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Local governance of critical infrastructure resilience: Types of coordination in German cities

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Abstract

The resilience of critical infrastructures in cities is key to being prepared for future crises. The challenge of enhancing critical infrastructure resilience addresses a multitude of actors. However, we lack conceptual, as well as empirical, understanding of how these different actors are coordinated. Therefore, this contribution asks how the different actors involved in critical infrastructure governance are coordinated at the local level. With the help of a typology of network governance coordination (political leadership, mutual exchange, and positive coordination), we look at the critical infrastructure crisis management in major German cities based on survey data with the scenario of a long-lasting, supraregional power outage. The results show that political leadership coordination, as a unilateral and information-based way of addressing public and private actors, is the dominant type. Only a quarter of the cities have chosen measures of mutual exchange coordination based on the consultation in an ad hoc manner. Measures of positive coordination where institutionalized joint planning is central are taken up only by a minority of German cities. Assuming that positive coordination is particularly important in dealing with unexpected events, positive coordination emerges as the missing piece of the resilience puzzle for many German cities.

KEYWORDS

coordination, critical infrastructure: crisis management, Germany, governance, power failure, urban resilience

1 | INTRODUCTION: THE CRITICAL INFRASTRUCTURE RESILIENCE PARADIGM AS A GOVERNANCE CHALLENGE

The enormous destruction of all critical infrastructures, including a long-lasting blackout, and over 150 deaths which were caused by the extreme weather conditions associated with the floods in Central Europe in July 2021 and the subsequent slow recovery, have shown that the protection and resilience of critical infrastructures in cities

must be given high priority. The failure of one or several critical infrastructures causes serious problems spilling over from technical systems to socioeconomic systems (Boin & McConnell, 2007b, p. 50) as was witnessed in 2021. In this way, critical infrastructures "serve as preconditions for societal prosperity, progress and well-being" (BMI, 2009, p. 3).

Critical infrastructure resilience, in contrast to the concept of critical infrastructure protection, does not only focus on preventing risks or mitigating impacts of threats (which would be subsumed

under the notion of crisis-management),[1] but rather focuses on the capacity to maintain critical infrastructures' functions and services when stress occurs (Labaka et al., 2016, p. 22; Pursiainen, 2018, p. 634). Thus, it is the physical infrastructure itself that should be made more resilient. However, critical infrastructure resilience is not an end in itself, but also naturally serves to increase the resilience of a community. Measures to increase resilience are expected primarily at the local level, as in Germany, and many other countries, executive and political responsibility for the provision of civil security is mainly delegated to local and regional governments (Bossong & Hegemann, 2013, p. 361). This includes the physical critical infrastructure but in consequence also the local community as such (Monstadt & Schmidt, 2019; Therrien & Normandin, 2020).

To be resilient, critical infrastructures have to be equipped with the following properties: robustness, redundancy, resourcefulness, and rapidity (Bruneau et al., 2003, pp. 737–738; Coaffee & Clarke, 2017, pp. 369–370). Robustness is defined as the capacity of a system to resist a given level of stress without any interference in terms of provision. Redundancy refers to the capacity of a system to sustain provision by substitution. Resourcefulness is defined as "the capacity to identify problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other units of analysis" (Bruneau et al., 2003, pp. 737–738). Rapidity refers to the time needed for achieving priorities and goals to absorb damages and malfunction. These properties refer to both physical and social dimensions of critical infrastructure resilience (Bruneau et al., 2003, pp. 737–738; Coaffee & Clarke, 2017, pp. 369–370). Therefore, critical infrastructure resilience is both a technological and a governance challenge. This paper focuses on the latter. The main challenge for governance lies in the fact that a multitude of different actors is addressed in critical infrastructure protection. The range includes public authorities and organizations with security tasks—especially the local crisis management authority—, private actors as operators of critical infrastructures, as well as other administrative public actors. The multitude of actors involved poses coordination problems (Peters, 2018), as the disaster of July 2021 dramatically demonstrated. Thus, this paper aims to gain knowledge as to how the governance of critical infrastructure resilience functions at the local level. Accordingly, we ask the question of how the different actors involved in critical infrastructure governance are coordinated.

