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Urban Flood Resilience Networks: Exploring the Relationship between Governance Networks, Networks of Plans, and Spatial Flood Resilience Policies in Four Coastal Cities

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Coastal cities facing growing flood risks are increasingly focused on resilience. Academic and policy discourse present a resilience-based approach to governing hazards as more collaborative, better connecting threats, systems, and actors. Literature on governance networks, collaborative governance, and networks of plans suggests collaboration enhances resilience, but empirical studies of the relationship between governance networks, networks of plans, and resilience policies are limited. This study addresses this gap by examining collaboration patterns and plans in the context of flood resilience in four U.S. cities (Fort Lauderdale, Baltimore, Boston, and Seattle). We use surveys and social network analysis to assess collaboration within the cities' flood governance networks. We analyze cities' networks of plans using three approaches: (1) plan quality evaluation, (2) plan cross-referencing, and (3) the spatial distribution and flood resilience impact of policies. We find that higher quality plans and those that integrate flood information are more likely to have policies reducing flood risk. Plans that are more connected to other plans also have higher plan quality scores and more flood information. At the city level, the relationship between collaboration across the governance networks and networks of plans appears more complex and requires additional research. *Key Words:* collaboration, flooding, governance networks, network of plans, urban resilience.

Flooding is one of the costliest natural hazards. Global flood exposure and U.S. flood damages have been increasing over time, and coastal flooding is expected to worsen in the future due to coastal development, more intense precipitation, and sea-level rise (Davenport, Burke, and Diffenbaugh 2021; Tellman et al. 2021). A rich and long-standing literature in geography demonstrates that social and biophysical factors combine to shape vulnerability to hazards, including flooding (White 1945; Blaikie et al. 1994; Cutter 1996). Moreover, a complex network of actors make interdependent decisions that shape a city's flood risk, from individuals' choices about where to live to what protective infrastructure governments choose to build (Chang et al. 2021; Lubell and Robbins 2022; Rufat and Howe 2023). In the face of

growing flood threats, many of these actors are increasingly focused on planning for resilience (Grove, Cox, and Barnett 2020). Although academics still debate the meaning of a resilience-based approach to planning, it generally recognizes the complex and interconnected nature of different systems and challenges and addresses them in a coordinated way (Muñoz-Erickson et al. 2021; Woodruff, Meerow, Stults, et al. 2022). The common implication, albeit rarely empirically tested, is that a focus on resilience enhances collaboration across governance networks, which, in turn, leads to a more cohesive network of plans and policies that reduce flood risk. This article examines these claims by combining different types of network data from four U.S. cities.

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Collaborative Governance Networks and Resilience

Governance networks refer to the actors (e.g., government officials, nongovernmental organizations, private companies) that are involved in managing a particular issue (i.e., flooding) within a defined area (Hileman and Lubell 2018). Scholars have long argued that the composition and structure of these networks shape policy outcomes (Bressers and O'Toole 1998).

Multiple literatures suggest that governance networks composed of more diverse actors lead to better, presumably more resilient, outcomes. In both the social-ecological resilience and urban climate change governance literature, this is reflected in the normative emphasis on polycentric and multilevel governance (Lebel et al. 2006; Betsill and Bulkeley 2007; Biggs et al. 2012). Climate change adaptation planning research suggests that plans developed by multiagency committees are of higher quality (Woodruff and Regan 2018), and a review of the literature on public participation in adaptation planning found consensus that more participation would be beneficial (Hügel and Davies 2020). Environmental justice scholarship also commonly emphasizes the importance of broadening and deepening participation in decision-making, often termed procedural justice (Agyeman et al. 2016).

The relationships between diverse actors are also critical, and more collaboration in particular is often linked to enhanced resilience (Moser et al. 2019; Hannibal et al. 2022) and more effective management of environmental challenges (Bodin 2017). Both the urban planning and resilience literature commonly claim that diverse and interdisciplinary collaboration in urban governance improves outcomes (Djalante, Holley, and Thomalla 2011; Dempwolf and Lyles 2012; Ziervogel et al. 2016). In the context of environmental planning, collaborative planning is thought to be more efficient, effective, and likely to “lead to evidence-based solutions that meet stakeholder values” (Berke 2008, 403). Studies of collaborative governance commonly report benefits such as enhanced social capital, trust, and learning (Folke et al. 2005; Tompkins, Lemos, and Boyd 2008), but few studies attempt to evaluate plan or policy outcomes. On the other hand, research suggests that more collaboration is not always better (Bodin 2017).

