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DOI
10.1016/B978-0-323-85251-7.00014-7

Publication date
2022

Document Version
Final published version

Published in
Coastal Flood Risk Reduction

Citation (APA)
Malecha, M., Yu, S., Roy, M., Brand, N., & Berke, P. (2022). Plan evaluation for flood-resilient communities: The plan integration for resilience scorecard. In *Coastal Flood Risk Reduction: The Netherlands and the U.S. Upper Texas Coast* (pp. 177-191). Elsevier. https://doi.org/10.1016/B978-0-323-85251-7.00014-7

CHAPTER 14

Plan evaluation for flood-resilient communities: The plan integration for resilience scorecard

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Wise land-use planning is one of the most effective ways to prevent or reduce damage from natural hazards such as flooding. Successfully incorporating hazard mitigation across the many plans and policies that guide a city's development can be challenging, however. Communities around the world struggle with this task, to one degree or another, but those that acknowledge and plan for hazards throughout an integrated network of plans are generally more resilient than those where plans conflict and hazards are downplayed.

Researchers developed the Plan Integration for Resilience Scorecard (PIRS) method to evaluate the coordination of local plans and assess the degree to which they target areas most prone to hazards (Berke et al., 2015; Berke, Malecha, Yu, Lee, & Masterson, 2018; Berke, Yu, Malecha, & Cooper, 2019; Malecha et al., 2019). Through the *spatial evaluation* of a community's network of plan documents, a PIRS analysis helps reveal where and how plans and policies are coordinated or in conflict, and where opportunities exist to strengthen resilience. When applied in practice, this enables policymakers to address incongruities and focus more effectively on parts of the community demonstrating high vulnerability.

In a PIRS evaluation, a community is first divided into smaller districts, such as census tracts or neighborhoods (Fig. 1, map A), which can be individually assessed and compared. Zones of increased hazard risk, such as floodplains, are then defined and intersected with these districts to create a new layer of "district-hazard zones" (DHZs). Finally, documents in the community's network of plans are spatially evaluated: DHZs are assigned scores for each policy in the plans that (a) affects vulnerability, (b) influences land use, and (c) applies to a specific location(s). Policies that increase vulnerability receive a score of "−1," while those that reduce vulnerability receive a "+1" score. Scores can then be indexed for each DHZ, with higher scores indicating greater policy focus on reducing vulnerability (Fig. 1, map B). Ideally, policies are scored independently by multiple trained researchers, with intercoder agreement calculations providing feedback to ensure