Governance processes, that is, the type of coordination involving independent actors to achieve critical infrastructure resilience, have barely been specified. They are mainly described as collaborative governance approaches without detailed specification (Boin & McConnell, 2007b, p. 55; Head & Alford, 2015, p. 722; Labaka et al., 2016, p. 24; Pursiainen, 2018, p. 635; Therrien & Normandin, 2020, p. 3). Since there is little research on the governance of critical infrastructure resilience at the local level, we do not pursue an explanatory approach here, but first want to explore the field empirically. Nevertheless, we show how the empirical data can be systemized by developing three types of coordination of critical infrastructure resilience governance (Section 2). Section 3 details the

method. In the following section, the results of a survey covering 68 German cities are presented to provide empirical evidence of the three types of coordination in critical infrastructure resilience governance (Section 4). Section 5 discusses the results and limitations of the study and provides an outlook on subsequent research perspectives.

2 | MODES OF GOVERNANCE FOR ENHANCING CRITICAL INFRASTRUCTURE RESILIENCE

Within the governance literature, Kooiman's definition is one of the common ways of describing the scope of the concept. He defines governance as "all those interactive arrangements in which public, as well as private, actors participate; aimed at solving societal problems, or creating societal opportunities; attending to the institutions within which these governance activities take place" (Kooiman, 2002, p. 73). This encompasses different forms of collective regulation of social issues "from institutionalized self-regulation by civil society, to various forms of cooperation between state and private actors, to sovereign action by state actors" (Mayntz, 2003, p. 72, transl. author). This view of governance led to an expansion of the old dichotomy of hierarchy and market, towards the introduction of the concept of networks (Thompson, 2003; Thorelli, 1986; Treib et al., 2007). Hierarchical governance is a top-down approach of "command and control," as exercised by governments through the coordination mechanisms of legislation and regulation. Market governance relies on competition between market actors using demand and supply interaction as a coordination mechanism. Businesses and companies are the dominant actors (Pahl-Wostl, 2019). Network governance was introduced as "horizontal forms of interaction between actors who have conflicting objectives, but who are sufficiently independent of each other so that neither can impose a solution on the other and yet are sufficiently interdependent so that both would lose if no solution were found" (Schmitter, 2002, p. 53). Rhodes argues that network-governance is characterized "by interdependence, and resource exchange" (Rhodes, 2001, p. 15). There are many authors, who either differentiate between the triad of governance modes or add other modes to this triad, such as community governance (Bednar & Henstra, 2018; Pierre & Peters, 2000; Tenbensel, 2005) so creating a horizontal mode of self-governance at the local level by mixing modes of governance with level-specific action. However, the nature of regulatory structures in which private and public actors interact is addressed in all these modes of governance.

When adapting previous research to modes of governance, we have to take into account the policy field and phenomenon we are addressing. In the face of liberalization and privatization, critical infrastructure systems have been separated into the functional tasks of production, operation, and service delivery. More importantly, these tasks have been transferred from public bureaucracy to private companies (Dunn-Cavelty & Suter, 2009, p. 180). In consequence, critical infrastructure resilience cannot be provided by public

authorities alone, but needs interdependent activities by independent actors who characterize different perceptions and pursue a range of interests and values (Boin & McConnell, 2007b, p. 55). In addition, regulation as a source of governmental power is limited in the area of critical infrastructure governance at the local level. Challenges to critical infrastructure resilience cannot be solved by traditional hierarchical forms of public administration but require alternative forms of governance (Therrien & Normandin, 2020, p. 3). Thus, hierarchical governance can only be expected to a very limited extent, mostly in providing prevention measures or top-down crisis responses (Boin & McConnell, 2007b, p. 54). Market governance is also not expected at the local level, due to the absence of a demand–supply relationship in critical infrastructure resilience governance. Market governance here refers to the operation of technological infrastructure only.

Network governance, on the contrary, seems to be appropriate in the case of critical infrastructure resilience. As explained above, critical infrastructures, functions, and services are provided by market actors on the one hand and by public authorities on the other. Both actor types are mutually dependent in terms of achieving critical infrastructure resilience. Critical infrastructure resilience can only be achieved by the coordination of these different actor types (Boin & McConnell, 2007a, p. 55; Head & Alford, 2015, p. 722; Therrien & Normandin, 2020, p. 3). Thus, network governance is needed to handle critical infrastructure resilience (Boin & McConnell, 2007b, p. 55; Labaka et al., 2016, p. 22).

