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Towards Resilient Rotterdam? Key conditions for a networked approach to managing urban infrastructure risks

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Abstract

Critical infrastructures are increasingly recognized to be playing important roles in urban resilience theory and practice. However, little is known about which governance challenges result from making them an integral part of urban resilience policies and what role city administrations play or could play in the resulting governance arrangements. We address these shortcomings in the scholarly literature by analysing the case of the Dutch city of Rotterdam, which has positioned itself as a front runner with regard to urban resilience. We find that the city administration is limited in its authority and depends on decisions made by other public and private actors, particularly those relating to the integrated management of interconnected infrastructure networks such as those for water and energy provision. We therefore argue that institutionalizing resilience will strongly depend on city administrations' institutional capacity to manage networks more effectively. For this, we derive key conditions for institutional adjustments in current governance arrangements. Necessary adjustments include redefining roles and responsibilities for cross-territorial risk management, cross-sectoral and cross-departmental budgeting of resilience measures, and integrating local actions and measures with those at regional and national levels of government. Our conclusions call for national and supranational legal reforms to establish uniform procedural rules for urban risk management and contingency planning to provide guidance for municipalities on how to enhance the resilience of their cities and infrastructures.

KEYWORDS

critical infrastructures, governance challenges, institutions, network management, Rotterdam, urban resilience

1 | INTRODUCTION

During recent decades, awareness of urban vulnerabilities to technical infrastructure failures has steadily increased (Graham, 2010; Linkov & Palma-Oliveira, 2017). In this context, critical infrastructures are often conceptualized as interdependent socio-technical systems where physical artefacts such as sewers and power generators interact with organizational and institutional arrangements (Guy et al., 2012). Critical infrastructures are usually defined as assets or systems that are essential for the

maintenance of vital societal functions and whose disruption or destruction would have a significant negative impact on a society's health, safety, security, and economic or social well-being (EU, 2008). In this study, we focus on urban infrastructures at the interface of water and energy provision. These systems are of particular importance because they mediate flows of goods and services that shape the character of today's networked cities (Chen & Chen, 2016). Because cities are geographical nodes of these flows and have dense populations, they are explicitly vulnerable to infrastructure failures (Monstadt & Schmidt, 2019). At the same time, urban crisis management highly depends on their seamless functioning (Fekete & Fiedrich, 2018). Hence, the ability to prevent and to prepare for infrastructural failures is undeniably a major component of a resilient urban system.

Resilience, as a new policy narrative for urban development (Béné et al., 2017), creates a new understanding of risk that highlights the need to break up existing policy silos, combat fragmentation and to establish multi-level, multi-sector and cross-territorial working relationships (Matyas & Pelling, 2015). However, urban scholars have noted that there is no consensus about how urban resilience should be institutionalized in current governance systems (Chandler & Coaffee, 2017; Coaffee et al., 2018). In addition, the scholarly literature on urban resilience tends to address cities as a bounded "container space" and to neglect the multi-scalar dimensions of infrastructurally mediated flows connecting cities closely to their rural hinterlands, neighbouring municipalities and other cities worldwide (Huck & Monstadt, 2019; Monstadt & Schmidt, 2019). Whilst municipalities and their administrations are often held responsible for developing and implementing resilience strategies and plans, they play different roles with respect to critical infrastructures. They regulate and partially own infrastructure systems such as those for wastewater management. At the same time, they are responsible for crisis and risk management to ensure their citizens' protection and safety. This latter role implies negotiation and coordination with other private and semi-private infrastructure providers, network owners and other actors with responsibilities for crisis and risk management. Yet, city administrations' role for the integrated management of critical infrastructures and the required conditions for effective network management remain largely unaddressed in the current literature. To address this void, we ask the following main research question: *Which key conditions are required for effective network management for enhancing urban infrastructure resilience?*

To answer the research question, we analyse existing and missing links between actors in the interface between urban development and infrastructure management in the city of Rotterdam: a city that has positioned itself as a front runner and innovative test bed for climate change adaptation by promoting demonstration projects such as floating pavilions and water retention basins (Gemeente Rotterdam, 2014). Accordingly, the city has received widespread scholarly recognition for its experimental approach to water-sensitive urban design and for its pioneering role in urban resilience (Dunn, Brown, Bos, & Bakker, 2017; Lu & Stead, 2013). Rotterdam's active role in various networks such as 100 Resilient Cities, ICLEI and C40, testifies to its great awareness of issues of resilience and climate adaptation.

For exploring certain governance challenges in Rotterdam, data gathering was primarily based on 26 semi-structured expert interviews. The interviews were conducted between October 2017 and May 2019, which allowed us to track relevant projects and actions of key actors over a longer period of time, rather than to obtain a snapshot of a situation. Interviewees included civil servants, senior advisors and consultants, strategic decision-makers from public and private sectors and senior academics with in-depth knowledge of Rotterdam's resilience policies. We selected interviewees from the planning, maintenance and water departments within the city administration as well as from governmental bodies at the regional and national level such as the safety region, the Rijkswaterstaat or the Ministry of Infrastructure and Water Management. In addition, we selected senior managers working on security-related issues and business continuity employed by private or public–private infrastructure providers or by owners of networks for water and energy provision such as Stedin and Evides. Appendix 1 lists interviewees, their affiliation and the main topics of discussion. We used qualitative content analysis (Gläser & Laudel, 2013) to categorize and distil relevant information from the coded interview transcripts. The codes we allocated referred to governance challenges we identified in multi-level, multi-sector and cross-territorial risk management of critical infrastructures and to what we considered to be the city administration's possibilities and limitations to respond to these governance challenges. Our preliminary findings were discussed with selected interviewees to collect further evidence and to confirm our conclusions. For the same reason, a draft of this paper was sent to all interviewees for comments before submission. For deriving key conditions for a networked approach to managing infrastructure risks, we triangulated our interpretation of the experts' perspective with research on scholarly and grey literature, including policy documents, plans and strategies.