Coastal Flood Risk Reduction
https://doi.org/10.1016/B978-0-323-85251-7.00014-7

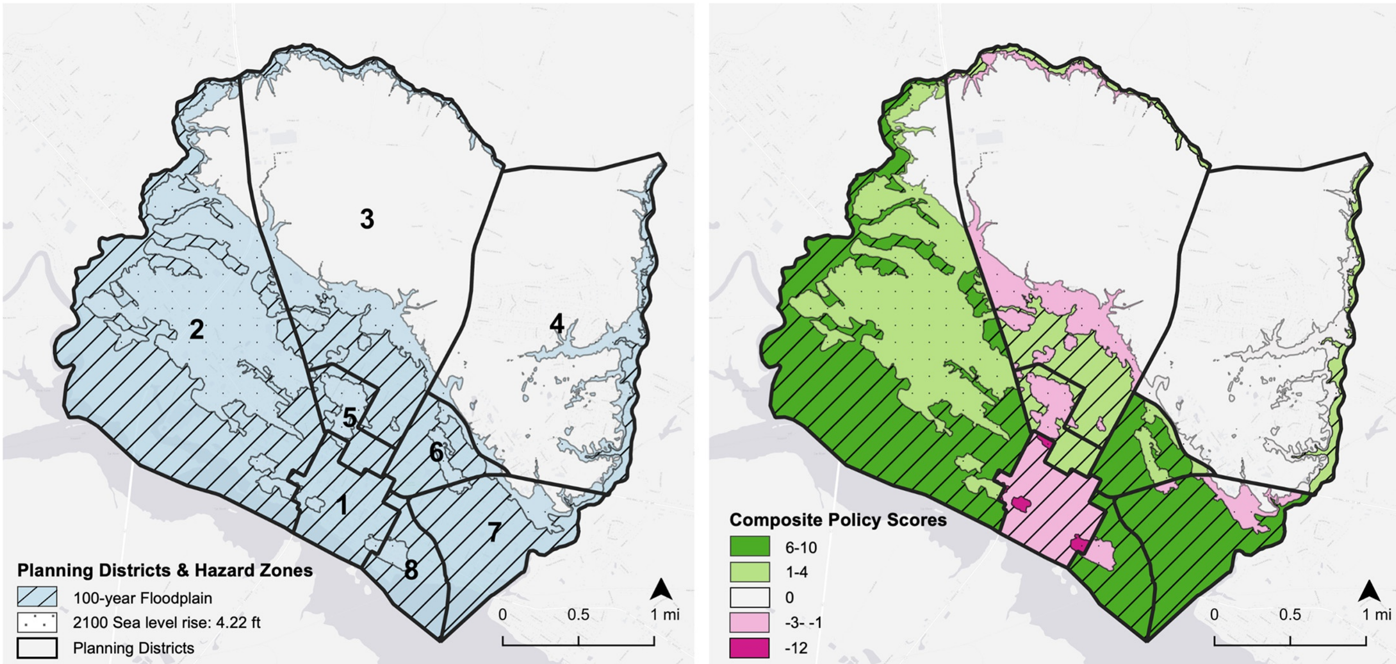

Fig. 1 Illustration of steps in the *plan integration for resilience scorecard* method.

accuracy. Cases of coder disagreement are then reconciled during a conference session, resulting in a final consensus scorecard. (For a more comprehensive description of the PIRS process, see Malecha et al., 2019.)

Transatlantic application

Though originally developed in the United States, the PIRS method was designed to be flexible, with potential for international applications. The uneven pursuit of resilience policies and conflicts among plans are by no means uniquely American phenomena. Nor is the imperative to resolve such problems: the United Nations declared in its landmark Sendai Framework for Disaster Reduction (United Nations General Assembly, 2015) that consistently integrating hazard mitigation in planning is crucial to building resilience, and that the failure of many communities to do so is a critical international concern.

The method was first applied in a sample of six cities along the US Atlantic and Gulf coastlines, including in the Houston, Texas region (Berke et al., 2018, 2019). Results revealed conflict between plan guidance in every community, but considerable variation across the study sample. Though perhaps unsurprising, given the decentralized governance structure and often limited coordination of US planning, these findings motivated an interest to apply the PIRS method in locations with better-integrated planning and hazard management. Would the method be pertinent and useful in places with less obvious plan conflict? What lessons might be learned that could help improve plan coordination for resilience the United States?

The unprecedented challenges wrought by climate change also suggest that even places with advanced planning and flood risk management systems might benefit from the perspective offered by the spatial evaluation of plans and policies. Although a global leader in water management and urban planning (Ward, Pauw, Van Buuren, & Marfai, 2013), the low-lying nation of the Netherlands is among the most flood-vulnerable countries in the world, especially in a changing climate. While comprehensiveness is a central aim of Dutch planning (Buitelaar & Sorel, 2010), flood risk management and local spatial planning practice are developed in separate silos, and have only recently started to integrate (Woltjer & Al, 2007). Land-use planning is beginning to be recognized as a method of reducing the risks and consequences of flooding (Neuvel & van den Brink, 2009), and the rigid Dutch water management strategy of attempting to prevent all flooding has begun to give way to a more flexible resilience approach, which seeks to minimize the consequences of flooding as part of a multilayer effort (Kaufmann, Mees, Liefferink, & Crabbé, 2016; Van Buuren, Ellen, & Warner, 2016).