For this analysis, the network governance mode must be conceptualized and differentiated further. A typology of three ideal types to sort coordination efforts in cities into discrete categories is required (Gerring, 2012). To do this, we combine three strands of literature on governance, participatory governance, and critical infrastructure resilience. The central aspect of our construction of different types of network governance is coordination (Behnke, 2018). We distinguish three types of coordination in network governance: (1) political leadership coordination, (2) mutual exchange coordination, and (3) positive coordination. To conceptualize these three types, we look at the following four indicators: "direction/main actor of coordination," "frequency/type of coordination," as well as "main aim of coordination," and "interaction mode."

The first indicator, the "direction/main cooperating actor," addresses the question of who takes up the initiative for coordination and serves as the main actor. This indicator can be developed from the governance literature and the discussion concerning the loss of importance of the state as a central actor (Kooiman, 2002, p. 74). If the main actor is one public actor who reaches out to the other public and private actors in a unidirectional way, then the network governance type is still close to hierarchy. Another possibility is that both public and private actors are involved but the coordination is still led by one public actor. This goes hand in hand with a bidirectional exchange within the coordination. If there is no main actor anymore and actors are jointly coordinating, this qualifies as "positive coordination." As coordination only by involving private actors as self-regulation is not part of the network mode of governance but the community mode (Bednar & Henstra, 2018; Pierre & Peters, 2000;

Tenbensel, 2005), it is not considered here. The second indicator, "frequency/type of coordination," addresses the way cooperation takes place with respect to the "frequency and type of coordination" by looking at temporary or institutionalized coordination (Bauer et al., 2014, p. 287). Coordination can either be in an ad hoc or an institutionalized manner (Estlund, 1997). Ad hoc coordination goes hand in hand with selective involvement of private actors by the main public actor, the aim of coordination being either to get information to the private actors or to consult private actors in the exchange of ideas and resources. It is reasonable to assume that ad hoc consultation takes place infrequently. Institutionalized coordination, however, refers to regular meetings based on free access for all arguments put forward and thus results in a discussion of all valid arguments put on the table from both public and private actors (Schmalz-Bruns, 2002, p. 279f). The next two indicators are closely linked. The third indicator, "main aim of coordination," is to mobilize and obtain information from private actors. According to the participation literature, this is the weakest form of involvement (Arnstein, 1969), which uses one-way communication where private actors only function as recipients of the information. In the next step, the public actor consults with the private sector and aims to exchange information and insights with the stakeholders. In the highest step of Arnstein's participation ladder, public and private actors aim for joint problem solving (Arnstein, 1969). Thus, the fourth indicator "interaction mode" only gives information to the private sector in the most basic interaction mode. In a more participatory form of involvement, private actors are involved as providers of information and other resources. Thus, there is an exchange between public and private actors by consultation. The strongest involvement of private actors in the deliberation mode conceptualizes both actor groups as being equal partners who define problems and ways to solve them, culminating in joint planning processes (Table 1).

2.1 | Political leadership coordination

The critical infrastructure literature assumes that a crisis is characterized by social chaos which can only be tackled by imposing a strategy and enforcing compliance (Dynes, 1990; Head & Alford, 2015, p. 729), and thus, the state has the leading role. To enhance critical infrastructure resilience, leadership, as a type of coordination, needs to be executed before a crisis occurs, that is, in the phase of prevention/preparedness (Boin & McConnell, 2007b, p. 55). Within the political leadership coordination type, the public actor who leads with respect to critical infrastructure resilience takes unidirectional action towards both private and other public actors. Especially private actors, such as operators, should be mobilized to take part in critical infrastructure resilience policies. Coordination meetings with private actors are scheduled on an ad hoc basis, whenever the coordinating public actor sees the need. The main coordination mode is the passing of information from the coordinating public actor to private actors and may also include requesting necessary information from the private actors.

TABLE 1 Types of coordination in network governance

	Political leadership coordination	Mutual exchange coordination	Positive coordination
Direction coordination	Unidirectional from public to private actors/public actor as the main actor	Bidirectional/public actor as main actor	Joint coordination equal participation (public + private actors)
Frequency/type of coordination	Ad hoc, as needed by public actor	Ad hoc as needed by public and private actors	Institutionalized, on a regular base
The main aim of coordination	Mobilize private actors, give information to private actors	Exchange information and insights	Joint problem identification and solving/ joint planning
Interaction mode	Information	Consultation	Deliberation

Source: Own data.

