritising action and fields
		Incorporating long-term and multi-scale thinking into decision-making, implementation processes and performance reviews

works and what does not (anymore) (Folke et al. 2005; Gupta et al. 2010; Chapin et al. 2010).

Unlocking capacity: recognising and dismantling unsustainable path dependencies

The deeply in societal structures, cultures and practices embedded root causes of excessive greenhouse gas emissions and unsustainability need to be phased out (Meadowcroft 2009; Loorbach 2014). Climate governance scholars explore mitigation options including emissions accounting, disincentives and decommissioning of high-carbon practices (Burch and Robinson 2007; Hermwille 2017). Sustainability transition scholars highlight processes for revealing and destabilising unsustainable, highly path-dependent regimes that are deeply embedded in dominant practices, actor networks, institutional structures and infrastructure designs and perpetuate maladaptation. The goal is to create institutional space for more sustainable practices (Kivimaa and Kern 2016; Geels 2014; Loorbach 2014).

The unlocking capacity represents the abilities of actors to recognise and dismantle structural drivers of unsustainable path dependencies and maladaptation. The revelation of drivers of unsustainability and path dependencies creates the condition forrevealing institutions, technologies and behaviours that need to be strategically phase-out (Meadowcroft 2009; Burch and Robinson 2007). Undermining vested interests and existing (financial, regulatory) incentive structures enables reducing the comparative advantage of business-as-usual towards emerging alternatives, for example, by penalising unsustainable practices (Bettini et al. 2015; Geels 2014; Kivimaa and Kern 2016). Breaking open resistance to change diminishes support for business-as-usual and creates opportunities and awareness for alternatives (Kivimaa and Kern 2016; Hermwille 2017).

Transformative capacity: creating and embedding novelties

Escaping high-emission trajectories and overcoming persistent unsustainability and maladaptation require the development and diffusion of radical alternatives (Tàbara et al. 2017; Kivimaa et al. 2017). Sustainability transitions, resilience and climate governance literatures alike endorse the development and testing of new ideas, narratives, practices, policies and solutions to transform established institutions, infrastructures, behaviours, economies, etc. (Loorbach et al. 2015; Westley et al. 2013). Important activities relate to the learning processes involved in the testing of innovations and their subsequent mainstreaming into policy and decision-making processes (Kivimaa et al. 2017; den Exter et al. 2014; Lonsdale et al. 2015).

Transformative capacity is defined as the abilities of actors to create novelties and embed them in structures, practices and discourses. Creating the condition for novelty creation ensures space, resources and networks for developing and testing innovations (Raven et al. 2010; Loorbach et al. 2015; Frantzeskaki et al. 2012; Olsson et al. 2006). To challenge dominant regimes and motivate wider acceptance, uptake and replication, the innovation needs to gain visibility (Nevens et al. 2013; Frantzeskaki et al. 2012; Moore and Westley 2011) and it needs to be anchored in existing or new structures, cultures and practices to make the implications and lessons from an innovation generalizable (Bos and Brown 2012; den Exter et al. 2014; Nevens et al. 2013; Kivimaa et al. 2017).

Orchestrating capacity: coordinating multi-actor processes

The distributed nature of climate governance activities at different scales and in different sectors requires encouraging, coordinating and assisting action in alignment with shared long-term goals to enable 'small wins' in multiple areas while creating momentum for larger-scale changes (cf. Patterson et al. 2016; Abbott 2017). In climate governance literature, orchestration is used to describe the indirect intermediation activities of, for example, international organisations such as the UNFCCC in aligning, enlisting and supporting state and sub-national actors and their climate actions (Chan et al. 2015; Abbott et al. 2015). Transition and resilience scholars highlight the importance of intermediary spaces and strategic partnerships for integrating and mediating different social interests and resources within polycentric governance structures (Frantzeskaki et al. 2014; Hodson and Marvin 2010). Meta-governance literature helps identifying activities that facilitate coordination in fragmented governance systems focusing on alignment, mediation and rule-setting (Jessop 1998; Capano et al. 2015; Sørensen 2006).

