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

Malecha, Matthew L.; Brand, A. D.; Berke, Philip R.

DOI
10.1016/j.landusepol.2018.06.029

Publication date
2018

Document Version
Final published version

Published in
Land Use Policy

Land Use Policy 78 (2018) 147–157

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

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

Matthew L. Malecha[a,*], A.D. Brand[b], Philip R. Berke[a]

[a] Texas A&M University, 3137 TAMU, College Station, TX, USA
[b] Delft University of Technology, Julianalaan 134, 2628 BL Delft, Netherlands

ARTICLE INFO

Keywords:
Resilience planning
Plan integration
Hazard mitigation

ABSTRACT

Rising damages from hazard events have led to calls for innovative research on resilience. Consistent integration of mitigation policies throughout a community's network of plans is increasingly seen as essential for effective resilience planning. To better understand coordination and conflicts in policy responses to flood hazards, this study evaluates a district in the city of Rotterdam, the Netherlands, using the *Plan Integration for Resilience Scorecard* method. An internationally recognized leader in resilience and water management, Rotterdam is nevertheless vulnerable to flooding, especially in a changing climate. Findings demonstrate that even a place as proactive in resilience policy as Rotterdam can benefit from the perspective gained using the scorecard technique. Although resilience is generally supported throughout the study area, conflicts remain. The scorecard reveals inconsistencies and opportunities to further reduce flood vulnerability by 'mainstreaming' resilience policies in the most influential plans.

1. Introduction

Damages and costs associated with flood events are mounting as a result of a changing climate, an increasingly urbanized and coastal populace, and local land use and development decisions (Kousky, 2014; Moser et al., 2014). National and international governmental organizations have responded with calls for research and implementation of climate change mitigation, adaptation, and resilience-building measures (Intergovernmental Panel on Climate Change [IPCC], 2014). In 2012, the United States National Research Council (NRC) recommended development of a "resilience scorecard" to help communities "track their progress toward resiliency" (NRC, 2012, p. 12). As part of the 2015 Sendai Framework, the United Nations (UN) declared that consistent integration of hazard mitigation policies is critical to effecting resilience, and that the failure of many communities to do so is a critical international concern (United Nations General Assembly, 2015).

Berke et al. (2015) developed and tested a resilience scorecard that focuses on the integration and responsiveness of a community's *network of plans* vis-à-vis physical and social vulnerability and coastal flooding hazards in the United States. Communities often adopt multiple plans (which together constitute a 'network') that guide future development patterns, including in hazardous areas. A network of plans frequently includes a master plan (also referred to as a comprehensive plan or a general plan), which serves as the community's primary guiding and coordinating policy document (Berke et al., 2006; Kim and Rowe, 2013). It may also include plans that focus on a particular sector of the urban system such as land use, housing, or transportation. With increasing frequency, communities are also preparing and adopting hazard mitigation plans and/or climate change adaptation plans in anticipation of future risks (Klein et al., 2005; Woodruff and Stults, 2016).

The *Plan Integration for Resilience Scorecard* (formerly known as the *resilience scorecard*) enables the spatial evaluation of community network of plan documents, giving planners and decision-makers a new perspective regarding the coordination and efficacy of their policy responses to coastal flooding (Berke et al., 2015). The development of this method is an important step toward answering the calls of the NRC and UN for greater resilience and plan coordination—goals long advocated by hazard planning specialists (Godschalk et al., 1998a,b). Plan Integration for Resilience Scorecards offer planners and researchers a new way to simultaneously evaluate community vulnerability, policy response, and plan integration. Areas of the community demonstrating vulnerability–policy discrepancies or inter-plan conflict can be targeted by policymakers.

* Corresponding author at: Department of Landscape Architecture & Urban Planning, Texas A&M University, 3137 TAMU, College Station, TX, 77843, USA.
E-mail addresses: malecha915@tamu.edu (M.L. Malecha), A.D.Brand@tudelft.nl (A.D. Brand), pberke@arch.tamu.edu (P.R. Berke).

https://doi.org/10.1016/j.landusepol.2018.06.029
Received 24 May 2017; Received in revised form 19 June 2018; Accepted 19 June 2018
Available online 02 July 2018

By way of expanding and validating that approach, this study applies the Plan Integration for Resilience Scorecard methodology in an international setting, specifically to a relatively vulnerable district in the port city of Rotterdam, the Netherlands. While an internationally acknowledged leader in flood safety (Ward et al., 2013), Rotterdam is nevertheless highly exposed to flood hazards, particularly as climate change begins to alter patterns of precipitation and glacial melt (City of Rotterdam, 2013; IPCC, 2014). The city has also produced multiple spatial plans, including the pioneering Rotterdam Climate Change Adaptation Strategy (*Rotterdamse Adaptatiestrategie*), making it a suitable candidate for the novel perspective offered by the Plan Integration for Resilience Scorecard technique.