2.2 | Mutual exchange coordination

Mutual exchange coordination goes beyond political leadership co-ordination. Here, the private actors play a more active role. It is a bidirectional exchange mode of public and private actors which, nevertheless, is still dominated by the public actor. The public actor still decides which private actors are asked to exchange views on the governance. The selection is based on the perceived usefulness of private actors for the effectiveness of policymaking. Usefulness is primarily based on pragmatic criteria, such as the expansion of the knowledge base through civil society expertise for more effective decision-making in the system. The inclusion of private actors' expertise, information, or other resources is done according to the need of the crisis manager and based on the discretion of the political actors solving the problem. Therefore, the interaction mode is one of consultation. Access to the consultation is granted only ad hoc and selectively by the responsible political actor.

2.3 | Positive coordination

Originally developed in the context of interministerial coordination, coordination of interdependencies between actors can occur as two ideal types "negative" and "positive coordination" (Scharpf, 2000). Negative coordination can be performed by unilateral behavior or bargaining, similar to that conceptualized above in political leader-ship coordination. Positive coordination is based on deliberation as an interaction mode (Scharpf, 2000, p. 229). Deliberation of principles and targets of crisis response is a governance challenge since both the definition of crisis, as well as principles and priorities of response activities, are political decisions (Boin & 't Hart, 2007, p. 49). In this way, we can conceptualize positive coordination as being a joint action of different public and private actors. Delib-eration refers to collective opinion-formation. According to the deliberative ideal, actors develop their preferences through demo-cratic talks that are characterized by reasoning and mutual justifi-cation (Jäske, 2019, p. 604). It is argued that these kinds of democratic talks produce meta consensus, as well as inter-subjective rationality (Niemeyer & Dryzek, 2007, p. 500). To allow for consensus-orientation and deliberation, coordination efforts are necessary on a regular basis to enhance trust and mutual commit-ment among the actors (Head & Alford, 2015, pp. 727–728).

In the following section, we will explore empirically to what extent the three types of network governance coordination identified have been implemented to increase critical infrastructure resilience within urban contexts in Germany. This is done by considering the scenario of a long-lasting, supraregional power failure.

3 | METHODOLOGY

3.1 | Case selection and scenario

To explore the types of coordination in critical infrastructure resilience governance found locally in Germany, a survey was conducted among major district-free German cities.[2] First, we restricted the survey to German cities to keep the polity dimension constant. Second, we ad-dressed only major cities (defined by a population of at least 100,000 inhabitants)[3] to ensure a certain amount of interconnected and inter-dependent critical infrastructure networks. In addition, German cities are endowed with duties and competencies according to the disaster control laws of the federal states (*Landeskatastrophenschutzgesetze*) and function as lower-tier disaster control authorities (*Untere Katastrophensch utzbehörde*) (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2019, p. 30). To fulfill these duties, major cities command a professional fire brigade which serves as a local crisis management authority. This allowed us to identify the respective person responsible for crisis man-agement within the local crisis management authorities of the city in a comparable way. As knowledge of the subject within the German city authorities is very centralized, one person from the lower-tier disaster control authority answered the questionnaire for each city. Thus, as dis-cussed later, we have to take into consideration, that the data reflects the perception of these individual public actors (see Section 5). The ques-tionnaire used was a standardized web-based (anonymized) questionnaire sent out to 68 cities, with a response rate of 72% (*n* = 49).[4] For com-parability reasons, the disaster scenario was predefined as a long-lasting, supraregional power failure, lasting at least 24 h and having a far-reaching spatial extent so resulting in far-reaching cascading failures across all sectors of critical infrastructure. The scenario also ensured the involve-ment of both all critical technical infrastructure sectors (i.e., electricity; gas

and oil; telecommunication/IT; transport/traffic; and water supply and sanitation) as well as various groups of actors, including all public and private actors mentioned above (Petermann et al., 2013).[5]

3.2 | Operationalization and data collection

Our framework indicates that to facilitate critical infrastructure resilience, interdependencies in crises response need to be coordinated between public actors, especially the local crisis management agencies, and other public actors as well as private actors to operationalize the three distinguished types of coordination, we defined measures to coordinate the actors taken by the cities by both working with the relevant literature (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe and Innenministerium Baden-Württemberg, 2010; Hessian Ministry of the Interior and for Sport, n.d.; Ministerium für Inneres und Bundesangelegenheitendes Landes Schleswig-Holstein, 2014), and further specifying and supplementing them through interviews with practitioners.[6] First, we grouped the measures according to the types of coordination developed to be able to make statements about the type of coordination actually used.