Enhancing resilience to flooding is not just a collective action problem (D. J. Yu et al. 2017), but a cooperation problem, where actors have conflicting interests and goals and must navigate various types of interdependencies (Lubell and Robbins 2022). Generally, dense collaborative networks have been shown to be more effective for high-risk cooperation problems (Bodin 2017; Bodin, Mancilla García, and Robins 2020). For flooding specifically, more collaboration across governance networks should theoretically bridge knowledge gaps between sectors and systems and allow sharing of scientific and experiential knowledge, leading to better planning and ultimately enhanced resilience (Rijke et al. 2013; Becker 2021). This emphasis on collaboration is mirrored in policy discourse. Arguably the highest profile urban resilience initiative to date, the Rockefeller Foundation's 100 Resilient Cities program, explicitly aimed to break down traditional silos and encourage collaboration among city departments (Webber, Leitner, and Sheppard 2021; Naef 2022).

Research also suggests that the resilience agenda could increase collaboration by acting as a “boundary object” that brings different actors and interests into governance networks that would otherwise have remained isolated (Brand and Jax 2007). Several recent empirical studies, mostly case studies of one or a few cities, do anecdotally link urban resilience efforts with increased collaboration (Spaans and Waterhout 2017; Fastenrath, Coenen, and Davidson 2019; Fastiggi, Meerow, and Miller 2021), but more research is needed to determine causation and generalizability.

Social network analysis (SNA) is commonly used in research to evaluate the structure of governance networks and collaboration (Bodin and Prell 2011; Sayles and Baggio 2017; Greer, Hannibal, and Portney 2020), but it has rarely been applied to analyze urban resilience or flood governance networks (Therrien, Jutras, and Usher 2019; Bixler et al. 2020; Becker 2021; Hannibal, Woodruff, and Malecha 2021). Analyzing the network of organizations working together on a particular issue or place can provide insight into how much collaboration occurs, how relationships are structured, and who is or is not participating (Klijn and Koppenjan 2012). Research applying SNA to governance networks suggests that network structures and their institutional fit with the complex social-ecological problems they tackle are important for policy outcomes (Ekstrom

and Young 2009; Rathwell and Peterson 2012; Sayles and Baggio 2017). Achieving this institutional fit is difficult for issues that span sectors (Bergsten et al. 2019), which managing hazards—like flooding—does (Bodin and Nohrstedt 2016).

There might be inherent trade-offs in network structures. A single coordinating actor might be very efficient, but the network is vulnerable to defection (Berardo and Scholz 2010; Bergsten et al. 2019). Larger, “boundary-spanning” governance networks might increase collaboration, but there tends to be greater consensus and realization of goals in “smaller, denser” networks (Dempwolf and Lyles 2012, 8). Given these complexities, the relationships between governance network structures and planning and policy outcomes remain unclear (Bodin 2017).

Networks of Plans and Resilience

When assessing planning and its likely impact on resilience within a particular place, scholars argue that we need to consider the “network of plans” (Berke et al. 2015). Different plans collectively shape the built environment, including community-wide comprehensive, hazard mitigation, transportation, climate action, parks and recreation, and small area plans. Recently, new approaches have been developed to evaluate them as a network (Woodruff, Meerow, Hannibal, et al. 2022).

The first approach, the Plan Integration for Resilience Scorecard™ (PIRS™), was developed by Berke et al. (2015) to assess the consistency, spatial distribution, and collective impact of networks of plans on flood hazards. PIRS™ analyzes the land-use policies in plans, scores them based on whether they would increase or reduce vulnerability to flooding, and maps them to applicable flood-prone neighborhoods. Policies from each plan are spatially “layered” to assess the overall effect on vulnerability. The methodology has been translated for practice (Malecha et al. 2019), applied in a growing number of studies and contexts (S. Yu, Malecha, and Berke 2021), endorsed by the American Planning Association, and adapted to heat hazards (Keith et al. 2022).