Although contextual differences necessitate slight modifications, the core evaluation process and measurements of integration are retained, thus providing support for the generalizability and utility of the Plan Integration for Resilience Scorecard analytical method beyond the United States. Furthermore, application of the scorecard analysis in the Netherlands allows a nuanced exploration of the ways natural hazard planning and governance affect plan quality and efficacy, adding to the important and growing body of knowledge on this subject (cf. Berke, 1996; Burby et al., 1997; Brody, 2003; Ward et al., 2013).

The next section provides a brief literature review to situate this study within the evolving hazard resilience and plan integration discourses. Contextual information will then be presented regarding the Dutch traditions of flood risk management and land use planning, followed by an introduction to the study area and its network of plans. The Plan Integration for Resilience Scorecard method, as generalized and applied in the Netherlands, will then be described. The paper concludes with a discussion of research findings, potential implications, and considerations for this and future research.

2. Literature review

Despite its recent popularity, the concept of *resilience* has been criticized for being ambiguous and difficult to operationalize (Klein et al., 2003; Alexander, 2013). Authoritative publications now define the term relatively consistently, if abstractly, as "[t]he capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation" (IPCC, 2014, p. 5).

A resilience approach to urban planning relies on a more straightforward and pragmatic interpretation, derived primarily from the field of hazard mitigation (Berke and Stevens, 2016). Godschalk et al. (1998a) were among the first to describe, succinctly and in practical terms, what it means to be a resilient community. Resilient places have infrastructure that can continue to function during and after a hazard event; critical facilities and residential communities located away from the most hazardous areas; building standards based on actual hazard risk; and a natural environment prized and protected for the ecosystem services it provides, such as flood attenuation (Godschalk et al., 1998a; Berke and Stevens, 2016). Social factors, such as income and education, have also been shown to affect community capacity and response to hazards (Van Zandt et al., 2012).

Achieving and maintaining resilience is contingent, in large part, on a community's ability to coordinate the plans and policies that guide its growth. Current research suggests that resilience can be affected by policies located anywhere in a plan network, including in documents seemingly unrelated to hazards (Berke et al., 2015; Kashem et al., 2016). Strong integration throughout the entire network of plans, including those not focused on hazards, is a critical part of building community resilience (Fidelman et al., 2013). Research has also shown that communities that plan for hazard mitigation through proactive land use policies are more resilient (Burby et al., 1997; Kim and Rowe, 2013).

Unfortunately, integrative hazard planning is currently the exception, rather than the rule, in many communities around the world (Burby et al., 1999; Macintosh, 2013). Policy coordination has often been included as part of the broader discussion of plan evaluation (Alexander and Faludi, 1989; Baer, 1997; Hopkins, 2001; Berke and Godschalk, 2009), but has only recently become the subject of more focused investigations (Woltjer and Al, 2007; Di Gregorio et al., 2017); the specter of climate change has increased the sense of urgency regarding the integration of mitigation and resilience policies and actions—often referred to as 'mainstreaming' (Klein et al., 2005; IPCC, 2014).

Recognizing the challenges communities face as they attempt to integrate multiple plans (which are often produced in isolation), planning researchers have developed new approaches and tools for plan assessment and coordination. Finn et al. (2007) introduced an 'information system of plans' (ISoP) to help integrate community plans, regulations, and resource data through a GIS-linked online database. They geocoded policies and actions containing spatial attributes in a GIS, allowing more focused comparisons, easier access to information, and detection of gaps and conflicts in plans. Finn et al. were correct to recognize the potential of using the spatial aspect of plans and policies to aid decision-making, though their approach is focused almost exclusively on project-level deliberations and requires significant time and technological inputs.