In the following section, we lay the basis for our analysis by engaging with the literature on the governance of urban resilience and critical infrastructures. Here, we develop an understanding of governance challenges as specific mechanisms and institutional constraints that impede actors' collective action to contribute to realizing certain policy objectives. In Section 3, we analyse ongoing project work and policymaking in Rotterdam, focusing on the city's resilience strategy as well as on risk management for critical infrastructure systems. From the statements of the interviewed experts, we identify specific governance challenges that arise when critical infrastructures become an integral part of urban resilience policies. In addition, we analyse how civil servants in Rotterdam address these challenges. Based on the results of our analysis, in Section 4 we derive some key conditions for effective network management of mutually dependent actors responsible for operating critical infrastructures. In Section 5, we conclude that municipal administrations such as Rotterdam find themselves in a position of having "responsibility without power" (Peck & Tickell, 2002, p. 386) because

effective network management requires institutional reform that extends beyond their administrative jurisdiction.

2 | INSTITUTIONALIZING URBAN RESILIENCE AS A GOVERNANCE CHALLENGE

Whilst definitions of urban resilience may differ from city to city (Spaans & Waterhout, 2017) and across academic debates (Huck & Monstadt, 2019), the following definition provides a general and encompassing elucidation:

> Urban resilience refers to the ability of an urban system – and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales – to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity. (Meerow, Newell, & Stults, 2016, p. 39)

As Matyas and Pelling (2015) argue, resilience can be imbued with greater analytical depth by elaborating on particular resilience capacities as distinct—although not discrete—options for decision-making and risk management. A literature review reveals three main strains of thought highlighting distinct resilience capacities that are relevant for cities and their infrastructure systems (cf. Hegger et al., 2016): *resistance* describes the capacity of a city and its citizens to resist shocks and stresses. *Recovery* accounts for the capacity to absorb and recover from shocks and stresses. *Adaptability* refers to the capacity to adapt, learn and transform. By making public its resilience strategy (Gemeente Rotterdam, 2016), the city administration of Rotterdam has assigned itself an active role in enhancing such capacities. However, issues such as the risk management of interdependent infrastructure systems constitute new ground for urban policy making in the city (Hommels, 2018).

Originating from the realm of homeland security in the United States, critical infrastructure protection gained recognition in security-related policy discourses in Europe and in other parts of the world at the beginning of this century (Bach, Bouchon, Fekete, Birkmann, & Serre, 2014; Collier & Lakoff, 2015). Scholars have highlighted infrastructural interdependencies and potential cascading failures that cross-sectoral and spatial boundaries (Rinaldi, Peerenboom, & Kelly, 2001). The assumption is that modern infrastructures are composed of tightly coupled systems in which the failure of a single system component, or failures at a limited geographical scale, can cause the failure of an entire system as well as of a functionally interdependent system of systems (Kröger & Zio, 2011). Moreover, exogenous risks (for instance, related to climate change) may be amplified by the increased complexity and interconnectivity of different infrastructure systems (Bollinger et al., 2013). Seager et al. (2017) argue that the amplification becomes even more severe when failures cross ownership, operational and regulatory boundaries. If relevant actors and organizations have never established working relationships, insufficient interorganizational communication and coordination in the time-sensitive management of acute crises can considerably amplify cascading infrastructure failures. Consequently, some authors (Hokstad et al., 2012; Linkov & Palma-Oliveira, 2017; Perrow, 1994) have advocated taking account of infrastructural interdependencies in risk management practices, which require there to be working relationships among the multiplicity of stakeholders involved in infrastructure governance (Bach et al., 2014), including public, private and semi-public actors (Dunn-Cavelty & Suter, 2009).

Only recently have scholars of urban resilience taken up these debates (Huck & Monstadt, 2019). For instance, Chang, McDaniels, Fox, Dhariwal, and Longstaff (2014) outline the vital importance of a shared understanding of regional infrastructure disruption for disaster-resilient cities. In addition, Monstadt and Schmidt (2019) point to the importance of considering functional interdependencies of critical infrastructure systems when institutionalizing urban resilience. Because urban threats and stresses are triggered by—or accelerated through—the growing complexity and interconnectedness of technical, social and ecological systems, urban scholars call for adaptive and networked forms of urban governance (Crowe, Foley, & Collier, 2016; Ernstson, Barthel, Andersson, & Borgström, 2010). It is very unlikely that any one actor or actor group can design and implement resilience policies alone. Rather, scholars in the field of urban and infrastructure resilience seem to agree on the need for actors to work together across administrative, sectoral and territorial boundaries in a more strategic way (Almklov, Antonsen, & Fenstad, 2012; Boin & McConnell, 2007; Coaffee & Clarke, 2016; Godschalk, 2003; Padt et al., 2014). Hence, it is necessary to establish new working relationships between actors that have previously worked separately, or to rearrange working relationships of incumbent stakeholders whose interests, goals and strategies might be at odds with each other (cf. Scharpf, 1978). This is in line with Klijn and Koppenjan's (2016, p. 11) concept of network management, which entails establishing "more or less stable patterns of social relations between mutually dependent actors." Against this background, institutionalizing urban resilience refers to the consolidation of adaptive and networked governance arrangements to enhance resilience capacities (cf. Folke, Hahn, Olsson, & Norberg, 2005; Jordan & Schout, 2006).