Orchestrating capacity refers to the abilities to coordinate multi-actor processes and foster synergies and minimise trade-offs and conflicts across scales, sectors and time. Strategic alignment is a key condition for orchestrating, because it supports the formulation of shared and long-term goals towards which actions are oriented (Hodson and Marvin 2010; Sørensen 2006; Abbott 2017; Loorbach et al. 2015). Mediating across scales and sectors in open networks represents conditions for knowledge and resource sharing and conflict resolutions to optimise interaction processes (Abbott 2017; Beisheim and Simon 2015; Jessop 2011; den Exter et al. 2014). The creation of opportunity contexts ensures overarching framework conditions that incentivise and assist actions towards shared and long-term goals (Jessop 2011; Abbott 2017; Chan et al. 2015).

Illustrating case study: understanding transformative climate governance capacities in Rotterdam

To show the utility of the capacities framework, we trace how the activities by which actors in the city of Rotterdam, the Netherlands, address climate change in city policy and planning practices created new types of conditions that manifest incapacities for transformative climate governance.

While climate governance in cities only represents one scale for addressing climate change, cities have become recognised as an increasingly important one both to prepare for the profound impacts of climate change urban populations and to mobilise the potential of cities for contributing to global resilience and sustainability (Castán Broto 2017; Wolfram and Frantzeskaki 2016). Additionally, urban climate governance is marked by complex multi-level and transnational relationships, including regional planning processes and transnational city networks (Castán Broto 2017). We selected Rotterdam as a case study, because Rotterdam is highly vulnerable to climate impacts such as rising water levels, intense rainfalls and heat waves (Molenaar et al. 2013) and it has built a reputation as a pioneer in addressing climate change, sustainability and resiliencein policy programmes and practical solutions. This enables to explore and illustrate our theoretical propositions in the capacities framework by studyingan actual empirical attempt of transformative climate governance (Yin 2003).

Case study methodology

The case study serves to illustrate the utility of the framework to assess the levels of transformative climate governance capacities and to identify the activities that create the capacity conditions, challenges and gaps. The analytical focus is on the climate-related policy and planning activities that are driven by the city government and how these create the conditions for transformative climate governance in Rotterdam.

We applied the framework in the following steps. Firstly, we analysed how the transformation dynamics are addressed as a result of climate governance in Rotterdam, i.e. how the capacity functions are exerted in climate policy and planning practice. For example, we identified what kinds of risks are recognised or overlooked, what path dependencies are addressed and what types of innovations are developed. This enables to assess the effectiveness of the capacities. Secondly, we identified the activities by which actors in Rotterdam created the conditions for addressing the transformation dynamics and that manifest in different capacity levels. This step involved a theory-driven coding of the collected data to relate the identified activities to the capacity conditions of the framework (Saldana 2009). In a final step, we identified capacity gaps that relate to shortcomings of climate governance outcomes in Rotterdam and insufficiently developed the capacities' levels and conditions. Supplementary Material B shows how the empirical material was systematically analysed by applying the governance capacities framework.

The case study provides a snapshot of transformative climate governance capacities in Rotterdam city. We did not intend to show how the capacities emerged over time and to determine an absolute value for the capacities' effectiveness and levels. We rather sought to illustrate the activities that by today manifest in the capacities and to show how the capacity levels and gaps influence how climate governance is practiced in an empirical setting. The study starts from 2007, when climate mitigation and adaptation first appeared on the city's policy agenda, to take the activities that have contributed to the emergence of the capacities into account without placing them on a timeline.

Different data were collected for the study: (i) between March and June 2015, 28 semi-structured interviews were conducted in person with climate governance practitioners in Rotterdam. An effort was made to ensure a mix of respondents; the interviewees included policy officers from the city government ($n = 11$) and regional ($n = 1$) and national ($n = 1$) governmental bodies, representatives from knowledge institutes ($n = 4$), local businesses and architects ($n = 6$), local NGOs ($n = 2$), community groups ($n = 1$) and politicians ($n = 2$). (ii) Desk research was performed including a press analysis and a literature review of policy documents (strategies, visions, plans on climate change from year 2005 to 2016) and scientific articles about climate and sustainability governance in Rotterdam and the Netherlands. (iii) Two of the authors were involved in different vision and strategy development processes in Rotterdam between 2012 and 2016. These processes included the redevelopment of the city harbour (Stadshaven) (Frantzeskaki et al. 2014) and the formulation of the resilience strategy (Gemeente Rotterdam 2016; Lodder et al. 2016).