Berke et al. (2015) responded more directly to the problems that plan conflicts pose to community resilience with their 'resilience scorecard'. By assessing community plans and measures of vulnerability at the planning district scale, the resilience scorecard method helps identify incongruities within a community's network of plans and with respect to areas of vulnerability. The scorecard allows planners and decision-makers to better focus their efforts on areas of greatest need and keep track of their progress toward integration and resilience goals. The authors tested their method by applying it to the small, vulnerable community of Washington (2015 population estimate: 9788), located in coastal North Carolina. Although their initial proof-of-concept was successful, the authors did not explore the method further (or test it) with respect to generalizability, explanatory power, or utility for praxis. Still, the resilience scorecard method holds great potential for advancing planning practice and the scientific understanding of community resilience by allowing planners to more effectively recognize areas of policy discord, 'hot spots' of vulnerability, and their spatial associations.

The primary goal of this paper is to test the generalizability of the Plan Integration for Resilience Scorecard[1] and its methodological value in a dissimilar planning and policy context. To that end, we have selected a somewhat extreme example: Feijenoord District in Rotterdam, the Netherlands. Like Washington (North Carolina), Feijenoord is river-adjacent and is relatively vulnerable. Unlike Washington, Feijenoord is a densely populated urban district, located in a city and country famous for advanced planning and flood risk management. Successful application of the Plan Integration for Resilience Scorecard method in Feijenoord, with its dramatically different governance and hazard circumstances, will provide evidence for the external validity of Berke et al.'s method.

[1] Renamed so as to differentiate it from the multiplicity of 'resilience scorecards' in existence worldwide – e.g. Disaster Resilience Scorecard for Cities (United Nations Office for Disaster Risk Reduction, 2015), Community Disaster Resilience Scorecard (Torrens Resilience Institute, 2015), Resilient Communities Scorecard (Vermont Natural Resources Council, 2013) – which approach the concept of resilience more generally. The Plan Integration for Resilience Scorecard method is focused on the integration, or lack thereof, in a community's network of plans and its relationship to community vulnerability and resilience.

3. Context: Planning in the Netherlands

3.1. Flood risk management & networks of plans

Flood risk management has existed for centuries in the Netherlands and relatively strict land use planning regulation is generally accepted as a social good, integral to the maintenance of safety and a high standard of living (Van der Valk, 2002; Wiering and Winnubst, 2017). Despite their relative sophistication, however, flood risk management and local planning practice in the Netherlands developed in separate silos, which have only recently begun to integrate (Woltjer and Al, 2007; Neuvel and van den Brink, 2009).

In many ways, the advanced state of Dutch flood risk management is a consequence of the country's long and complicated history with water (Wiering and Winnubst, 2017). The Dutch were draining wetlands for agricultural purposes at least as far back as the 11th century, and protecting this investment has required significant and continuous engineering and planning efforts ever since (Wesselink, 2007). Still, with 60% of its surface area of 34,000 km^2 located below sea level and/or adjacent to water (Van Alphen, 2016), the Netherlands is one of the most exposed countries in the world with respect to coastal and riverine flooding, especially in an era of increasing climatic uncertainty (City of Rotterdam, 2013); approximately two-thirds of the country's population lives below sea level (PBL Netherlands Environmental Assessment Agency PBL, 2010). The Netherlands also has a troubled history of floods, including an epic 1953 event that devastated the country's southwest and precipitated the modern era of Dutch water management, in which flood risk is a fundamental driver of policymaking (Jonkman et al., 2008; Correljé and Broekhans, 2015).

Today the small, densely populated nation of 16.8 million inhabitants (500 persons/km^2) (2014 values; Centraal Bureau voor de Statistiek [CBS], 2016) is world-renowned for its advanced spatial planning and flood risk management (Ward et al., 2013). Since the second half of the 20th century, flood prevention has been the primary policy target of Dutch national water management. However, projected changes in climate and land use threaten to upset this delicate balance, and the official 'resistance' 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 (Klijn et al., 2004; Van Buuren et al., 2016) as part of a multi-layer water safety approach (Kaufmann et al., 2016). The full scope of effects of this policy shift is presently unknown, as multi-layer safety has yet to be implemented beyond several initial pilot projects (Stichting Toegepast Onderzoek Waterbeheer STOWA, 2014; Van Buuren et al., 2015).

Comprehensiveness and integration of land use planning are viewed as paramount in Dutch planning (Nadin and Stead, 2008; Buitelaar and Sorel, 2010). Consistency in decision-making between the three tiers of government is formally regulated, to be achieved through required communications aimed at consensus-building and mutual adjustment of planning proposals (Van der Valk, 2002). Planning and building regulations in the Netherlands are centrally authorized, but powers are distributed among various administrative bodies working at multiple scales (Hobma and Jong, 2016). The country's 12 provinces and 390 municipalities share spatial planning obligations, with the latter responsible for approving and enforcing the land use plan (*bestemmingsplan*), a fundamental neighborhood-scale document that simultaneously regulates planning and acts as a vision statement and development guide (Hobma and Jong, 2016). Municipalities are required to have up-to-date land use plans for their entire territory, and to follow a standardized national format (Needham, 2005) which requires acknowledgement of all related plans and policies, contributing (in theory) to a well-integrated network of plans.