To operationalize our analysis, below we explain some key terms.

Firstly, *institutions* can be understood as the "rules of the game named governance" which structure the roles and guide the interactions of different actors (Hohn & Neuer, 2006, p. 294). In this context, *actors* are those that have the power and resources to contribute to realizing certain policy objectives or, conversely, to prevent others from doing so. They compose a subgroup of the wider group of stakeholders who have a stake or interest in the decision-making process (Hegger et al., 2014, p. 4131). Importantly, institutions can be either formal (e.g. written laws, regulations or standards) or informal (e.g. working routines, traditions or established epistemologies; North, 1990). As such, institutions in socio-technical infrastructure systems can range from laws and regulations on water provision to

standards on disaster risk management, and from established working routines of infrastructure providers to traditional epistemologies of certain professionals like risk contingency managers or planners. A number of scholars argue that some sort of institutional reform is required to cope with and adapt to the increasing digitalization, privatization and globalization of critical infrastructure networks and services and to emerging risks such as those imposed by climate change (e.g. LaPorte, 2007; Zaidi & Pelling, 2015).

Secondly, *governance arrangements* can be defined as institutional constellations resulting from the interplay between state and non-state actors involved in relevant policy domains (definition adapted from Hegger et al., 2014, p. 4131). Governance arrangements for interdependent critical infrastructure systems are characterized by a complex web of public and private actors such as different municipal departments, regional planning authorities and national or international regulators, private and semi-private network owners and service providers and consumers, and producers of infrastructure services. Consequently, public–private partnerships receive considerable attention in governance debates on critical infrastructures (Dunn-Cavelty & Suter, 2009). Often, these governance arrangements are described as being fragmented and thus limit the collective action of the various relevant actors that would be required to manage the cascading effects of failing infrastructure networks (de Bruijne & van Eeten, 2007). Interestingly, the urban level of infrastructure management and the particularity of urban vulnerabilities to infrastructure failure has received only minor attention in the literature on critical infrastructures (Huck & Monstadt, 2019). Moreover, the particular role of municipal administrations in these risk governance arrangements has so far seldom been discussed.

Thirdly, if critical infrastructures are an integral part of urban resilience policies, their fragmented management can be seen as a major *governance challenge* for institutionalizing urban resilience (Monstadt & Schmidt, 2019). From this, it follows that *governance challenges* can be defined as those mechanisms and institutional constraints that impede actors' collective action to contribute to realizing certain policy objectives. When enquiring about the potential role of a city administration for institutionalizing urban resilience, we therefore have to enquire about the capacity they have to perpetually overcome particular governance challenges and to initiate institutional reform. In this sense, institutionalizing urban resilience requires strategic action and long-term thinking (Godschalk, 2003). Whilst explicit governance challenges have already been defined for certain fields such as flood risk management (Dieperink et al., 2016) and the nexus of spatial planning and disaster risk management (Sapountzaki et al., 2011), to our knowledge this is not the case for the integrated management of critical infrastructure systems at the urban level. In order to identify certain governance challenges in Rotterdam, we reveal three analytical dimensions of institutional fragmentation gleaned from the literature:

- *Horizontal fragmentation* refers to the multi-sectoral character of infrastructure management. It is argued that disconnects between relevant policy domains (e.g. emergency management, environmental management, urban planning and infrastructure management) or between relevant infrastructure sectors and their relevant private–public and private stakeholders impede collective action to achieve urban and infrastructure resilience (e.g. Almklov et al., 2012; McPhearson, Andersson, Elmqvist, & Frantzeskaki, 2015; Medd & Marvin, 2005).
- *Vertical fragmentation* concerns issues of multi-level governance where local, regional, national and international policy-making is not sufficiently synchronized (e.g. Adger, Hughes, Folke, Carpenter, & Rockstrom, 2005; Dewulf, Meijerink, & Runhaar, 2015; Vedeld, Coly, Ndour, & Hellevik, 2016). Equally important are mismatches between the policy level where the problem arises and the level where policies to tackle it are formulated (Padt et al., 2014).
- *Territorial fragmentation* relates to the misalignment of neighbouring or otherwise connected territories, which might become an issue because infrastructure networks cover dissimilar territories and threats or failures might easily cascade between them, requiring action to be taken far away from the places where the initial problem arose (Chelleri, Waters, Olazabal, & Minucci, 2015; Coaffee & Clarke, 2016; Ernstson et al., 2010).