These changing circumstances—together with an opportunity provided by a National Science Foundation Partnerships for International Research and Education (NSF-PIRE) grant—prompted researchers from Texas (Texas A&M University) and the Netherlands (UT Delft) to collaborate in applying the PIRS method in three separate studies in three Dutch cities: Rotterdam, Nijmegen, and Dordrecht. The studies were an occasion for comparisons and knowledge building, permitting the testing of the PIRS methodology in a new hazard and planning context, facilitating its continued development, and providing a novel perspective on Dutch plan integration and resilience as the country adjusts to new planning and water management challenges.

The remainder of this chapter presents summaries of the three case studies and then concludes with a brief discussion of key lessons learned from this cross-cultural research endeavor. Just as the PIRS provided a new lens to evaluate Dutch planning, the research in the Netherlands revealed insights that may help build resilience and advance flood risk management in coastal Texas and across the United States.

Feijenoord, Rotterdam

The first of the three studies (for full article, see Malecha, Brand, & Berke, 2018) was designed as a preliminary test of the generalizability of the PIRS methodology in the planning and hazard context of the Netherlands, and an exploration of how the method would suit the new situation. Feijenoord District, in central Rotterdam, was selected as the focus of the initial investigation. Successful application of the PIRS method in Feijenoord, with its different governance and hazard circumstances, provided evidence for the external validity of the PIRS method and paved the way for the subsequent studies.

Context

Feijenoord District, the second largest city in the Netherlands and the largest port in Europe, is located in central Rotterdam. Situated along a bend in the Nieuwe Maas River, this densely populated urban quarter has over 70,000 residents (Centraal Bureau voor de Statistiek [CBS], 2016) and is exposed to both storm surge and fluvial flooding (de Moel, van Vliet, & Aerts, 2014). Feijenoord's nine neighborhoods are among Rotterdam's most vulnerable (Centraal Bureau voor de Statistiek [CBS], 2016).

Like much of Rotterdam, the majority of southern Feijenoord is actually below sea level but is *embanked*—protected from river flooding from by an intricate system of dikes (City of Rotterdam, 2013). More than half of the district is located behind the bank dike (Fig. 2), where flood safety is the responsibility of the regional water authority (Correljé & Broekhans, 2015). Although a very high safety standard is maintained (Jonkman, Kok, & Vrijling, 2008), the unlikely event of a dike breach or extraordinarily high river levels would mean catastrophe for the low-lying neighborhoods (City of Rotterdam, 2013).

The remainder of Feijenoord is *unembanked*—directly exposed to the river. These parts of the district have a higher likelihood of flooding, but are elevated on higher ground. In contrast with the embanked areas, responsibilities for safety in these areas remain somewhat ambiguous (Runhaar, Mees, Wardekker, van der Sluijs, & Driessen, 2012; Ward et al., 2013). Thus, despite very high safety standards, some