Plans often do more than just list specific policies, which are the focus of PIRS™. Plans could “signal” visions and goals, disseminate information, and bring actors together (Hopkins and Knaap 2018). Consequently, Woodruff, Meerow, Hannibal, et al.

(2022) proposed three additional approaches to evaluate networks of plans that complement PIRS, including comparing the quality of the plans within the network and using SNA to assess how plans cross-reference each other. No study to date has examined how these different elements of networks of plans are related. For example, are plans that meet more of the normative plan quality criteria, such as including information on flood risk, more likely to contain policies that mitigate risks?

Although empirical research on networks of plans is nascent, existing studies suggest that plans are often not well-connected and even contradictory (Berke et al. 2019; Bacău, Grădinaru, and Hersperger 2020). For example, hazard mitigation and climate change plans both aim to mitigate flood risks but are rarely integrated (Matos et al. 2023). Some studies suggest that inconsistencies are due to a lack of coordination between the organizations that develop various plans, but this has not been examined empirically (S. Yu, Malecha, and Berke 2021).

In short, a significant body of literature from different fields on the attributes of governance networks suggests that more collaboration leads to better planning and resilience outcomes, and there is a growing literature on how networks of plans shape resilience. Empirical studies of the relationship between governance networks and networks of plans are lacking (Hannibal, Woodruff, and Malecha 2021).

This study addresses this gap, combining data on flood resilience governance networks and multiple methods of analyzing networks of plans in four coastal U.S. cities. We begin with the individual plan level. Here we hypothesize that higher quality plans, with more flood resilience-related goals and information and stronger participation and implementation components, will better address flood risk, as determined by the PIRS™ (Hypothesis 1 [H1]; Figure 1). We also expect that better integrated plans, or those more directly connected to others in the cross-referencing network, will more effectively address flooding, thereby evaluated as being higher quality plans with higher PIRS™ scores (H2).

We also explore the relationship at the city level, although the sample size is small. We hypothesize that cities with more collaborative governance networks will have higher quality plans (H3) and more policies that reduce flood risk, as assessed by PIRS™ (H4).