Twenty-one regional Water Authorities, which possess regulatory and taxing powers, plan and manage the country's complex relationship with water; each produces a water plan (*waterplan*) that addresses water quantity, quality, and safety issues (Hobma and Jong, 2016). Although spatial planning and flood risk management developed separately in the Netherlands, with local decision-makers and regional Water Authorities pursuing their own independent policies, concerns about drainage have led to mandated collaboration (Woltjer and Al, 2007; Neuvel and van den Brink, 2009). The now-standard 'water assessment' (*watertoets*) legally binds land use and water planning by requiring municipalities to "consult with Water Authorities where the preparation of land-use plans is concerned" (Hobma and Jong, 2016, p. 8). Thus, flood-hazard-related policies are found today in many parts of a Dutch community's network of plans.

The relatively recent acknowledgement of spatial planning as an instrument to reduce flood consequences in the Netherlands (Neuvel and van den Brink, 2009) suggests, however, that even in a country labeled 'a planner's paradise' (Faludi and van der Valk, 1994; Roodbol-Mekkes et al., 2012), the coordination and efficacy of policy responses to flood hazards may not be self-evident. Runhaar et al. (2012) indicate that Dutch planners find climate change and related adaptation measures challenging to confront due to deficiencies in knowledge, resources, and urgency, as well as unclear legal obligations in *unembanked areas* (which are located outside the city's protective dike system; see Section 3.2). This applies to Rotterdam as well, despite the city's recently elevated international profile as a leader in water management—a consequence of its ambitious 'Climate Proof' program (Runhaar et al., 2012; City of Rotterdam, 2013). Therefore, applying the Plan Integration for Resilience Scorecard method in the City of Rotterdam is important both in terms of testing the method's generalizability and as a new perspective on plan integration and responsiveness as Rotterdam adjusts to new planning and water management challenges.

3.2. Study area: Feijenoord District, Rotterdam, the Netherlands

The Plan Integration for Resilience Scorecard is applied in the district (*wijk*) of Feijenoord, located south of the Nieuwe Maas River in central Rotterdam, the second largest city in the Netherlands (2016 population: 616,260 [dataset Centraal Bureau voor de Statistiek CBS, 2016]) and the largest port in Europe (Fig. 1). Feijenoord is a densely populated urban district with more than 70,000 residents (dataset Centraal Bureau voor de Statistiek CBS, 2016) that is exposed to both storm surge and riverine flooding, though engineering works reduce flood risk (City of Rotterdam, 2013; de Moel et al., 2014b). Feijenoord's nine neighborhoods (*buurten*), shown in Fig. 1, are among Rotterdam's most vulnerable (dataset Centraal Bureau voor de Statistiek CBS, 2016).

Like much of Rotterdam, the majority of southern Feijenoord District is located below sea level (indicated by blue coloring in Fig. 2) but is *embanked*, or protected from riverine flooding by an extensive dike system (City of Rotterdam, 2013; Ward et al., 2013). More than half of Feijenoord's land area – including the neighborhoods of Vreewijk, Bloemhof, the majority of Afrikaanderwijk, and all but a small portion of Hillesluis – is located behind the south bank dike (Fig. 1). These largely residential neighborhoods are almost entirely built-out. Fig. 3 shows the appearance of the dike in the Afrikaanderwijk neighborhood. Flood safety in embanked areas is the responsibility of the regional Water Authority, which produces the required water plan and maintains the dikes to prevent overtopping or failure (Correljé and Broekhans, 2015). A very high safety standard has been set by the Dutch national government, and thus annual flood risk in the embanked part of Feijenoord District is estimated at 1 in 4000 (Jonkman et al., 2008). In the unlikely event of a dike breach or extraordinarily high river levels, however, damage to the low-lying neighborhoods would be catastrophic (City of Rotterdam, 2013).