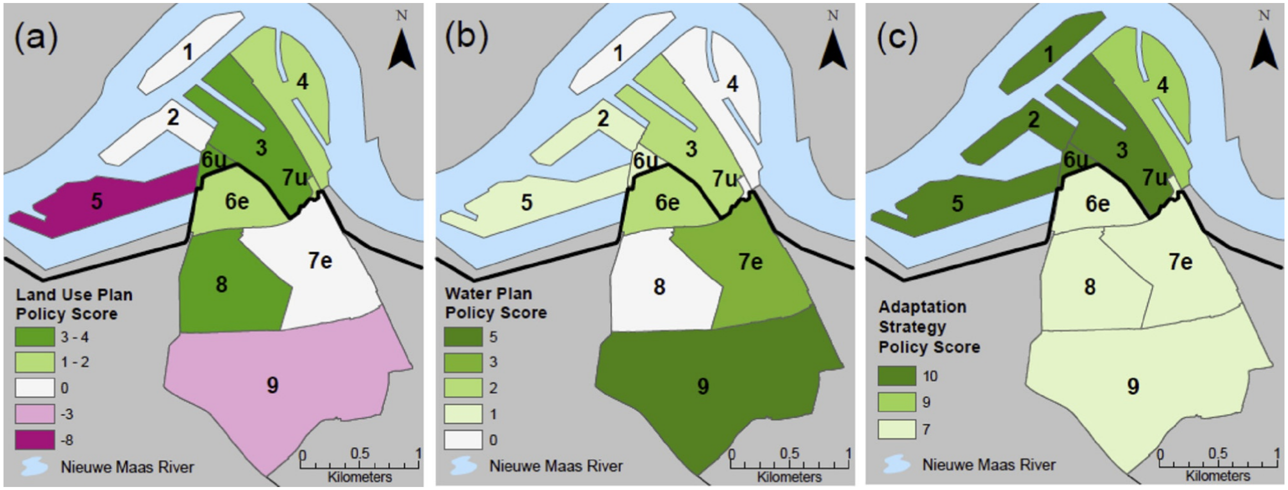

Fig. 2 Policy scores by plan type and neighborhood-hazard zone in Feijenoord district (*pink* = negative; *green* = positive): (A) land-use plans (all shown in one map), (B) submunicipal water plan, and (C) Rotterdam climate change adaptation strategy. *(Reproduced with permission from Malecha, M. L., Brand, A. D., & Berke, P. R. (2018). Spatially evaluating a network of plans and flood vulnerability using a plan integration for resilience scorecard: A case study in Feijenoord district, Rotterdam, the Netherlands.* Land Use Policy, 78, *147–157. https://doi.org/10.1016/j.landusepol.2018.06.029.)*

uncertainty and vulnerability remain in Feijenoord and Rotterdam, and especially when an ever more unpredictable climate is factored in (de Moel, Bouwer, & Aerts, 2014).

Process

The local context was incorporated in all aspects of the PIRS analysis of Feijenoord District. In Rotterdam, as in the Netherlands as a whole, neighborhood-level land-use plans are important for guiding land use and planning policy, making the neighborhood the ideal subjurisdictional unit to be used in a spatial analysis. Hazard zones were delineated following the Dutch conceptualization of flood risk—which is a function of both elevation and responsibility for water management (de Moel, van Vliet, & Aerts, 2014; Jonkman et al., 2008)—and thus were defined as the embanked and unembanked areas. Within this framing, all of Feijenoord (along with much of the country, in fact) is located in at least one hazard zone, with two neighborhoods straddling both zones: 6e (embanked)/6u(unembanked) and 7e/7u (Fig. 2). With the district divided into 11 distinct neighborhood-hazard zones (NHZs), the network of plans affecting Feijenoord was spatially evaluated. The evaluation focused on local and municipal plans, including 10 neighborhood land-use plans, a Submunicipal Water Plan, and Rotterdam's Climate Change Adaptation Strategy.

Findings

When summed across all plans, scores for all NHZs were positive (overall mean = 10.4; unembanked mean = 10.4; embanked mean = 10.3), indicating that the network of plans generally emphasized vulnerability reduction across Feijenoord District. Disaggregating the scores by plan type and NHZ reveals a more nuanced picture (Fig. 2), however. Shown in aggregate, the land-use plans in Feijenoord (Fig. 2A) reflect development pressures and neighborhood goals, which vary across the district. At the time of analysis, the unembanked part of Feijenoord District was the focus of substantial development to attract affluent residents. Several neighborhoods—especially Katendrecht (#5)—were transforming from working ports to modern residential districts, and development pressures were a challenge to the prioritization of flood resilience, with some policies increasing flood vulnerability.

The submunicipal water plan (Fig. 2B) and climate change adaptation strategy (Fig. 2C) both generally reduced flood vulnerability, but affected Feijenoord in different ways. The water plan focused primarily on the embanked neighborhoods, with more resilience-building policies in Vreewijk (#9) than anywhere else. The adaptation strategy was aimed at building resilience throughout the district, but especially in unembanked neighborhood—focused on threats from the Nieuwe Maas. It appears that the water plan and adaptation strategy may have been designed to fill policy gaps—compare Fig. 2B and C to A.