Through grouping, the measures used by cities, a rough distinction between three groups of actors became evident: (1) private actors consisting of utility companies for critical infrastructure; (2) public actors which are authorities and organizations with security tasks (later in the figures referred to as "public actors"); and (3) other public actors from the administration, as there are departments of the city administration which do not deal with security issues but might be concerned with issues relevant in crisis situations (later referred in the figures as "other admin"). These groups are addressed separately by the measures within the types of coordination as shown in the Figures 1–4 (see below).

There are three kinds of *measures* which are assigned to the *type of political leadership coordination* and so highlights the information-based character of this type: First, measures that raise the awareness of public and private actors concerning the risk of a long-lasting power failure, based on information from the leading public actor (Regierungspräsidium Karlsruhe, 2014, p. 21); second, measures that focus on the information about appointing a contact person in case of emergency to report to the crisis management team; and third, measures on the information that involves the dispatching of a representative to the administrative crisis team in the case of a long-lasting power failure (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe and Innenministerium Baden-Württemberg, 2010, p. 14; Haritz, 2016, p. 265; Lauwe, 2018, p. 4; Ministerium für Inneres und Bundesangelegenheitendes Landes Schleswig-Holstein, 2014, p. 69; Prior & Roth, 2016, p. 15).

Within the *second type "mutual exchange of coordination,"* we look at measures that focus on communication in the sense of mutual exchange of information. Therefore, the respondents were asked if the precautions for communication are taken to know if they have exchanged information about the precautionary measures of both the utility companies and the public against a power failure, including the logic of action of the private operators (e.g., duration of internal processes) (Schmidt & Scharf, 2017,

p. 39). In addition, we asked if the services of private actors have been already assessed, thus, whether private actors have shown the lower-tier disaster control authorities that the impact of a long-lasting power outage on the service provision had been estimated. These measures also include technical prerequisites which could be used to set up a communication system for exchange including the utility company, public authorities, and other parts of the administration even in the absence of communication devices that fail rapidly in a catastrophic event (i.e., communication via landline, mobile phone, or email). We asked whether technical conditions are provided on each side. Other questions focused on measures for mutual exchange concerning joint exercises in scenarios of a power failure, including private and public actors (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe and Innenministerium Baden-Württemberg, 2010, p. 26; Hofinger et al., 2013, p. 229f.) to exchange insights about lessons learned. This includes the outcome of these measures which may result in an exchange with the other parts of the city administration about the extent to which they have prepared for a power outage or are considering the possibility of a power outage in their work (John-Koch, 2014, p. 3f.).

Concerning the type of positive coordination, we asked about measures focused on institutionalized and regular collective meetings and exchanges (e.g., "round tables") to jointly define problems and solutions of critical infrastructure resilience. This set of questions additionally asked if these meetings had resulted in the setup of a joint or common plan of how to deal with the consequences of a power outage (John-Koch, 2014; Lauwe, 2018, p. 3f.; DIN SPEC 91390:2019-12) and whether municipal city departments had been involved by sharing information and feedback (John-Koch, 2014, p. 3f.).

In the following analysis, we will show measures used by the local crisis management authorities to coordinate public and private actors in critical infrastructure resilience within these three different types. As we do not have an explanatory design, there is no hypothesis. However, we assume that all types are applied but most cities coordinate rather in political leadership than in a positive coordination type.

4 | CRITICAL INFRASTRUCTURE RESILIENCE GOVERNANCE WITHIN URBAN CONTEXTS IN GERMANY

Within the network governance type "political leadership coordination," nearly all local crisis management authorities in German cities ask both public and private actors for information about a contact person and a representative in the crisis team in case of a crisis. To a lesser extent, there are measures applied to raise awareness about crisis scenarios and the risks of a long-lasting power failure in all actor groups. All in all, the general level of the values is very high, which is not surprising, as the political leadership coordination contains measures where local crisis management authorities can act single-handedly to inform actors and collect relevant data without interacting with the others to any great extent.