The remainder of the district – including Noordereiland, Feijenoord,

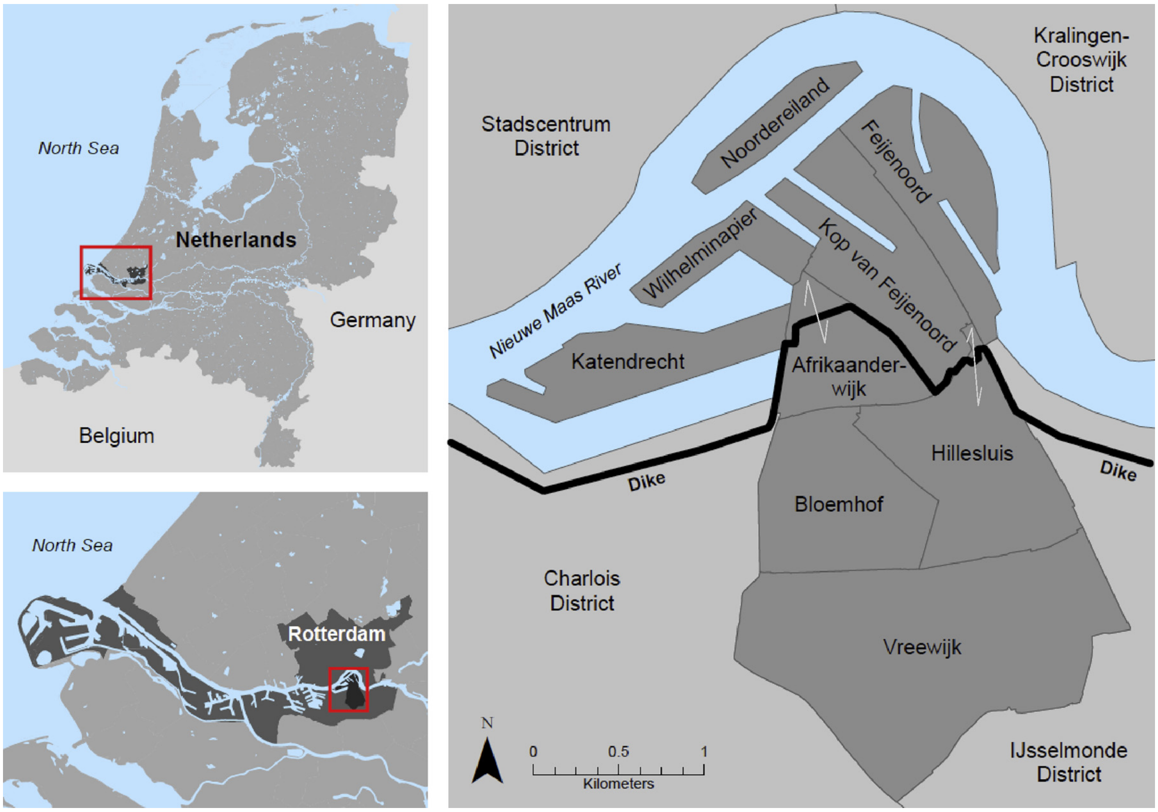

Fig. 1. Neighborhoods in Feijenoord District, with locator maps of the Netherlands and Rotterdam environs.

Kop van Feijenoord, and the rapidly redeveloping Wilhelminapier and Katendrecht neighborhoods, as well as parts of Afrikaanderwijk and Hillesluis – is located on higher ground but is *unembanked*. Being directly exposed to the river (see Fig. 4), these neighborhoods have a greater probability of flooding compared to the embanked neighborhoods, though inundation and damages are mitigated by higher elevation and by the Maeslant storm surge barrier (*Maeslantkering*), which prevents storm surges from the North Sea (City of Rotterdam, 2013). In sharp contrast with the embanked areas, where flood safety (through prevention) is the sole responsibility of the