3 | ROTTERDAM'S GOVERNANCE CHALLENGES IN INSTITUTIONALIZING URBAN RESILIENCE: AN INFRASTRUCTURAL PERSPECTIVE

With over 600,000 residents, Rotterdam is the second largest city in the Netherlands. The city is part of the densely populated Randstad metropolitan region and is close to The Hague, which is the seat of the Dutch government. Its location in the Rhine–Meuse–Scheldt river delta accounts for the city's fundamental role in the Dutch economy, as it hosts Europe's largest cargo port, accounting for 6.6% of the national GDP (Port of Rotterdam Authority, n.d.). However, it also explains the city's vulnerabilities to risks induced by climate change, such as rising sea levels and heavy rain events. Since approximately 80% of the city is below sea level, urban life in Rotterdam heavily depends on protection mechanisms such as dikes and storm surge barriers, as well as on a system of drainage ditches, canals and pumping stations to keep the city dry. In turn, this system depends on electricity and communication (including Internet), which makes it vulnerable to power outages and cyber attacks.

In 2016, Rotterdam released the Resilient Rotterdam Strategy (hereafter: resilience strategy), which developed from the idea to position climate adaptation challenges in a resilience framework (Hommels, 2018, p. 274) and at the same time to better connect existing initiatives on social cohesion, climate adaptation, infrastructure management and cyber protection (Interview 4). Rotterdam is the first Dutch city to have developed such a comprehensive resilience strategy and to have financed specific resilience personnel such as the Chief Resilience Officer. Some authors therefore describe Rotterdam as being at an advanced stage with respect to institutionalizing urban resilience (Lu & Stead, 2013; Spaans & Waterhout, 2017). However, this

also means that the city can hardly fall back on role models elsewhere, for example for exploring new policy areas such as the integrated risk management of interdependent infrastructures in urban areas.

Clearly, infrastructure resilience involves not only sectoral planning and regulation (e.g. for water and electricity) but also issues of spatial planning, asset management, civil protection and physical safety. Moreover, incumbent actors at other governmental levels as well as private and semi-private infrastructure providers and network owners play important roles in the governance of critical infrastructures and hence in institutionalizing urban resilience. For instance, the Province of South Holland's core tasks refer not only to spatial planning but also to environmental management and regional public transport. Regional electricity provider Stedin closely depends on national network provider Tennet but is also regulated by the Ministry of Economic Affairs. Regional water provision is organized by the semi-private company Evides and regulated by the Ministry of Infrastructure and Water Management. Wastewater management and regional flood defence are planned by regional water authorities (*waterschappen).* The port of Rotterdam as a major transportation and logistics hub is managed by the port authority (*Havenbedrijf Rotterdam*). Cross-cutting risk and crisis management is regulated by the Ministry of Justice and Security, which also has under its aegis of the national counterterrorism agency (National Coordinator for Security and Counterterrorism, known by its Dutch abbreviation NCTV) responsible for the overall resilience of Dutch critical infrastructure (NCTV, n.d.). Whereas emergency and crisis management in the Netherlands are a local responsibility, municipal executives are grouped into so-called safety regions (*veiligheidsregios*). The Rotterdam–Rijnmond safety region covers Rotterdam and 14 neighbouring municipalities, the harbour of Rotterdam and Rotterdam The Hague Airport. Some of the tasks of the safety region are to prepare an integrated risk profile for the region and to coordinate different stakeholders—including infrastructure providers and emergency services—in times of emergency (for more details on the role of the safety region, see Prins, Cachet, Ponsaers, & Hughes, 2012).

3.1 | Coordinating policy and infrastructure domains in Rotterdam

With regard to institutionalizing resilience, our analyses reveal that Rotterdam is characterized by some degree of horizontal fragmentation which becomes visible in issues of cross-departmental cooperation within the municipality as well as in problems of cross-sector cooperation and coordination across different infrastructure sectors.

3.1.1 | Anchoring resilience thinking in the municipality

As a member of 100 Resilient Cities, Rotterdam has made use of a standardized process to develop a resilience strategy, including broad stakeholder involvement. Interviewees from the municipality perceived this process as highly beneficial because through it they made new contacts and discovered unknown interdependencies with other departments of the city administration (Interviews 4, 8). However, shortly after the strategy was released, cross-departmental collaboration declined, because most of the defined projects were allocated to different departments in the city (Interview 22). "Anchoring resilience thinking" at the strategic decision-making level in the municipal administration remains a challenge for the resilience team consisting of the Chief Resilience Officer and two civil servants (Interviews 4, 22).

Our analyses reveal three main governance challenges that hamper greater cross-departmental cooperation and collective resilience action. Firstly, an external observer identified relatively rigid epistemic traditions within the individual municipal departments (Interview 15). This respondent argued that the same people who were responsible for climate adaptation planning are now responsible for the resilience strategy, which may lead to climate change issues being given preferential treatment compared with other resilience matters and that friction might arise if the resilience team starts to interfere in issues that were previously managed by other people. Secondly, an interviewee argued that cross-departmental cooperation remains challenging as long as the municipal budget is allocated in a departmental way (Interview 22). Thirdly, a lack of political support for urban resilience as opposed to other municipal programmes such as those promoting the energy transition or circular economy was identified (Interviews 22, 24). An interviewee from 100 Resilient Cities even argued that the resilience strategy competes directly with these programmes with respect to which future vision will gain political support (Interview 18).