Towards transformative climate governance in Rotterdam?

Climate change mitigation and adaptation were first introduced on the city government's agenda in 2007 with the goal to reduce CO_2 emissions in Rotterdam by 50% in 2025 compared to 1990, the participation in the C40 Climate Leadership Group and the launch of the Rotterdam Climate Initiative (RCI). Concomitantly, water policy entrepreneurs formulated the goal to become climate-proof by 2025 while creating opportunities to enhance the city's social and economic attractiveness (RCI 2009; de Greef 2005). This resulted in the launch of the Rotterdam Climate Proof programme in 2008 as part of the RCI.

Until today, the climate change focus was successively expanded towards sustainability, liveability and resilience (Gemeente Rotterdam 2012, 2015, 2016)—climate adaptation and mitigation are integrated with goals for a clean, green, healthy, safe and economically robust city. This strategic approach was institutionalised in the city government's cross-cutting Sustainability and Climate Adaptation Offices that coordinate climate, resilience and sustainability-related actions and seek collaborations with other city departments, other levels of government (e.g. regional water boards), businesses, community organisations and knowledge institutes to develop and share knowledge and implement projects. The city participates in transnational city networks such as the Rockefeller Foundation's 100 Resilient Cities (100RC) programme, which supported the development of a resilience strategy and facilitates knowledge exchange between cities.

The city gained international recognition particularly by its high-profile proof-of-concept experiments for climate adaptation that deliver co-benefits for greening, recreation, community-building and economic development. Examples include the Benthemplein water square, which combines rainwater management with area development, the multi-functional underground water storage facility at Museumplein car park and the floating pavilion. The Dakakkers is the first multi-functional rooftop garden in Rotterdam, combining flood protection with commercial and recreational use. Currently, a 100% climate-proof neighbourood in the Zomerhofkwartier is being developed.

In the following, we identify the activities that contributed to this approach to climate governance in Rotterdam and how the resulting capacities influence how transformation dynamics are addressed.

Stewarding capacity in Rotterdam

Stewarding capacity influences which and how disturbances are anticipated and what responses are enabled. In Rotterdam, stewarding is mainly addressed in relation to water safety, a long-standing policy priority in the city and the Netherlands. The introduction of other resilience goals connected water-related risks with improving neighbourhoods, liveability and emergency services. Stewarding capacity has resulted in a relatively high level of flood protection, but key challenges include the enabling of individual adaptation measures and the mainstreaming of adaptation into policy and planning decisions.

Stewarding capacity is manifest in vast knowledge about future climate-related risks and vulnerabilities. The knowledge is largely water related, though there is an increasing consideration of socio-economic vulnerabilities like inequality and cyber security. National, regional and international knowledge programmes and partnerships support knowledge generation. For example, Knowledge for Climate, a Dutch research collaboration, and the public-private National Delta Programme contributed to research on climate risks and adaptation strategies (e.g. van den Berg et al. 2013; van Veelen 2013). Knowledge was generated in form of scenarios (Ligtvoet et al. 2015), flood maps (RCI 2012) and participatory visioning processes (Frantzeskaki et al. 2014). Knowledge generation is also mandated; for example, the province of South Holland asks municipalities to make risk assessments for inhabitants of outer-dike areas.

Water and flood safety are shared responsibilities across national, regional and local governmental bodies including the regional water boards, Rijkswaterstaat (the Dutch Ministry of Infrastructure and Water Management), the Province of South Holland and the city government. This results in both large-scale and small-scale measures: to protect Rotterdam and the surrounding region from flooding, the national and regional governmentsestablished a large-scale flood and sea-level rise defence system, including the Maeslantkering storm surge barrier, permanent sand dunes and dikes. The city government implements zoning plans and small-scale flood protection measures throughout the entire urban area, including blue-green corridors, integrating buildings with dikes and multi-functional water storage facilities. An integrated planning approach supports context-specific interventions to address climate risks and contribute to equity, urban green and economic development. Public-private partnerships such as the RCP or neighbourhood-based planning processes promote collaboration between public and private partners for project development.