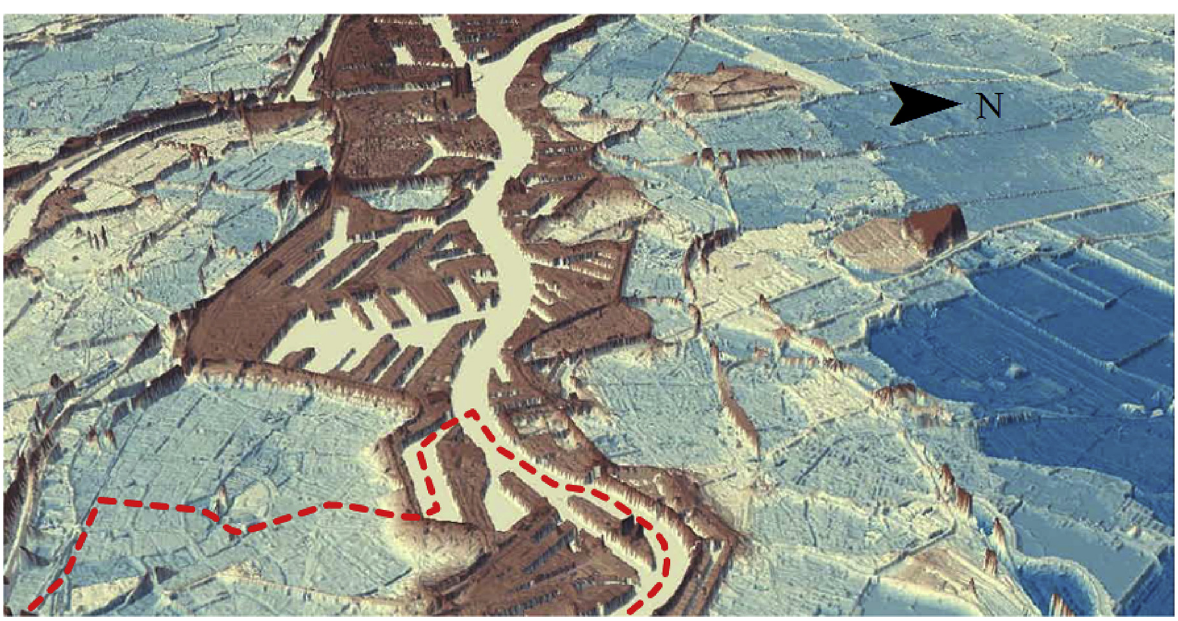

Fig. 2. 3D model showing land elevation in centralRotterdam (looking west, down the Nieuwe Maas River; brown = higher elevation; blue = lower elevation). Most of Feijenoord District is shown in the left-central foreground (red dotted line). The island in the river is the Noordereiland neighborhood. The sharp border between light blue and brown areas along the river generally indicates the presence of a dike. [Source: I. Bobbink, TU Delft, via City of Rotterdam (2013)]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Fig. 3. Street scene in Afrikaanderwijk neighborhood, Feijenoord, Rotterdam. Part of the dike dividing the neighborhood into *embanked* and *unembanked* sections is shown in front of the buildings (grass knoll, short brick wall) [Photo by author].

regional Water Authority, responsibilities in unembanked areas are relatively ambiguous. According to Dutch national policy regarding the riverbeds (*Beleidslijn Grote Rivieren*), individual developers are responsible for damage to new developments, whereas the municipality is in charge of public spaces and *may* contribute to flood response through provisions included in spatial and evacuation plans (Neuvel and van den Brink, 2009; Runhaar et al., 2012; Ward et al., 2013).

Although current Dutch safety standards are very high, some uncertainty and vulnerability remains, particularly with respect to unembanked areas (de Moel et al., 2014a). Additionally, while Rotterdam's policy professionals appear to be aware of the threats posed by an ever more unpredictable climate, including changes in the intensity and seasonality of rainfall (City of Rotterdam, 2013), the ways this concern is borne out in planning and policy across the network of plans is not yet well understood. High standards and cognizance of climate change notwithstanding, how well-integrated are the city's plan documents

Fig. 4. Aerial view of northern Feijenoord District and the Nieuwe Maas River, looking west, showing the unembanked neighborhoods of Noordereiland (center), Feijenoord (bottom left), and Kop van Feijenoord (middle left) [Source: City of Rotterdam (2013)].

with respect to flood resilience? The Plan Integration for Resilience Scorecard method is used to explore this issue, beginning with Feijenoord District and its constituent neighborhoods.

4. Methods: Plan Integration for Resilience Scorecard analysis in the Netherlands

The resilience scorecard method proffered in Berke et al. (2015) is adjusted to fit the cultural and hazard context in Feijenoord District, Rotterdam. Creating a Plan Integration for Resilience Scorecard entails the (1) delineation of planning and hazard zones and (2) evaluation of the community's network of plans for integration and responsiveness to flood vulnerability.

4.1. Step 1: Delineate planning & hazard zones

Delineating 'planning zones' divides the city into smaller units that can be individually evaluated and compared, allowing for a finer-grained spatial analysis than is possible by evaluating plans at the community-wide scale (cf. Piantadosi et al., 1988). The existence of neighborhood-level land use plans in the Netherlands, and their importance for guiding land use and planning policy, makes the neighborhood the ideal planning zone in Feijenoord District.