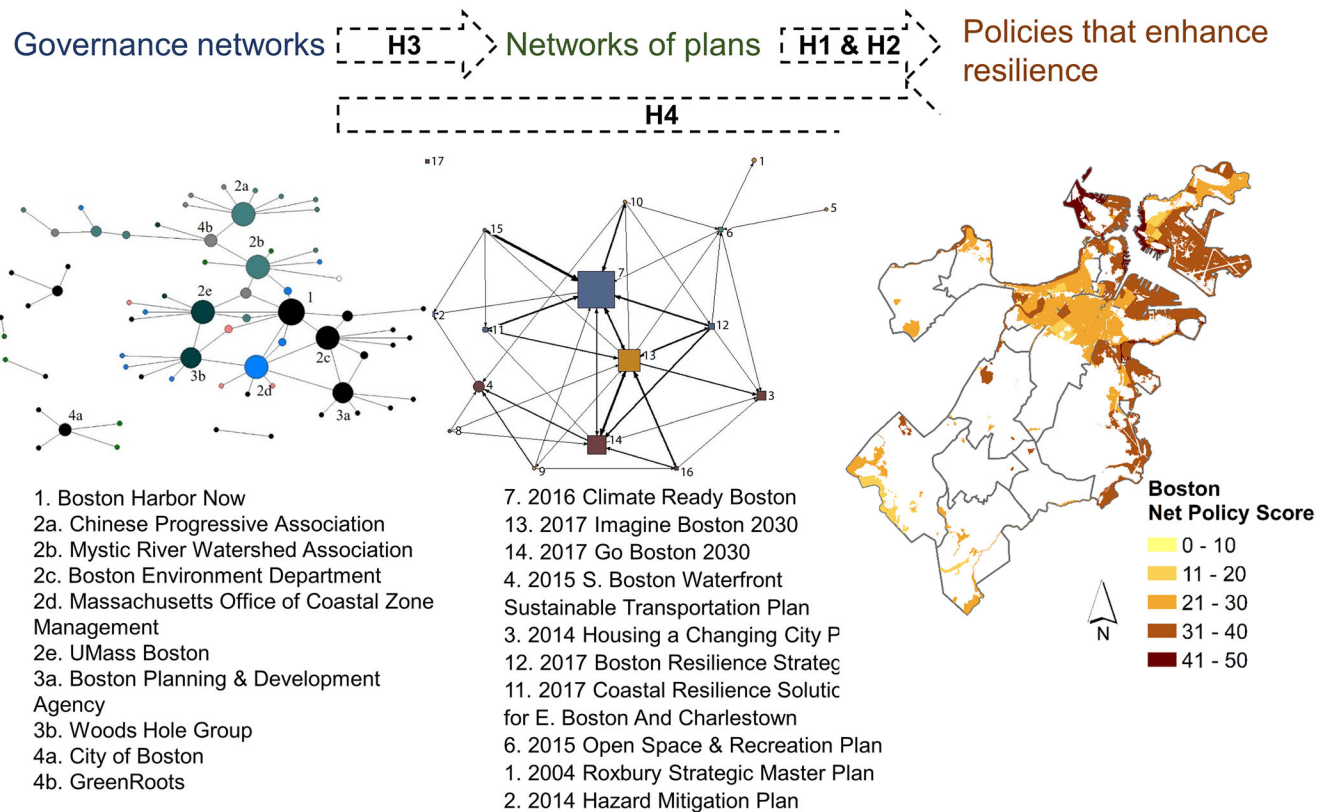


Figure 1. Conceptual framework of the study including the four hypotheses (H1, H2, H3, & H4) and different types of networks, illustrated using data from Boston. The governance network on the left shows the organizations who collaborate at least weekly on flood resilience, with the top 10 organizations by indegree listed, the middle network of plans shows the cross-referencing network, with the top 10 plans in terms of indegree listed, and the map on the right depicts the PIRSTM net policy scores.

Methodology

We use a multiple case study approach, combining quantitative analysis and SNA of survey data from actors involved in flood resilience governance, content analysis of plans, and spatial analysis of plan policies in four coastal U.S. cities: Boston, Massachusetts; Seattle, Washington; Baltimore, Maryland; and Fort Lauderdale, Florida.

Case Study Cities

These four geographically diverse coastal cities are recognized leaders in hazard and climate change planning (Figure A.1, [Supplemental Material](#)). Boston, Seattle, and Fort Lauderdale had resilience plans and chief resilience officers. We include Baltimore as a control because the city is widely praised for integrated hazard planning, but not explicitly focused on resilience. These four cities are therefore “influential cases” for flood planning, but “diverse cases” for other criteria including level of resilience policy support, population, and geography (Seawright and Gerring 2008).

Data Sources

Assessing Collaborative Governance Networks. In each city, we conducted a survey on flood resilience planning between May 2019 and January 2020. The survey asked respondents to “list the specific organizations, departments, or agencies that you have collaborated with in the context of flood resilience during the past year” and to identify the frequency of collaboration (weekly, monthly, or annually). We first surveyed senior members of all city departments and organizations listed as a participant or implementation partner in two or more of the plans we analyzed. We then used a snowball sampling approach to survey any additional organizations listed as collaboration partners by survey respondents. The methodology is detailed in the [Supplemental Material](#).

We created an adjacency matrix from the survey responses to capture the frequency of collaboration among organizations. We focus here on two network-wide cohesion metrics commonly used in SNA literature, calculated using UCINET version 6 software (Borgatti, Martin, and Freeman 2002): average

degree and fragmentation for the weekly collaboration network. Average degree is the mean number of connections each organization within the network has with other organizations. Networks with a higher average degree are more interconnected. We also calculated the average degree for the network of city departments or bureaus to examine how these organizations collaborated, given the emphasis on this in practical resilience discourse. Fragmentation measures the share of organization pairs that are not connected; thus, a lower fragmentation score indicates greater network cohesion.

The survey also included questions about the city's flood resilience planning efforts, including, "In [city], how has collaboration around flooding changed as a result of resilience initiatives?" "How aligned (i.e., consistent, in agreement) do you think [city's] plans are with each other?" and "How do you think [city's] plans will affect vulnerability to flooding in the future?" We aggregated these responses and calculated mean values.

Assessing the Network of Plans. For each city, we collected all current plans affecting development in flood zones. We analyzed the content of twenty-eight plans for Baltimore and seventeen plans each for Boston, Fort Lauderdale, and Seattle in three ways: an assessment of plan quality, a network-based analysis of plan cross-referencing, and a PIRSTM spatial assessment of the policies in the plans that would affect flood resilience. Each method is described briefly here but detailed in the [Supplemental Material](#).