Stewarding capacity in Rotterdam faces several shortcomings. Firstly, policies and interventions focus mostly on water safety and on technical measures to optimise the current system. This fails to incentivise long-term and co-beneficial adaptive solutions: no direct financing is available, and it is difficult to capitalise the (uncertain) benefits. Secondly, climate-proofing is not mainstreamed and existing regulations remain inconsistent and unspecific. For example, existing guidelines on what tilesare used in residential areas hinder the installation of permeable tiles during road maintenance. Responsibilities for maintaining flood safety are unclear. This especially affects outer-dike areas, where residents are responsible for limiting their risks of water damage. Regional and local authorities assess the security situation and provide information and support. However, inhabitants are not aware about risks, and they have limited tools or incentives for flood-proofing their homes.

Unlocking capacity in Rotterdam

Unlocking capacity determines what and how drivers of unsustainability and path dependencies are recognised and reduced. Unlocking climate governance efforts in Rotterdam focuses on energy-related drivers of emissions in connection

with drivers of air and noise pollution and waste. Despite progress on sustainable energy and transport, unlocking capacity is curtailed by powerful political and economic interests that prevent a fundamental questioning of what drives unsustainability in Rotterdam. For example, two new coal plants were established to power the energy-demanding activities in the port, driving the city's CO_2 emissions up by 42% compared to 1990.

Research on drivers of unsustainability and emissions in Rotterdam helps identifyingtargetareas for action. Supported by the C40 networks, the RCIcarried out research on key emission contributors and identified the port, mobility and buildings as key intervention points. Annual reports monitor the effect of interventions. Other research develops transition pathways or roadmaps to explore different options for how to achieve a sustainable port industry or sustainable mobility (Samadi et al. 2016).

A support network of key (political and civil society) actors is critical to create the condition for increasing opportunities for change. For example, the RCI brings together key actors from the city government, the port and industry to mobilise their ideas and commitment for energy conservation, sustainable energy and CO_2 capture initiatives. The local energy cooperative Blijstrom supports the government's efforts to inform and assist building owners to retrofit. This type of awareness raising supports a wider outreach to more heterogeneous populations. It also enabled to identify homeowner associations as a critical actor group because of their leverage in changing energy use in buildings.

Political support is critical for changing incentive structures and creating investment opportunities. The support from the council for the sustainability strategy provides budget for investments in windmills, energy efficient municipal buildings and electric vehicles. A recent success was the ban of old vehicles from the city centre. However, the ban also exemplifies the challenge to radically destabilise business-as-usual: while requiring relatively high investments (e.g. for installing monitoring systems), these have little effect (in terms of actual vehicles banned and pollution reduced).

The increasing emissions levels in the port underscore the challenge in Rotterdam to fundamentally question existing economic interests and networks. The energy transition pathways for the port premise the unabated continuation of industrial activities to not jeopardise the economic position of the port and job opportunities. Relatedly, the existing incentive structures still favour short-term interests and investments and sustainability is not part of the working process but remains only a consideration in explicit sustainability-labelled projects. As a result, while there are efforts to develop new business cases—for example, involving privileges and funding constructions for electric freight transport and retrofitting—these remain thin. Renewable energy projectsalso face complex regulations and permit requirements (e.g. buildings need to comply with aesthetic guidelines) and require technical expertise.

Transformative capacity in Rotterdam

Transformative capacity influences what type of new innovations is developed and how they are embedded into structures, cultures and practices. Rotterdam has gained its frontrunner reputation from the climate change, sustainability and resilience strategies and the experimenting with innovative pilot projects. In developing and implementing the new strategies and operational approaches, governance processes themselves were innovated to enable more open-ended, hybrid and collaborative decision-making. However, the innovative strategies, solutions and networks still act within niches and remain disconnected from other planning and decision-making processes.