Nijmegen

The second study pushed the PIRS application in the Netherlands in new directions, incorporating additional administrative scales, comparing the results to several measures of community vulnerability, and investigating the ways a national program, "Room for the River," was incorporated at the local level (for full article, see Yu, Brand, & Berke, 2020). Despite the sectoral origins of flood safety and spatial planning, the Dutch planning system was beginning to increase coordination (ESPON, 2017), and this study explored whether that trend would be apparent in a community's network of plans.

Context

Nijmegen, an inland city with a population of over 165,000 (Centraal Bureau voor de Statistiek [CBS], 2016), was selected for study in part for its location along the Waal River, which makes it naturally exposed to fluvial flooding, and also for its status as the location of the flagship project of the "Room for the River" program. The goals of the project were to (1) protect the city from future floods and (2) enhance spatial quality. Rather than raise or strengthen dikes, per the traditional approach, the ambitious project relocated part of one to create a wider floodplain and provide more room for future floodwaters, thereby reducing the threat to the city.

Process

The PIRS evaluation in Nijmegen expanded the network of plans to include national and provincial documents. To facilitate the spatial analysis, the city was divided into NHZs—there are 44 neighborhoods in Nijmegen, and hazard zones were again defined as the embanked and unembanked areas.

Several vulnerability analyses were added to the PIRS evaluation in this study. *Physical vulnerability* was determined using the mean housing value data from the Dutch Centraal Bureau voor de Statistiek (CBS). *Social vulnerability* was established by adapting the Social Vulnerability Index (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011) to the Dutch context and measured using an index of indicators derived from the CBS. *Environmental vulnerability* was measured using the percentage of protected area in a NHZ as an indicator of environmental exposure (Villa & McLeod, 2002).

The PIRS analysis involved the spatial evaluation of all 14 documents in Nijmegen's network of plans, including national-, provincial-, and municipal-scale plans. Plans at all three tiers of the Dutch government can affect local decisions; the integration of some plan elements at higher administrative tiers is even mandatory in some cases (ESPON, 2017).

Findings

The network of plans in Nijmegen was shown to be generally supportive of resilience across the city. Composite policy scores from all 14 plans at the national, provincial, and local level ranged from +1 to +64. There was high variability between scores in the embanked and unembanked neighborhoods, however. A mean of 5.18 for embanked neighborhoods and 13.00 for unembanked neighborhoods suggests differences in policy emphases plans targeting different spatial areas; unembanked neighborhoods received significantly more attention for reducing risk, on average, than their embanked counterparts.

Several key findings are revealed upon closer inspection (Fig. 3). First, the national-scale *Delta Plan: Room for the River Waal* and provincial-scale *Environment Vision Plan*, created specifically for the Room for the River program, paid more attention to flood resilience in the enlarged unembanked areas. Second, local plans emphasized the building of flood resilience to accompany development in embanked areas. Third, plans at higher tiers again appeared to be filling policy gaps in the more development-focused local plans—a pattern that suggests that flood resilience may still be finding its way in the Dutch planning system.

The analysis of the vulnerability results revealed that, in general, higher physical vulnerability correlated positively with policy scores across Nijmegen NHZs, indicating a prioritization of vulnerability reduction in physically vulnerability areas than the network of plans. This suggests that Nijmegen's plans aligns with the flood safety goal of the Room