To respond to these challenges, the resilience team opted to exploit the possibilities of linking resilience goals to the existing goals of other municipal programmes and to concentrate efforts on selected pilot and demonstrator projects (Interview 22). This strategy caused other interviewees (Interviews 2, 15) to criticize the rather informal and non-binding character of the resilience strategy. Moreover, one interviewee argued that Rotterdam runs the risk of cross-departmental cooperation lasting only as long as project funding and therefore having to be re-established when the next project starts (Interview 1).

3.1.2 | Issues of cooperation and coordination across different infrastructure sectors

Although interviewees report there are well-established governance arrangements to coordinate and cooperate within single infrastructure sectors, they identify an institutional void with regard to infrastructure providers' joint responsibility for risk management (Interviews 6, 7, 13, 14). Infrastructure providers focus most of their attention on internal contingency management and use internal preparedness strategies that are insufficiently communicated to or coordinated with other providers or municipal planning and crisis management. In fact, at municipal level, there is no coordinating body that aligns different sectoral approaches, detects infrastructure interdependencies or defines critical infrastructures at city level. Consequently, infrastructure

providers like Stedin or Evides take little part in discussions on urban resilience in Rotterdam (Interviews 8, 9, 11), neither are municipal actors involved in internal risk and contingency management of infrastructure providers (Interviews 7, 13).

Again, interviewees highlighted the challenges that accompany diverging and relatively rigid epistemic traditions of different actors. For instance, it was mentioned that public and private organizations still lack a shared understanding relating to risk and contingency management (Interviews 8, 9, 11, 19, 21). Whereas for infrastructure providers like Stedin or Evides the paramount concern is to protect the physical system from damage, the municipality focuses on the safety of its citizens. Moreover, public flood risk management can be described as moving from a purely protectionist approach to a more adaptive one (Francesch-Huidobro, Dabrowski, Tai, Chan, & Stead, 2017), thereby considerably increasing cooperation between the municipality of Rotterdam, the water authorities and the regional environmental protection agency (Spaans & Waterhout, 2017). However, several interviewees noted that infrastructure providers did not necessarily undergo the same cultural change process and were still focusing their attention on protection measures rather than on adaptation potential (Interview 15), with each provider "focusing on their core business" (Interview 13). In addition, representatives from network providers argued that interdependencies are very hard to manage because cross-sector cooperation is very time-intensive and resource-intensive as it involves understanding the other's culture, strategic logic and rationale. As such, the absence of an obligation to invest in cross-sector initiatives and the lack of dedicated budget to promote them is hampering cooperation and coordination across different infrastructure sectors (Interviews 7, 13, 15).

Interestingly, Stedin, Evides and the municipality of Rotterdam maintain very close relationships, as evidenced by the agreement they have entered into to coordinate their maintenance of the city's underground infrastructure (Interview 9). Not only is it more cost-efficient to bundle operations in the underground, it also reduces the risk of damaging other infrastructure networks whilst digging and it reduces traffic disruption and the need to cut off services to residents. Having a common goal (i.e. cost efficiency in replacement and repair) has made it possible to build stable working relationships between public and private partners. However, the cooperation is restricted to asset management and it is not planned to include continuity management or strategic risk management in the near future (Interview 23).

3.2 | Multi-level governance for infrastructure resilience

Although the NCTV is making slow progress in identifying cross-sector interdependencies at the national level (Interview 19), interviewees mention missing an information flow to the regional and local levels (Interviews 19, 26). There seem to be very limited possibilities for Rotterdam to contribute to national projects in this policy domain; neither are national ministries' part of resilience discussions in the city. Even more surprisingly, we found limited cooperation between the safety region and the municipality of Rotterdam in urban resilience and infrastructure management, although their expertise in risk management would be beneficial for future-oriented planning (Interviews 8, 11, 26).

The main challenge to increasing the information flow from the NCTV to lower levels of government is apparent from the regulatory frameworks and existing contracts with infrastructure providers that prohibit data sharing (Interview 19). Although safety regions struggle to obtain information from private infrastructure providers (Interviews 11, 26), the NCTV is often not allowed to provide them with specific information—for example on the location of specific vulnerable assets (Interview 19). In addition, there is still uncertainty about who is actually responsible for issues of cross-sector infrastructure resilience and at what level of government (Interviews 11, 19, 26). From the perspective of the safety region, interviewees particularly regret the lack of a formal mechanism that would make them part of planning processes in the municipalities (Interview 11). Also mentioned in this context was the difficulty of broadening the scope of the safety region from purely reactive disaster management to proactive risk management (Interviews 3, 11, 26). Interviewees do not expect this to change unless a major disaster forces a political re-think and the reallocation of budgets for risk management (Interviews 25, 26).

Because both sides are starting to recognize their co-dependencies, cooperation between the safety region and the municipality has slowly increased in recent years (Interviews 3, 11, 16). One way this is taking place is through scenario workshops conducted by the municipality to improve evacuation planning (Interview 3). In addition, a leading manager from the safety region (Interview 26) hopes to formally establish an advisory role for the safety region in planning processes for the municipal structural plan (*gemeentelijke omgevingsvisie*) that is currently being prepared. To our knowledge, there is as yet no ambition to include municipalities in NCTV projects or to involve the NCTV in the local resilience debate.