To analyze plan quality, we used established plan evaluation methodologies (Berke and Conroy 2000; Lyles and Stevens 2014; Stevens, Lyles, and Berke 2014). We developed a protocol that includes forty-three criteria across four common plan quality principles: goals (eight criteria), fact base (thirteen criteria), public participation (eight criteria), and implementation and monitoring (fourteen criteria). Plans were then coded for presence or absence of each criterion. Principle scores were calculated based on the percentage of criteria included in the plan. We averaged the principle scores to compute overall plan quality. We also focused on the fact base principle, which captures the extent to which plans include flood information such as floodplain maps, flood loss estimates, and vulnerable populations.

Consistent with methodological recommendations for content analysis, at least two researchers read and coded all plans. Researchers compared their

coding on a criterion-by-criterion basis to identify and reconcile disagreements. To ensure reliability, we calculated percentage agreement (average = 83 percent) and Krippendorff's alpha (average = 0.6).

To better understand how plans are coordinated, we tabulated cross-referencing between plans (Bacău, Grădinaru, and Hersperger 2020). For each plan, we recorded the number of times it referenced every other plan in the city and created an adjacency matrix. We then represented this information in a single network using UCINET and calculated the percentage of all plans within the network that were isolated from (did not cross-reference) other plans and the average number of times plans were cited (average indegree).

Assessing Resilience Policies with PIRSTM. To determine the implications of policies proposed in plans for long-term flood risk, we used the PIRSTM approach outlined by Malecha et al. (2019). First, we divided each city into district hazard zones. We used 2010 Census tracts as the basis of district hazard zones to facilitate comparisons across cities. Census tracts were then intersected with two hazard zones—the 100-year floodplain (FP) and projected sea-level rise for 2100 (SLR) (Sweet et al. 2017)—to create 114 district hazard zones in Baltimore, 170 in Boston, 92 in Fort Lauderdale, and 65 in Seattle.

Two researchers independently read each plan and collected policies that (1) contained a recognizable policy tool, (2) were spatially explicit, and (3) would affect physical vulnerability to flooding if implemented in a flood-prone area. We focused on policies that affect physical vulnerability to flooding by guiding where, how, and what development occurs in a city.

We then scored policies based on their potential effect on flood resilience. Policies that reduced physical vulnerability, such as preserving open space or building flood-protective infrastructure, received a score of +1. Policies that increased physical vulnerability or reduced resilience received a score of −1. We calculated the number of positive and negative policies, the net policy score (sum of positive and negative scores), total number of policies, and the percentage of positive policies (i.e., proportion that would potentially enhance flood resilience).

Each policy was then mapped to district hazard zones. We sum the scores for all the policies that apply to each district to get the net score. To ease comparisons, we also calculated the average net scores for district hazard zones.

Results

We find evidence that higher quality, more integrated networks of plans have greater potential to enhance resilience to flooding (as assessed through PIRSTM), but the relationship between collaboration and resilience planning appears more complex.

Plan-Level Analysis

We examined relationships at the level of individual plans using Pearson correlation coefficients. As hypothesized (H1), we find a significant positive correlation between plan quality and the PIRSTM metrics (Figure 2). This includes the overall plan quality (average principle score) and the fact base principle score, both of which are positively associated with the PIRSTM total number of policies, number of positive policies, net score, percentage of positive policies, as well as the average policy net score by district. This suggests higher quality plans and those that include flood information are more likely to have policies that enhance resilience to flooding and less likely to have policies that would potentially increase vulnerability. To our knowledge, this is the first time these two plan elements have been empirically linked, and this helps fill a gap in the literature with respect to validating established plan quality characteristics and plan quality evaluation broadly as a useful indicator of a plan's likelihood to contribute to resilience. Our finding that the fact base principle was also correlated with PIRSTM metrics demonstrates the benefit of mainstreaming climate risk information across all planning efforts. Mainstreaming is widely promoted in the context of climate change planning, but often not implemented in practice (Reckien et al. 2019).