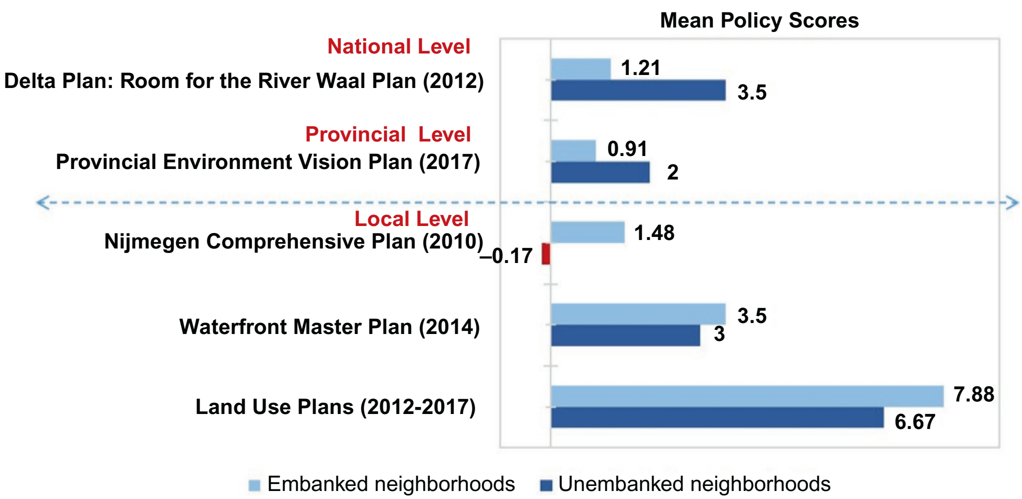

Fig. 3 Mean policy scores for plans at three administrative tiers affecting the city of Nijmegen. *(Reproduced with permission from Yu, S., Brand, A. D., Berke, P. (2020). Making room for the river: Applying a plan integration for resilience scorecard to a network of plans in Nijmegen, Netherlands.* Journal of the American Planning Association, *1–14. https://doi.org/10.1080/01944363.2020.1752776.)*

for the River program to reduce physical vulnerability, with a strong focus on existing development in unembanked neighborhoods. In contrast, an inverse relationship was found between policy scores and social vulnerability. This suggests that socially vulnerable neighborhoods may not be prioritized by Nijmegen's network of plans—a potential social justice issue. Interestingly, for environmental vulnerability, correlation results are negative for embanked neighborhoods and positive for unembanked neighborhoods. Nijmegen's network of plans was successfully pursuing the preservation of nature in the enlarged unembanked neighborhoods, but missing an opportunity to encourage similar environmental-resilience-focused efforts throughout the city.

De Staart neighborhood, Dordrecht

The third study extended the application of the PIRS method in the Netherlands in yet another direction—this time focusing on uncertainty in hazard planning and evaluating a network of plans against multiple future flood risk scenarios with multiple measures of policy effectiveness (for full article, see Roy, Brand, & Berke, *forthcoming*). De Staart, a flood-vulnerable neighborhood in the city of Dordrecht, was used for this test case.

Context

The PIRS framework was used to evaluate the effectiveness of a community's network of plans against *future* flood scenarios. The analysis focused on a neighborhood in the City of Dordrecht, a highly flood-vulnerable yet critical urban center in the Rhine Delta, which is at the forefront of proactive flood risk management (Gersonius et al., 2016). Most neighborhoods in Dordrecht are protected by dikes and polders, but the neighborhood under study, De Staart, is unembanked; its primary flood defense is elevation.

The neighborhood has an average elevation of 3 m above NAP (the Amsterdam Ordnance Datum, used to indicate sea level), rendering most areas safe against a 1:2000 chance flood event. The sense of safety has catalyzed increased industrial and residential developments in recent years. However, based on the climate change scenarios (City of Dordrecht, 2009), by 2100, large areas and several critical facilities, including a fresh water supply plant and a prison, are likely to flood. Effective management of open spaces and new development complemented by the protection of the critical facilities can help avoid losses. The PIRS study was meant to provide foresight on opportunities to proactively strengthen adaptation efforts.

Process

The evaluation was focused on whether land-use planning decisions in Staart, Dordrecht were effectively anticipating future flood impact scenarios. Three future flood inundation scenarios were collected based on the middle WB21 climate scenario (Gemeente

Dordrecht, 2009)—current, 2050, and 2100. Inundation levels were aggregated from KNMI'06 river discharge report (Weiland, Hegnauer, Bouaziz, & Beersma, 2015), KNMI'06 sea-level rise and precipitation scenarios (Royal Netherlands Meteorological Institute, 2007), and flood inundation levels from a Deltares report on Staart (Asselman, 2010). The three inundation levels were spatially intersected with 10 De Staart subneighborhood districts, creating district-hazard zones (DHZs).