3.3 | Cooperation and coordination across different territorial jurisdictions

Whereas emergency management was originally organized at a municipal level, the Rotterdam–Rijnmond security region covers the territory of 15 municipalities. Regional flood risk management operates largely in the administrative jurisdictions of water authorities. Three of them intersect with the municipal boundaries of Rotterdam, which considerably increases the coordination effort because each water authority has its own democratically elected committee (Interview 24). Neither the safety regions nor the regional water authorities are aligned with the territorial jurisdictions of the provinces. Network operators and service suppliers often operate beyond the geographical boundaries of the municipality, safety region or water authority. For instance, Evides' water supply area extends from the Rotterdam area to the coast in the West and to the border with Belgium in the South, whilst Stedin's electricity network covers the areas of Rotterdam and The Hague and extends inland towards Utrecht. The particular geographies of infrastructure

operation are at odds with the existing territorial jurisdictions of traditional risk management and public administration. In addition to that, the Ministry of Infrastructure and Water Management defined so-called "spatial adaptation regions" that did not coincide with provincial jurisdictions or the jurisdictions of water authorities or safety regions. Here, municipalities and water authorities were supposed to work together to identify potential consequences of floods on critical infrastructures in so-called "stress tests." However, it is fair to state that this experiment failed (Interview 21).

Adding an extra layer to the existing complex geographies of risk management in the form of "adaptation regions" complicated cooperation between relevant actors, leading to uncertainty about who was responsible for what and where (Interviews 5, 21). Two major issues were the lack of a dedicated budget for conducting the stress tests and the failure to define a governance structure for allocating roles and responsibilities among the actors (Interview 21). Another issue was that municipalities were unable to obtain information from private and semi-private infrastructure providers on their vulnerabilities and location of assets because there was no established working relationship between most of them (Interview 21). It was mentioned that infrastructure providers and network owners do not have the capacities and resources to participate in every single municipal initiative or to take part in exercises organized by different safety regions whose jurisdictions happen to intersect their supply area (Interviews 14, 19). Finally, we found that the municipality of Rotterdam had difficulty in maintaining cooperation on cyber resilience with the three water authorities because the board members changed during the political election cycle (Interview 24).

The Ministry of Infrastructure and Water Management recently discarded the "spatial adaptation regions" and is now working with two provinces as pilots to see whether this scale is more suitable. In these pilot regions, the project leader cooperates with a representative of the province and a representative of a local safety region. An important goal of this cooperation is to establish contact with critical infrastructure providers for conducting the "stress tests." Moreover, it is an attempt to concentrate forces, because safety regions face similar problems in receiving information from critical infrastructure providers so as to be able to conduct risk assessments (Interview 21). City administrations, however, are not part of the resulting consortia.

4 | KEY CONDITIONS FOR EFFECTIVE NETWORK MANAGEMENT OF MUTUALLY DEPENDENT ACTORS RESPONSIBLE FOR OPERATING CRITICAL INFRASTRUCTURES

In response to the identified governance challenges, Rotterdam's city administration is slowly starting to act as a network manager within the governance network associated with urban and infrastructure resilience. According to Klijn and Koppenjan (2016, p. 11), governance networks are "more or less stable patterns of social relations between mutually dependent actors, which cluster around a policy problem, a policy programme and/or a set of resources and which emerge, are sustained and are changed through a series of interactions." Developing a resilience strategy in cooperation with a broad range of stakeholders clearly exposes the potential to serve as strategic anchor point, laying out common values and providing a clear methodology. Defining common goals and co-creating policies are substantial prerequisites for what Goldstein (2012) calls collaborative resilience. Moreover, aligning resilience goals with those of other municipal programmes in Rotterdam contributes to sustaining resilience thinking across different municipal departments as proposed, for example, by Sapountzaki et al. (2011). Initiating scenario workshops with the safety regions on evacuation planning or conducting workshops with the three water authorities to evaluate cyber-related vulnerabilities further establishes social relationships that cross jurisdictional boundaries and cluster around urban and infrastructure resilience. These efforts by the municipality clearly contribute to establishing new cross-boundary working relationships as advocated by urban and infrastructure resilience scholars (e.g. Coaffee & Clarke, 2016; Crowe et al., 2016). In other instances, the initiative comes from other actors, such as the safety region (which is trying to be assigned a formal role in strategic municipal planning processes) or the Ministry of Infrastructure and Waterworks (which is starting to collaborate with provinces and safety regions to assess infrastructure vulnerabilities). A particularly promising way of more effectively coordinating infrastructure policies and management across individual infrastructure domains and their territorial scopes is to increase involvement of the Rotterdam–Rijnmond safety region, as it already maintains the necessary contacts with infrastructure operators and network owners in the region. Whilst the safety region is already important in coordinating the different emergency services (Prins et al., 2012), its role for proactive infrastructure management and planning in Rotterdam could be strengthened.