The data of the network governance type "mutual exchange coordination" shows that overall the local crisis management authorities use

these measures to a lesser extent than the first type of coordination. However, it is obvious that private actors have exchanged information and knowledge with the local crisis management authorities. In nearly 80% of the cases, local crisis management authorities are able to estimate the impact of a long-lasting power outage on service provision due to the exchange of knowledge with the private actors (see Figure 2 "impact assessment of service"). Also, the public (55%) and private actors (70%) have provided information about precautionary measures against a power failure. In the case of rapidly failing communication via landline, mobile phone, or email in times of crisis, we see quite huge differences between public and private actors. While, among public actors, technical solutions are given to communicate with other actors and the local crisis management authorities through coordination this is only the case for private actors in 45% and other administrative actors in 30% of respondents. The exchange coordination in this area has not functioned in a satisfactory way to date. In particular, the coordination between the local crisis management authority and the city administration is still treated comparatively poorly. This may indicate that here disaster management is still rarely perceived as a cross-cutting administrative task, while the coordination with private actors seems to be progressing. In more cases, 55%, the information was obtained from parts of the city administration (which do not have security tasks) about the extent to which they are

considering the possibility of a power outage in their work and have prepared for it. Nevertheless, the local crisis management authorities have not yet gained much insight into private actors' logic of action when it comes to internal processes, for example, the duration of such processes. As joint exercises only take place very infrequently and on an irregular basis, it is not surprising, that participating in joint exercises (for public and private actors) is not a measure taken up in many cities (only around 45%).

Regarding the "positive coordination" type, it is obvious that a very low level of implementation can be seen. It seems that local crisis management authorities met on a regular basis mostly with private actors (35%) compared to public actors with security tasks (30%). However, we can see an even weaker engagement with actors from other administrative units (20%). The rate in the latter case decreases even further when we look at collective meetings (13%). This form of institutionalized, multilateral exchange at round tables is highest in the case of public actors (35%) and lower in the case of private actors (25%). This low implementation of the governance type of positive coordination is remarkable and yet not entirely surprising. Multilateral exchange formats on this scale are not well-established in disaster management. The implementation of such measures is also personnel- and time-intensive, which leads to high transaction costs.
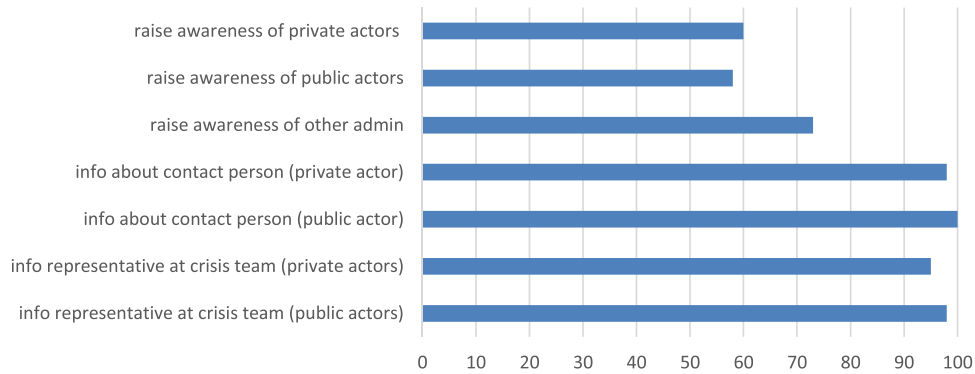

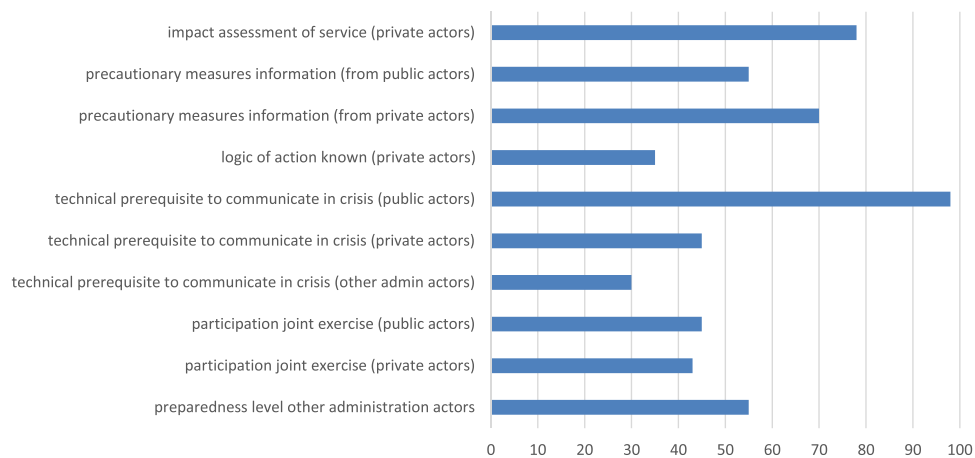**FIGURE 1** Measures network governance type "political leadership coordination" (in %). *Source*: Own data