The PIRS methodology was then used to collect, code, and analyze the effectiveness of policies from five city and regional plans using three measures of policy effectiveness. Policies in "plan and adapt" method are theorized to anticipate future flood risk by being (1) *robust*, that is, protecting assets against multiple projected future flood risk or (2) *flexible or low-regret*, that is, providing benefits in current flood scenario and providing opportunities for modification or enhancement against future flood scenarios (Hallegatte, 2009; Stults & Larsen, 2020). Thus, robust policies reduce vulnerability to floods in all three scenarios (score = +1 in current, 2050, and 2100). Flexible policies reduce vulnerability in the current scenario, but would need to be monitored in the future (score = +1 in current, 0 in 2050 and 2100). Finally, we identified policies that induce vulnerability in current or future flood scenarios (score = −1) and called them (3) *adaptation opportunities*.

Findings

Overall, the network of plans was found to effectively reduce vulnerability in the current flood risk scenario. Out of a total of 68 policies affecting vulnerability to floods in De Staart, 25 (36.8%) were robust, that is, they reduced vulnerability to floods in current, 2050, and 2100. A smaller proportion of policies (20.6%) were low-regret policies. They reduced vulnerability in current scenarios, but would need to be monitored against changing flood impact scenarios.

Fig. 4 shows composite scores by districts for the three flood scenarios. All districts in De Staart have positive composite index scores in the current scenario, suggesting that there are more policies that reduce vulnerability than those that increase vulnerability. Several districts, such as District 10, an industrial area, remain fairly robust through 2100. Water-based industrial land uses are retained and are supported by policies that discourage building new commercial development (City of Dordrecht, 2013). On the other hand, scores in a few districts (e.g., 1, 3, 4, 5) drop to negative scores in 2050 and 2100. This is predominantly due to development regulations encouraging residential and commercial density in the proposed "urban environment" in Stadswerven region (City of Dordrecht, 2009).

This analysis provides important insights into (a) policies that need to be monitored and (b) current policy approaches across the network of plans that inadvertently eliminate opportunities for future adaptation. It serves as a critical, albeit preliminary, step to examine and manage climate impact uncertainty.

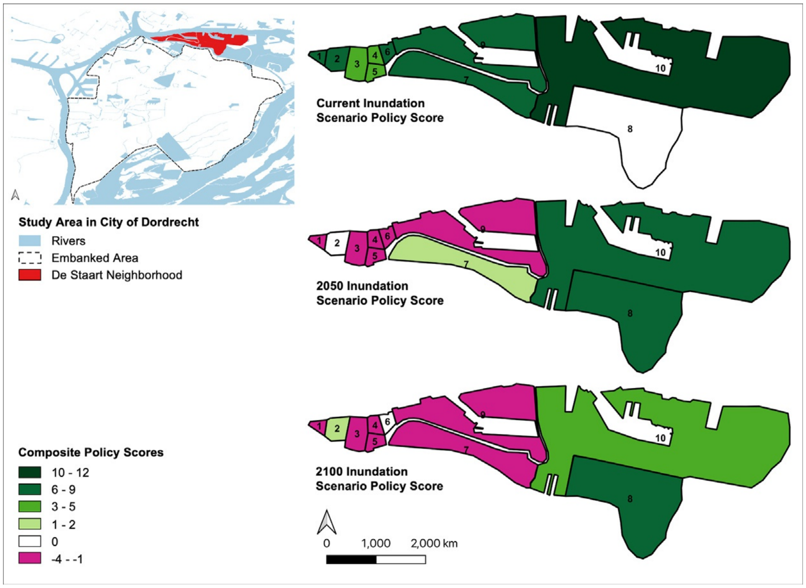

Fig. 4 Policy scores for current, 2050, and 2100 scenarios in De Staart, Dordrecht.