'Hazard zones' are then delimited and intersected with the neighborhoods to create a new layer of *'neighborhood hazard zones'*, which are the ultimate unit of analysis for the study. Flood hazard areas are often tied to natural features (e.g. 100-year floodplain adjacent to a river). In Rotterdam, however, decades of altering the local landscape by elevating land and constructing dikes has greatly influenced the circumstances of neighborhood flood exposure (Ward et al., 2013). Thus, following the Dutch conceptualization of flood risk, which is a function of both elevation and responsibility for water management (Jonkman et al., 2008; de Moel et al., 2014b), the hazard zones used for our examination of Feijenoord District are the previously described *embanked* and *unembanked* areas (see Section 3.2). Within this framing, the entire district (along with most of the city and much of the country) can be understood as existing within a flood hazard zone, even if the risk is relatively low. Embanked areas are protected by flood defenses but, due to their low elevation, are at risk of catastrophe in the event of a collapse or overtopping. The low elevation also poses a unique risk due to the lack of natural drainage for floodwaters. Unembanked areas, located between the dike and the river, are at greater risk of riverine flooding, though the land has been elevated to mitigate the effects (City of Rotterdam, 2013).

Dividing Feijenoord District into culturally relevant neighborhood hazard zones facilitates improved analysis of its network of plans. The ways plans and policies differ in their approach to flood hazards, as well as how these differences play out spatially and according to risk type, can be documented and evaluated. All Feijenoord District neighborhoods are located in at least one hazard zone, with Afrikaanderwijk and Hillesluis the only neighborhoods in both zones (Fig. 1). In total, there are 11 spatially distinct neighborhood hazard zones in the study area.

4.2. Step 2: Evaluate network of plans & generate Plan Integration for Resilience Scorecard

The study area's network of plans is then spatially evaluated. Policies that influence land use and development are identified in each of the community plan documents. The policies are then spatially assigned to neighborhood hazard zones and scored according to their effect on flood vulnerability. Policies that increase vulnerability receive a score of "-1", while those that reduce vulnerability receive a "+1" score. Table 1 contains examples of policies used in the analysis of Feijenoord District. Scores are totaled for each neighborhood hazard zone to create a policy score index. Higher scores indicate greater policy focus on reducing vulnerability. Negative scores suggest that the plan may actually increase flood vulnerability in a neighborhood hazard zone.

Consistent with Berke et al. (2015), this analysis focuses on local and municipal plans. In the Netherlands, mandatory standardized acknowledgement of plans produced by larger governmental units (provinces, the central state) is designed to reduce plan conflict (Neuvel and van den Brink, 2009; Buitelaar and Sorel, 2010), and thus a high degree of 'vertical plan integration' can be assumed. The network of plans for Feijenoord District includes ten neighborhood land use plans (Katendrecht has two), the Sub-municipal Water Plan for the districts of Charlois and Feijenoord (*Deelgemeentelijk waterplan Charlois en Feijenoord 2011-2016*), and Rotterdam's Climate Change Adaptation Strategy (*Rotterdamse Adaptatiestrategie*).

Established content analysis procedures (Berke and Godschalk, 2009) were followed, with policies scored independently by two researchers. The resulting intercoder agreement (0.84) falls above the suggested coefficient threshold for acceptable plan evaluation. Each case of coder disagreement was reconciled through reexamination of the policy in question and assignment of a final score. This resulted in a final, consensus scorecard.

5. Findings and discussion

This section demonstrates the viability of the scorecard method in a non-U.S. context by examining (1) overall composite policy scores, (2) scores for the individual plans, and (3) the spatial distribution of plan scores across neighborhoods in Feijenoord District, Rotterdam. The discussion is structured around the district's two hazard zones – the *embanked* and *unembanked* areas – given their demonstrated salience to flood risk and policy approaches in the city. To facilitate comparison and description, neighborhood hazard zones have been assigned

Table 1
Examples of policies included in Feijenoord District scorecard.