We find partial support for H2 (Figure 2). Plans that are more connected within the network are higher quality overall and have a stronger flooding fact base. The relationship between a plan's connections to other plans and PIRSTM is less clear. We do not find any negative correlations, nor do we observe significant positive correlations. Plans with a greater share of positive policies and more total policies tend to cite (and be cited by) more plans. Net scores and average net scores by district are not significantly related to plan citations. In fact, plans that cite more plans and plans more frequently cited in other plans both seem to have significantly more

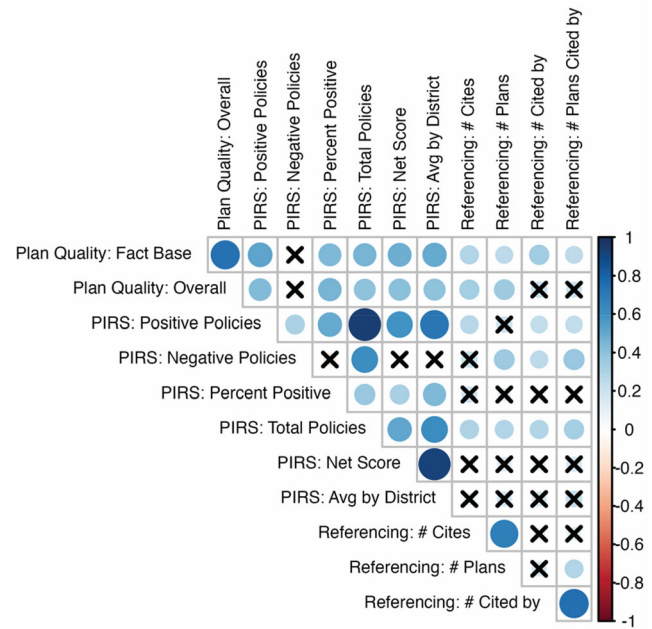


Figure 2. Pearson correlation matrix for plan quality, Plan Integration for Resilience Scorecard (PIRSTM), and cross-referencing metrics at the plan level across the four cities. Larger darker blue circles indicate a larger positive correlation; larger and darker red circles indicate a larger negative correlation. Xs indicate no significant relationship at $p < 0.05$. For definitions of the variables, see Table A.3 of the [Supplemental Material](#).

negative policies that would increase vulnerability. This could be because comprehensive plans that should be central in the plan network also often have more negative policies because they call for new development or infrastructure, some of which are in flood zones.

City-Level Results

The exploratory city-level analysis does not point to a clear relationship between the collaborative governance network and the network of plans (H3) or the governance network and resilience policies (H4; Table 1). Aggregate values for many indicators are similar across the cities, with large variation within cities, meaning differences between cities are small and potentially affected by low survey response rates. This makes it impossible to draw conclusions about the hypotheses. Observed similarities between cities are somewhat surprising given their different flood risk profiles, planning emphasis on resilience, and plan and governance network sizes (Supplemental Material). Although this city-level

analysis is exploratory rather than statistical, we nonetheless believe it provides a useful starting point for future research on the relationship between these different network types, which is clearly needed.

Keeping these data limitations in mind, the results do not suggest that more collaborative governance networks are associated with higher quality plan networks or policies that support resilience. Seattle appears to have a slightly more collaborative governance network (highest average degree), but Seattle does not have the highest overall plan quality or PIRSTM scores. In contrast, collaboration indicators across Fort Lauderdale's governance network are the lowest of the four cities (lowest average degree, highest fragmentation), but it has some of the highest PIRSTM metrics. Future research should explore whether more planning participants lead to more consistent plan networks and policies, or whether having more collaborating organizations makes it harder to focus on any one hazard or policy (Lyles et al. 2014). Interestingly, there does seem to be more alignment between survey respondents' relative perceptions about whether collaboration had increased in the city and our assessment of the quality of the network of plans. The survey question, however, asks whether collaboration increased irrespective of the baseline level of collaboration.

Survey respondents' perceptions of plan alignment in the cities appear generally consistent with our plan analyses. Survey perceptions of the plans' likely

impact on vulnerability to flooding are less consistent with relative PIRSTM results, but cities' PIRSTM results are also similar. This inconsistency could also result from question wording, which did not specify "physical" vulnerability, although this is the focus of PIRSTM.