Despite the many positive outcomes of the resilience strategy in Rotterdam with regard to public awareness and the implementation of boundary-crossing initiatives and projects, it is becoming clear that to establish "more or less stable patterns of social relations between mutually dependent actors" (Klijn & Koppenjan, 2016, p. 11), project-based work as currently advocated by the resilience strategy might not be sufficient. Rather, the short-term character of many projects brings the risk that actors will relapse into siloed working habits after a particular project ends and that relationships will have to be re-established time and again. This stands in contrast to the notion of institutionalization as a consolidation of adaptive and networked governance arrangements, as defined in Section 2 (cf. Folke et al., 2005; Jordan & Schout, 2006). Apparently, there is a lack of procedural rules providing guidance on how to enhance and maintain cross-boundary working relationships between the large numbers of relevant actors in order to stabilize networked governance arrangements. The case of Rotterdam offers some indications of the key conditions for effective network management of the mutually dependent actors responsible for operating critical infrastructures, which can lay the basis for the development of such rules. These are elaborated below.

Firstly, cross-sectoral budgeting of infrastructure resilience measures and cross-departmental budgeting of municipal projects

would contribute to establishing lasting working relations at a strategic level both in the municipality and among public and private infrastructure providers. The resulting collective action across departmental and sectoral borders could help to dilute rigid epistemic traditions by creating co-designing processes and shared goal definitions (cf. Huck & Monstadt, 2019). As such, it could contribute to further broadening the focus of climate adaptation in Rotterdam to include other potential risks such as power failures or cyber attacks. It could also contribute to establishing a shared understanding of risk between public administration and private infrastructure providers that are accountable for both the protection of physical systems and the safety of the citizen (cf. Dunn-Cavelty & Suter, 2009).

Secondly, better integration of actions and measures at the local level with those at regional and national levels of government would contribute to more effective risk management practices (cf. Vedeld et al., 2016). This includes rules for sharing information on infrastructure vulnerabilities between different levels of governance, as well as multi-level negotiations on the allocation of budget and responsibility. In this sense, it would prevent actors at lower governance levels being made responsible for particular measures such as defining infrastructure vulnerabilities without having sufficient jurisdiction, institutional capacity or budget. Hence, it could contribute to solving the current problems that have arisen as a result of the minor role played by safety regions in proactive cross-sector infrastructure resilience and by the inability of the NCTV to provide them with information. From an urban resilience perspective, defining critical infrastructures at a municipal level and discussing and agreeing on acceptable levels of risk in the city or in certain parts of the city seem to be promising exercises. They would address the current mismatch in which the effects of infrastructure failures are mainly felt at local level, but policies to deal with such disruptions are designed at national level (cf. Padt et al., 2014).

Thirdly, our analysis calls for the roles and responsibilities for cross-territorial risk management to be redefined. Defining *who* is responsible for *what* and *where* across historically grown and separated entities such as safety regions, water authorities, provinces and municipalities clearly requires considerable investments in time, money and personnel (cf. Dewulf et al., 2015). However, such negotiation processes are necessary to prevent inefficient and uncoordinated action by individual actors and to do justice to the cross-boundary character of infrastructure systems (Seager et al., 2017). The case of Rotterdam shows that not only is it necessary to give infrastructure providers clear duties and responsibilities, but also to give them a clear picture of whom they should provide with what kind of information and when.

In summary, our analysis contributes to practical and scholarly debates on institutionalizing urban resilience in four ways. Firstly, by combining approaches of urban resilience and critical infrastructure research, it helps to better understand the urban level of infrastructure risk management and the particularity of urban vulnerabilities to infrastructure failure. Secondly, it reveals particular governance challenges associated with the management of critical infrastructures in urban areas and it discloses the need for institutional reform. Thirdly, it provides key conditions for such an institutional reform. We argue that procedural rules for approaching different dimensions of institutional fragmentation (horizontal, vertical and territorial) must be (re)designed. Uniform procedural rules could guide municipalities and regions in contingency planning, vulnerability and risk assessment and in crisis management, harmonize risk management and define which relevant actors should participate and how they should do so. Fourthly, our analysis provides insights into the particular role of municipal administrations in institutionalizing adaptive and networked governance arrangements, which will be presented in the remaining section of this manuscript.

5 | CONCLUSION: ON THE POTENTIAL ROLE OF MUNICIPALITIES IN INSTITUTIONALIZING URBAN RESILIENCE

By participating in the 100 Resilient Cities Programme, Rotterdam's city administration has assigned itself an active role in institutionalizing urban resilience and has positioned itself as an international front runner. Some governance challenges nevertheless remain to be overcome, particularly with respect to the integrated management of interconnected infrastructure networks such as those for water and energy provision. Although municipalities are often formally responsible for developing and implementing urban resilience strategies and plans, their responsibility for institutionalizing favourable conditions for effective network management is limited. To some extent, municipalities like Rotterdam face a condition which Peck and Tickell (2002, p. 386) refer to as "responsibility without power."