FIGURE 2 Measures network governance type "mutual exchange coordination" (in %). *Source*: Own data
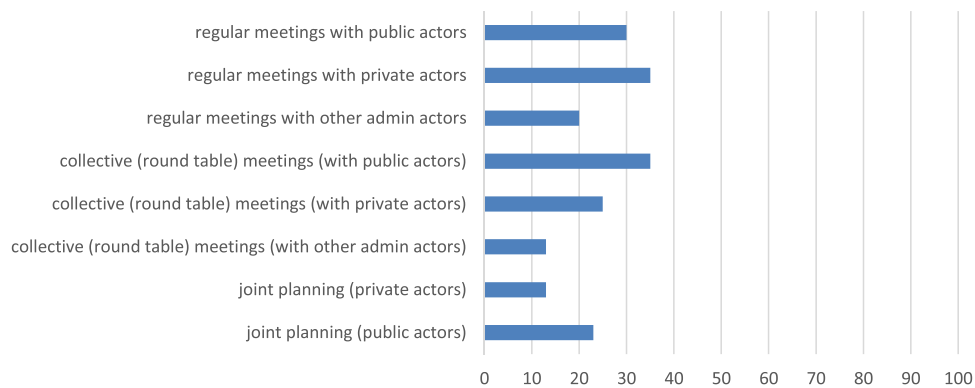
FIGURE 3 Measures network governance type "positive coordination" (in %). *Source*: Own data
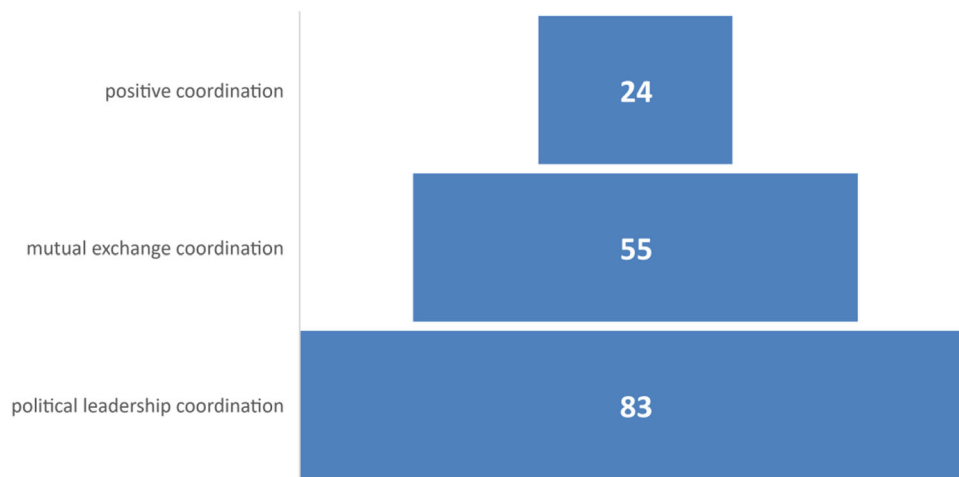

FIGURE 4 Comparison types of coordination (in %). *Source*: Own data

The same holds for joint planning processes which are only reported as measures in a few cases. If at all, planning includes public actors and only also involves private actors in 13% of the cities.

The first impression, that most measures chosen by local crisis management authorities can be assigned to the coordination type of political leadership and the least part of the measures to positive coordination, can be validated if we aggregate the data within the diverse types. Figure 4 demonstrates the notable differences found. Thus, deliberative processes which lead to joint planning and collective coordination are still rare.

5 | CONCLUSION: TYPES OF NETWORK GOVERNANCE COORDINATION IN CRITICAL INFRASTRUCTURE RESILIENCE—STILL A LONG WAY TO POSITIVE COORDINATION

This contribution aimed to gain knowledge of how the governance of critical infrastructure resilience takes place at the local level. We asked how the different actors involved in critical infrastructure

governance are coordinated. To answer this question, we defined a conceptualization of three types of network governance coordination—"political leadership coordination," "mutual exchange coordination," and "positive coordination." This allowed the rough category of network governance to be more finely differentiated to more effectively illuminate resilient critical infrastructure governance. We answered the empirical question by gathering data by means of a survey among major German cities. Local crisis management authorities, as the legally responsible actor, were asked to give information about the scheduled measures in the case of a long-lasting, suprarregional power outage.