Transformative capacity is manifest in the creation of ample informal and protective spaces, in which relatively small groups of public and private actors from different governance levels come together to share knowledge and develop innovations. These spaces facilitated collaboration, out-of-the-box thinking and navigatingexisting regulatory constraints. In the mid-2000s, policy entrepreneurs used international momentum to introduce mitigation goals and to reframe the city's water management approach from 'keeping water out' towards 'water as opportunity for liveability' (de Greef 2005). This created informal spaces to formulate new strategies and develop projects. Innovative solutions like the Benthemplein water square and the floating pavilion could be developed by positioning them as proof-of-concepts to provide inspiration for a climate-proof city and to market the city as a frontrunner.

The new strategic goals were mainstreamed into operational processes, and innovative solutions were upscaled and replicated. For example, the Rotterdam Adaptation Strategy (RCI 2012) demonstrates prototypes of adaptive solutions. The goals were connected to ongoing strategies and processes, including the redevelopment of the old city ports (Frantzeskaki et al. 2014; Frantzeskaki and Tillie 2014). Lessons learned from implementing proof-of-concept projects support their replication and upscaling. The maintenance of the Benthemplein water square proved tedious due to its technical complexity. Other water squares were implemented with reduced complexity but building on the success principles of the Benthemplein square. The involved architecture firm plans to upscale the Benthemplein square to a climate-proofcity quarter—the Zomerhofkwartier. The planning process builds on the water retention function already covered and on experiences, collaborations and financing options created during the water square process.

The integration of diverse goals and the facilitation of protected, open-ended innovation processes prompted new

governance structures and networks that promote and coordinate priority-setting, mainstreaming and experimentation activities. Local, regional and international partnerships were established, including the RDM Campus, 100RC and Clean Tech Delta, which support the development of innovations by providing space for continuous experimentation.

While there is abundant space for experimentation, the innovative strategies, solutions and networks remain disconnected from ongoing planning and decision-making processes. There is no consistent translation of strategic objectives into action programmes. This results in limited mainstreaming of, for example, climate adaptation into institutional and legal frameworks. Learning from practical experiments to harvest lessons and feed them into strategies and agendas remains largely informal due to time constraints. The innovations often remain stand-alone initiatives, which are showcased internationally, rather than locally, to create business opportunities for local companies.

Orchestrating capacity in Rotterdam

Orchestrating capacity enables coordinated climate governance interventions in line with overarching visions for sustainability and resilience. The innovation processes in Rotterdam resulted in long-term sustainability and resilience goals that guide climate governance activities. New formal and informal governance structures and networks emerged to mediate priorities, knowledge and resources across sectors and scales. However, limited outreach beyond a relatively small actor group, disconnection from ongoing governance processes and unavailability of viable long-term financing signify orchestrating capacity gaps.

Orchestrating capacity is visible in the long-term strategic direction for climate mitigation, adaptation, sustainability and resilience, which resonates in official policy documents, changing narratives and the ways solutions are designed and implemented. The strategies were formulated in collaborative processes including citizen surveys and cross-departmental and public-private debate to stimulate ownership. The integration of different goals helps to develop multi-functional solutions, identify trade-offs and it spurs new coalitions. For example, theprogramme ‘River as Tidal Park’ to strengthen the Meuse river as central, green space connects economic activity, greening, biodiversity and recreation and is implemented by the port authority, the city government and environmental organisations.

To coordinate the implementation of the strategic agenda, diverse formal and informal networks and communication channels were created to integrate and mediate priorities across scales and sectors. The Rotterdam Climate and Sustainability Offices are tasked with motivating, overseeing and coordinating planning processes across sectors. Their cross-departmental set-up makes them central nodes for knowledge exchange and pooling. The offices’ policy officers initiate and organise joint visioning processes, identify opportunities for experimentation and piggy-backing climate mitigation and adaptation initiatives, search and allocate funding sources and participate in cross-scale collaborations and international city networks. The position of the Chief Resilience Officer provides a key contact point for pooling all resilience efforts in the city. Each Climate Office’s member was placed in different city departments to ensure the office’s agenda is taken up in each department’s initiatives.