The results of our study show the need for national and supranational levels of government to design and implement legal reforms that institutionalize uniform procedural rules for urban risk management and contingency planning, providing guidance for municipalities on how to enhance the resilience of their cities and infrastructures. As our analysis revealed, key conditions for such an institutional reform may include the clarification of roles and responsibilities for cross-territorial risk management, cross-sectoral and cross-departmental budgeting of resilience measures, and a better alignment of local activities with activities at regional and national levels of government. In contrast to defining universal resilience and safety standards, procedural rules may, for example, guide municipal governments in how to assess place-based vulnerabilities, how to prepare integrated contingency plans in a more standardized manner and whom to engage in such assessments, planning procedures and other risk management practices. As such, procedural rules could help not only to operationalize national infrastructure resilience strategies and their unsubstantiated claim of achieving voluntary cooperation among governments, businesses and civil society but also to establish uniform institutional frameworks for urban resilience policies (Monstadt & Schmidt, 2019, p. 17). In this sense, our study shows that academic and policy debates on urban resilience should focus more on how local levels of governance are embedded in complex territorialities of infrastructure systems and the different governance levels involved in managing these systems.

100RC addressed supranational levels of government by releasing "prospectuses" for the United States, the European Union and

other world regions (100RC, n.d.). For instance, it aimed at "pushing EU policy to support urban resilience" (100RC, 2017). However, international city networks such as 100RC can hardly be held responsible for inducing legal reform at national or supranational levels of government. Rather, they can serve as a test bed for urban resilience measures, promote the exchange of experiences among municipalities and put resilience on the urban policy agenda. As the role of international networks has so far often been neglected in scholarly literature (for an exception, see Leitner, Sheppard, Webber, & Colven, 2018), their influence on policy-making at different levels and how they can contribute to institutionalize urban resilience deserve further examination. 100RC could serve as an interesting case study as it was unexpectedly dissolved in summer 2019, and therefore, there is an opportunity for an ex post analysis of its activities. In addition, future research would potentially benefit from focusing more on political decision-making at different levels of government (and how they interact), which was beyond the scope of this study. Gaining these kinds of insights from cities approaching the challenge of institutionalizing urban resilience will be important for future research and for tackling the question raised by Coaffee and Lee (2016) of what resilience *does* instead of solely asking what it *is*.

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CONFLICT OF INTEREST

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APPENDIX 1

Expert interviews overview

TABLE A1 Overview of interviews

Interview #	Organization	Date	Place	Main topic of interview
1	Municipality of Rotterdam—Spatial planning	04.10.2017	Rotterdam	Climate adaptation, municipal strategies
2	Municipality of Rotterdam—Spatial planning	06.10.2017	Rotterdam	Municipal organization and project management
3	Municipality of Rotterdam—Water Management	13.10.2017	Rotterdam	Emergency management, local, regional and national flood management
4	Municipality of Rotterdam—Resilience Team	25.10.2017	Rotterdam	Rotterdam Resilience Strategy
5	Ministry of Infrastructure and Water Management—"vitaal & kwetsbaar"	27.10.2017	The Hague	Critical infrastructures, climate adaptation, national perspective
6	Next Generation Infrastructure	30.10.2017	Delft	Critical infrastructure resilience
7	Evides—crisis and contingency management	31.10.2017	Rotterdam	Crisis and contingency management
8	Municipality of Rotterdam—Resilience Team	01.11.2017	Rotterdam	Rotterdam Resilience Strategy, Cyber security
9	Municipality of Rotterdam (2 interviewees)—Asset management	01.11.2017	Rotterdam	Asset management, underground infrastructures
10	Municipality of Rotterdam—policy adviser	06.11.2017	Rotterdam	Energy Transition, municipal strategies
11	Safety Region—risk management	29.11.2017	Rotterdam	Emergency management, regional risk management, Rotterdam Resilience Strategy
12	Port of Rotterdam—Asset management	06.12.2017	Rotterdam	Asset management, resilience management in the port
13	Stedin—crisis and contingency management	08.12.2017	Utrecht	Crisis and contingency management
14	TNO (retired)	13.12.2017	Utrecht	Critical infrastructure resilience
15	TNO	13.12.2017	The Hague	Critical infrastructure resilience, Rotterdam Resilience Strategy, Cyber resilience
16	Rijkswaterstaat	20.12.2017	Utrecht	Water safety, critical infrastructure resilience
17	Rijkswaterstaat	20.12.2017	Utrecht	Water safety, critical infrastructure resilience
18	100 Resilient Cities	12.01.2018	Skype interview	100 Resilient Cities, Rotterdam Resilience Strategy
19	Ministry of Security and Justice—National Coordinator for Security and Counterterrorism (NCTV)	23.01.2018	The Hague	Cross-sector infrastructure resilience, NCTV
20	Ministry of Security and Justice—National Coordinator for Security and Counterterrorism (NCTV)	04.04.2019	The Hague	Follow-up to interview #19
21	Ministry of Infrastructure and Water Management—"vitaal & kwetsbaar"	04.04.2019	The Hague	Ministerial cooperation, critical infrastructures and climate adaptation
22	Municipality of Rotterdam—Resilience Team	26.04.2019	Skype interview	Follow-up to interview #4
23	Municipality of Rotterdam—Asset management	16.05.2019	Skype interview	Follow-up to interview #8
24	Municipality of Rotterdam—Resilience Team	16.05.2019	Skype interview	Follow-up to interview #9
25	Safety Region—crisis response	21.05.2019	Rotterdam	Emergency management, critical infrastructure resilience
26	Safety Region—risk management	21.05.2019	Rotterdam	Emergency management, municipal planning