Although the plan-level association between plan quality and PIRSTM metrics is positive, when we compare the city networks this becomes muddled. It is possible that some plans drive the network plan quality and PIRSTM scores. We find considerable variation within each city in terms of both plan quality and PIRSTM. In Boston, for example, overall plan quality ranged from 0.29 to 0.75. Future research should investigate these patterns. More detailed profiles of each city are available in the [Supplemental Material](#).

Although inconclusive, our city-level results would be consistent with recent literature suggesting that more collaboration is not a panacea for environmental challenges (Bodin 2017). All four cities' governance networks seem similarly loosely connected (average degree around 2), even though all cities encourage cross-departmental partnerships and collaboration in plans. It is possible that enhanced connectivity only translates into measurable benefits in planning at higher levels of collaboration, or it might come at an unacceptable cost of efficiency (Bergsten et al. 2019) or transparency and accountability (Bodin 2017). The fact that we do not find

Table 1. City-level comparison

Data source	Indicator	Fort Lauderdale	Boston	Baltimore	Seattle
Governance networks					
SNA survey	Average degree	1.67	2.12	1.92	2.33
SNA survey	Average degree of city organizations	2.39	3.46	2.55	3.50
SNA survey	Network fragmentation	0.85	0.39	0.54	0.55
Survey question	Collaboration increased: Proportion	0.63	0.71	0.31	0.25
Networks of plans					
Plan quality	Overall plan quality: M (SD)	0.42 (0.19)	0.51 (0.17)	0.38 (0.20)	0.47 (0.14)
Plan quality	Overall plan quality: Median	0.47	0.49	0.30	0.44
Plan quality	Fact base quality: M (SD)	0.24 (0.23)	0.41 (0.34)	0.15 (0.25)	0.19 (0.22)
Plan quality	Fact base quality: Median	0.23	0.31	0.00	0.15
Plan cross-referencing	Proportion of plans isolated	0.00	0.06	0.21	0.18
Plan cross-referencing	Average indegree	2.53	3.06	1.36	2.12
Survey question	Plans aligned: M (SD)	0.65 (0.28)	0.53 (0.27)	0.42 (0.27)	0.45 (0.26)
Policies that enhance resilience					
Scorecard	Proportion positive policies	0.93	0.67	0.80	0.78
Scorecard	FP district M (SD)	37.37 (5.98)	32.08 (5.98)	37.96 (4.11)	32.94 (2.79)
Scorecard	SLR district M (SD)	37.35 (6.00)	27.72 (6.25)	34.40 (3.07)	33.11 (3.72)
Survey question	Plans affect vulnerability to flooding: M (SD)	0.78 (0.19)	0.76 (0.23)	0.65 (0.21)	0.69 (0.18)

Note: SNA = social network analysis; FP = flood-prone; SLR = sea-level rise.

clear support for our city-level hypotheses suggests that the relationship between governance networks, plan networks, and flood resilience policy outcomes might be nuanced and context-specific. The literature points to potential mediating variables that future research should examine, including leadership (Bodin 2017), public attention to flooding issues (Fried, Hamilton, and Berardo 2022), governance network fit with the biophysical reality (Ekstrom and Crona 2017), and maturity of the policy arena (Berardo and Scholz 2010).

Conclusion

The academic and policy discourse often contains normative claims about the value of collaboration in enhancing planning and better addressing hazards like flooding. Resilience planning is often associated with collaboration, including in major international policy initiatives. Yet limited empirical evidence supports widespread claims that more collaborative governance leads to better plans and policies. This study began to fill that gap by bringing together several novel network data sets for four cities. We examined the flood resilience governance network using surveys and SNA, the network of plans that shape development, and the spatial distribution and potential for policies in the network of plans to enhance flood resilience. We do not observe clear patterns across the four cities for how these three elements are related. We do, however, find a positive relationship between plan quality, plan cross-referencing, and flood resilience policies at the individual plan level. Future research should continue to unpack how and when collaboration affects the different plans and policies that shape resilience to hazards.

Supplemental Material

Supplemental data for this article can be accessed on the publisher's site at: <https://doi.org/10.1080/24694452.2023.2284299>.

Disclosure Statement

Any opinions and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Government or the

U.S. Census Bureau. This work was mostly or entirely completed while Dr. Sierra Woodruff and Dr. Bryce Hannibal were at Texas A&M University.

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