The empirical results show that political leadership coordination is the dominant type of network governance in critical infrastructure crisis management. Thus, the traditional path of informative measures combined with appointing contact persons and crisis team representatives is still preferred. In addition, around half of the local crisis management authorities have already chosen measures of mutual exchange coordination, such as mutually exchanging information about precautionary measures and technical options of communication devices in times of crisis. However, here we can also see that any further developed measures, such as the participation in

joint exercises in crisis scenarios, are implemented to a lesser extent. Most of the measures of positive coordination, such as regular and collective meetings, are taken up by only around one-quarter of German cities, which is quite a low rate. When more collective and joint measures are taken, we see more development in the co-ordination of public actors with security tasks than with private actors, whereas measures concerning other administrative public actors are rarely performed. The latter indicates that critical infrastructure resilience is still not seen as a real cross-sectional task. Thus, our research clearly shows that most German cities are not properly prepared for critical infrastructure crises. This outcome could help to explain the poor crisis management in the 2021 floods.

However, our study must cope with biases concerning its conceptional framework and methodology. First, the survey was conducted by addressing local crisis management authorities of major German cities. The questionnaire was, thus, filled out by the person responsible for crisis management of critical infrastructures. The approach is plausible because the local crisis management authorities play a crucial and leading role in critical infrastructure crisis management and without their initiative, no coordination is taken in major German cities. Thus, they must be seen as the spider in the net, making their perception invaluable for our study. Nevertheless, their view has to be counterbalanced with the perceptions of the other actor groups. Second, this paper only addressed coordination with institutionalized stakeholders. The July 2021 flood crisis showed again that the self-organization of citizens plays an important role in critical infrastructure resilience. The population, as a key actor in disasters, is not considered to be a coordinating partner of local crisis management authorities. Thus, in a further step, the community governance mode mentioned in the beginning will be included and its interaction with the positive coordination examined. Third, all measures were evaluated in a dichotomous way which excludes degrees of reach, consistency, and impact. The financial basis, the scope of the measures, or the consistency with which the measures are planned and implemented, thus remain in the dark. This disadvantage was compensated for by carrying out individual case studies which were not included in this contribution.

Despite this caveat, this analysis contributes to the systematization of types of coordination in critical infrastructure management in a crisis. We were able to make the different usage of the three types in German cities visible. This diversity is an expression of Germany's federal system with its far-reaching possibilities for local crisis management to set its own priorities. Nevertheless, the range here remains surprising. The next step in the research will be to answer the following questions. Firstly, how can these differences in the usage of the three types be explained? Over and above the usual factors, such as resources, staff, and so forth, experiences in disasters could be examined. Second, what could the contribution of the three types or rather the hybrid use (Pahl-Wostl, 2019) of the types be to resilience amount to? The literature on critical infrastructure resilience, as well as the participation literature, suggests that more collective and joint efforts of coordination will have a positive effect on resilience. It seems that leadership and exchange coordination are important for enhancing critical infrastructure resilience. However, they reach their limits when unexpected situations arise. To be resilient to irregular events, we would assume that positive coordination must be implemented to allow for the maintenance of critical infrastructure services by collaboration. This implies that all three types are needed to gain resilience in an additive manner.

DATA AVAILABILITY STATEMENT

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ENDNOTES
[1] Basically, crisis management can be defined as "the processes by which an organization deals with a crisis before, during and after it has occurred" (Christensen et al., 2016, p. 888) while the concept of resilience describes "the capacity to bounce back" or the tolerance of a system with regard to disturbances (cf., Zolli and Healy 2012). Thus, critical infrastructure resilience has to be considered as a complement and further development of traditional crisis management, as presented by Boin and McConell (2007a). Both concepts are not mutually exclusive but emphasize different goals.

[2] The data collection was carried out in May 2018 as part of the XXX funded by XXX. Research data are not shared.

[3] City-states have been excluded because of their dual function as the lowest and highest regional level of civil protection.

[4] The questionnaire was pretested in five cities with less than 100,000 inhabitants.

[5] Respondents data was only included in the analysis when these criteria were met, which is the case for 82% of respondents (N = 40).

[6] Interviews with members of local crisis management teams, employees of the Federal Office of Civil Protection and Disaster Assistance, and the Hessian Ministry of the Interior and Sport, April 2018.

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