Public-private partnerships support the activities of the Climate and Sustainability Offices on tactical and operational levels. The RCI is responsible for streamlining, encouraging and supporting initiatives for energy conservation, sustainable energy and CO_2 capture. Projects are implemented together with different networks consisting of local government agencies, companies, knowledge institute and citizens. The Global Centre of Excellence on Climate Adaptation and the Climate Adaptation Academy were launched in Rotterdam. These contribute to international city alignment and knowledge exchange by providing training programmes on climate adaptation and resilience.

While orchestrating capacity in Rotterdam informally emerged from the need for oversight and coordination of climate governance activities, orchestration is limited to a relatively small actor group. Climate governance is still considered as ‘doing something extra’ for higher costs. There is a disconnect between the more diffuse and informal resilience and sustainability networks and more formalised decision-making and planning processes. A key challenge in light of the prevailing focus on (short-term) economic development is to ensure financing of the implementation of the strategic agendas by setting conditions for collaborative, long-term investments and determining responsibilities for carrying costs.

Discussion: lessons learned and ways forward for understanding and supporting transformative climate governance

We presented a novel framework that distinguishes between four capacities for transformative climate governance. Drawing on our illustrative case study of climate governance in Rotterdam, wediscuss the utility of the framework for understanding and supporting capacities for transformative climate governance. We also reflect on future applications and limitations of the framework for analysing and facilitating the ongoing change towards transformative climate governance.

Understanding and supporting capacities for transformative climate governance: activities, conditions and capacity gaps

Our case study demonstrates how the capacities framework helps to map the activities by which multiple actors create

new types of conditions for accomplishing transformative climate governance, to assess the effectiveness of the established capacities and to identify capacity gaps. A growing number of scholars voice the urgency for a 'transformation of governance' to respond more radically and systemically to ongoing transformation dynamics and to address the mismatches of existing governance regimes that these dynamics reveal (Patterson et al. 2016; Loorbach 2014; Termeer et al. 2017). However, while existing work in climate governance and transformation governance literatures has informed policy and practice actions, the insights and knowledge on actors, responsibilities and roles in partnering for bringing these actions to realisation remain mostly theoretical (Gillard et al. 2016; Koop et al. 2017; Castán Broto 2017). Research on experimentation and politics in climate governance (Kivimaa et al. 2017; Hoffman and Loeber 2015) and operational governance approaches like transition management (Loorbach et al. 2015) contribute practical but fragmented insights on agency-level understandings of governance for transformation.

The action-oriented perspective of the capacities framework creates a bridge between 'what is the solution' and 'ability to realise the solution'. It provides a systemic, multi-level and learning-based understanding of what types of governance capacities enable transformative climate governance and by which activities they are established, changed and enriched over time. It thus enables an assessment and explanation of the available conditions for the governance capacities, how the capacities influence the way climate governance is practiced, and it enables the identification of opportunities, challenges and capacity gaps. Supplementary Material B summarises the governance activities that have contributed to creating different types of conditions manifest in new capacities for transformative climate governance in Rotterdam.

For example, we learn from our case study that multi-scale governance networks and integrative planning approaches support fit-to-context solutions, but they require a clear definition and communication of responsibilities, collaborative decision-making processes and flexible regulation to account for diverse regional and local needs. Connecting to key stakeholder groups increases societal support and awareness for renouncing 'the old', yet unlocking capacity can beconstrained in fundamentally questioning existing unsustainable practices because of vested political and economic interests. Transformative and orchestrating capacities in Rotterdam almost simultaneously emerged through the creation of space and informal networks for strategic and operational innovation, which also propelled new types of governance arrangements and structures. The utilisation of momentum for change, such as changing international narratives, and cross-sectoral and public-private collaboration were critical for creating innovation space.