Conclusions

The studies described in this chapter exemplify the cross-cultural exchanges of knowledge and ideas that are at the heart of the NSF-PIRE program. A plan evaluation methodology developed in Texas to address issues of plan conflict and flood vulnerability was successfully applied and found to be generalizable in the Netherlands, a globally acknowledged leader in planning and water management. Researchers from the United States and around the world collaborated to great effect, bringing their unique expertise and understanding to bear on these important issues that exist, to one degree or another, in every country. Three case studies, in three Dutch cities, conducted over 3 years and led by three different researchers (supported by two others) resulted in findings that add to the flood risk planning and management discourse on both sides of the Atlantic.

As expected, the networks of plans in all three study locations in the Netherlands scored higher on the PIRS evaluations than did those in US communities. Long experience with the engineering and governance challenges posed to cities by flooding has led to more hazard-aware planning, on the whole. The scores were also more consistent across the Dutch cities—a likely result of stronger requirements for coordination and uniformity than currently exist in the United States. Lessons can be learned from these analyses that may advance the cause of flood resilience in both countries, however.

The PIRS method, and the concept of spatial plan evaluation, was introduced as a new tool and perspective for planners during a time of transition in the Netherlands, a global leader in urban planning and water management. Dutch planners and policy-makers were beginning to consider the usefulness of wise land-use planning and evacuation procedures as the second and third lines of defense, respectively, in a new multilayer water safety approach (Kaufmann et al., 2016; Van Buuren et al., 2016)—long neglected due to an overreliance on engineering solutions. All three case studies not only revealed strong integration of flood-resilience measures, but also noted instances where more explicit acknowledgement of the (minute, yet nonzero) plausibility of catastrophic flooding due to dam failure or overtopping would be beneficial. This very high standard, which was used in all three studies, resulted in occasional negative-scoring policies and revealed potential gaps and conflicts in plans regarding flood vulnerability. Employing this exacting lens, however, and evaluating the plans and policies spatially, may help in the reassessment as the Netherlands continues the process of updating its land use and water management approach.

The PIRS method's focus on differentiating hazard areas also brought to the fore the apparent ambiguity of responsibilities for water safety and flood mitigation in the unembanked parts of the study cities, and in the Netherlands more generally. Across all three case studies, some of the lowest plan scores were consistently found in unembanked neighborhoods, and this is especially the case for the influential neighborhood land-use plans. The lack of clarity about these areas (and the absence of a legally binding measure such as the "water test") may be leaving them significantly more vulnerable than other places, especially in a changing and increasingly volatile climate.

While unsurprising, the consistent finding of stronger plan integration toward resilience in the Netherlands provides empirical evidence for the wisdom and effectiveness of many aspects of the Dutch approach. Adopting (or at least adapting) these approaches might significantly improve plan integration and flood risk management in Texas and the United States. The first lessons to be learned relates to the value of communication in plan development—often mandated and enforced—which results in a generally complementary network of plans. This even appears to be the case with plans at different administrative scales; these preliminary spatial analyses suggest that each plan across a cities and throughout the administrative hierarchy has a specified purview and focus that acts to generally reinforce (rather than conflict with) the other plans in the network.

Secondly, the accumulation of evidence from the PIRS evaluations in the Netherlands signals the value of planners taking a leading role in preparing cities for threats from natural hazards. Planners sit at an important crossroads, and communities benefit when they are given the charge and authority to produce holistic plans that acknowledge and integrate hazard mitigation. This includes the serious consideration and candid use of scientific predictions about the likely effects of climate change to develop scenarios, plans, policies, and regulations—given equal, or even greater, weight than other drivers such as development pressures.

At the root of all of this, though, is a national mindset that appears to permeate (even dominate) government and planning around proactive, hazard-aware land use and water management—with public safety as the highest priority. This is something that is sorely needed as the climate crisis continues, and is something that American, and especially Texan, planners and decision makers would do well to emulate.

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