While the capacities require different institutional contexts, skill sets and instruments, our case study shows that the capacities mutually reinforce each other and that gaps in one capacity can impede another. Other scholars found that adaptive capacity can overshadow transformative capacity by prompting people to protect existing structures and functions even though this will cause higher costs and vulnerabilities in the long term (Wilson et al. 2013; Pahl-Wostl et al. 2013). In Rotterdam, transformative and orchestrating capacities support stewarding and unlocking capacity by integrating and mainstreaming different goals (e.g. social resilience), connecting actors to each other for the development of solutions and mediating interests. Key challenges across capacities remain because of limited mainstreaming of innovative long-term and integrated thinking into institutional and regulatory frameworks and a prevailing focus on economic development in planning and decision-making practice. While there is a lot of strength in the informal approach through which emerging cross-departmental and public-private networks in Rotterdam organise orchestration and experimentation, the impact on wider policy and planning processes is limited. Limited mainstreaming results in trade-offs—even between resilience and sustainability goals: charging stations for electric cars were set-up in a flood-prone area, increasing water-related vulnerabilities and threatening to cause power outages during floods.

Strengthening the capacities in Rotterdam requires rethinking how orchestrating and anchoring processes can be structurally supported and provided with a legitimate mandate to create long-term and integrated framework conditions that counter short-term economic interests and clarify responsibilities. Linking strategies, projects and actors in line with complex goals such as resilience, which are not easily understood, requires engaging credibly with a range of stakeholders and bringing in technical and process expertise (Brown 2017).

Applications and limitations of the framework

We suggest the framework as a tool to derive more generalizable results on how and what new forms of climate governance are emerging on global to local scales and how effective these are for addressing climate change and steering transformation dynamics.

The application of the framework to different contexts and scales can yield generalizable results on activities, opportunities and challenges for building capacities for transformative climate governance. For example, the framework can support the comparison of cities to reveal the most effective pathways for increasing governance capacities to accomplish transformative climate governance in relation to different contextual needs, institutional conditions and resources (Koop et al. 2017). The framework can also support action-oriented research to facilitate the co-creation of governance capacities in specific contexts through practice-based governance frameworks such as transition management (Hölscher 2018).

Future research needs to assess rigorously the effectiveness of the governance capacities in accomplishing transformative

climate governance (Jordan et al. 2015). The framework leaves room for formulating indicators to assess certain capacity levels (Pedde S, Kok K, Hölscher K, Frantzeskaki N, Holman I, Dunford R, Smith A, Jäger J. Advancing the use of scenarios to understand society's capacity to act towards achieving the 1.5 degree target. Submitted to Global Environmental Change) or for linking the capacities to evaluation schemes, which, for example, enable the assessment of the impact and directionality of climate experiments (Luederitz et al. 2017). Evaluating the capacities' effectiveness also requires reflection on legitimacy and normativity issues to determine whether vested interests and power imbalances influence decision-making (Avelino et al. 2017).

Central to debates on transformation of governance is a hybridisation of actors (Patterson et al. 2016). In our case study, the local government remains the critical actor leading efforts on climate, resilience and sustainability. Within the Climate and Sustainability Offices, actors take on new roles as orchestrators of climate governance efforts in Rotterdam. They closely collaborate with private businesses and civil society organisations. The capacities framework can be connected with an actor analysis to pay attention to what types of actors engage in which activities, to clarify the role of partnerships and to reflect on whether transformative climate governance implies a reorganisation of governmental tasks vis-à-vis private actors (Hölscher et al. 2017b). This question extends across governance scales: for example, regulatory authority in Rotterdam for climate mitigation is constrained due to a lower prioritisation nationally (Lenhart 2015).

Conclusions

In light of the persistent failure to reduce emissions decisively, facilitate long-term resilience against climate change and account for the connectedness of climate change with other social, environmental and economic concerns, the climate governance landscape is changing towards more polycentric, hybrid and experimental approaches that include multi-scale, cross-sectoral and public-private collaborations.

We presented a capacities framework to provide a systematic analytical tool for understanding and supporting the ongoing changes towards transformative climate governance. The framework provides an agency-focused understanding of the types of governance capacities that are required for addressing climate change in the context of ongoing transformation dynamics and for steering such dynamics towards sustainability and resilience. Our illustrative case study of climate governance in Rotterdam shows the utility of the framework for assessing the available conditions for the governance capacities, discussing how they influence the way climate governance is practiced and identifying actors and activities, opportunities, challenges and capacity gaps.

The ongoing changes in climate governance open up multiple questions about actor roles, effective governance processes, legitimacy and how effective climate governance in the context of transformations can be supported. We invite future research to apply (elements of) the framework to explore these questions.

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