Policy	Plan (year: page)	Effect on Vulnerability
"Within land use 'Power of amendment 1' (*wro-zone - wijzigingsgebied – 1*) a maximum of 173 residential units are allowed (Bloemfonteinstraat/ Joubertstraat), as long as the municipality and the public owners of the property have reached an anterior agreement to do so."	Afrikaanderwijk Land Use Plan (*Bestemmingsplan Afrikaanderwijk*) (2011: 103)	Policy allows construction of many new residential units, increasing residential density and vulnerability to flood events; the affected neighborhood receives a score of -1 for this policy
"The houses in the Leeuwenkuil-site north in the Afrikaanderwijk will be demolished, and the site is suited to contain water."	Sub-municipal Water Plan for Charlois & Feijenoord (2011: 23)	Policy directs reduction of residential population density through demolition of housing and acknowledges suitability of site for water storage; the affected neighborhood receives a score of +1 for this policy
"In all new developments in outer-dike Rotterdam the risk of flooding will continue to be taken into account when determining the construction elevation."	Rotterdam Climate Change Adaptation Strategy (2013: 36)	Language directs new developments in the unembanked part of the city to consider flood risk during planning, reducing vulnerability to flooding; all affected neighborhood hazard zones receive a score of +1 for this policy

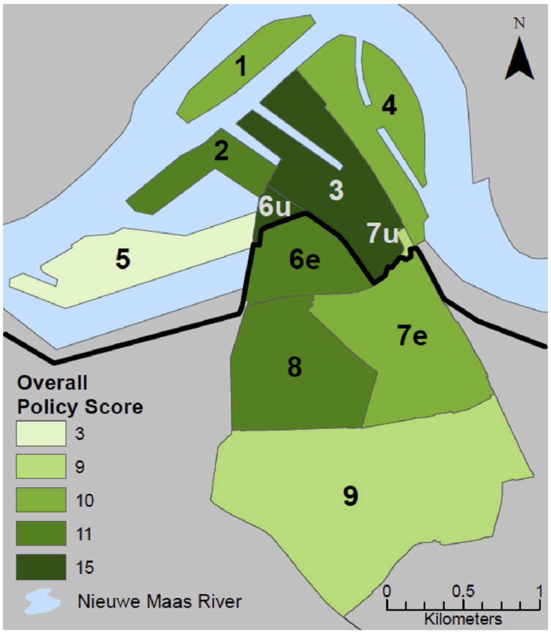

Fig. 5. Overall (composite) policy scores in Feijenoord District neighborhoods. Neighborhoods have been numbered to facilitate discussion: (1) Noordereiland; (2) Wilhelminapier; (3) Kop van Feijenoord; (4) Feijenoord; (5) Katendrecht; (6 u) Afrikaanderwijk – unembanked portion; (6e) Afrikaanderwijk – embanked portion; (7 u) Hillesluis – unembanked portion; (7e) Hillesluis – embanked portion; (8) Bloemhof; (9) Vreewijk.

numbers and, in the case of neighborhoods in both hazard zones, letters (e.g. '6 u for the unembanked portion of Afrikaanderwijk, '7e' for the embanked portion of Hillesluis; see Fig. 5).

5.1. Overall policy scores

When scores are summed across all three plan categories, all neighborhood hazard zones receive positive overall policy scores (overall mean = 10.4; unembanked mean = 10.4; embanked mean = 10.3), indicating that the network of plans emphasizes vulnerability reduction across Feijenoord District (Fig. 5; also see Appendix A for district hazard zone plan scores and descriptive statistics). When compared to the application of the scorecard method in the small city of Washington, North Carolina (Berke et al., 2015) – which produced mixed results and identified multiple areas of high plan conflict – this suggests that plan integration is stronger in Feijenoord, a result consistent with known differences between the two communities in terms of planning capacity and flood mitigation priorities.

The Dutch planning system mandates vertical and encourages horizontal integration of spatial plans (Van der Valk, 2002). Combined with deliberate municipal (and national) prioritization of flood resilience, this is reflected in high plan scores, especially when compared to the U.S. example. The overall policy score results thus provide support for the scorecard method's validity, and are also a testament to the advanced state of planning and flood risk management in Rotterdam.

Despite the generally positive results, however, overall policy scores vary considerably from the mean in Feijenoord's unembanked neighborhoods (std. dev. = 3.8); they are more consistent in the embanked part of the district (std. dev. = 0.8). This suggests differences in both the goals and the spatial foci of the individual documents in the network of plans. These variations and their significance are the subject of the remainder of this discussion.

Table 2
Policy score statistics, by plan type and hazard zone.

	Plan Type					
	Land Use Plans		Water Plan		Adaptation Strategy	
Hazard zone	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Unembanked	0.3	3.7	0.7	0.7	9.4	1.0
Embanked	0.8	2.6	2.5	1.8	7.0	0.0
Overall	*0.5*	*3.3*	*1.4*	*1.5*	*8.5*	*1.4*

5.2. Policy scores by type of plan and hazard zone

Disaggregating the scorecard results by type of plan and hazard zone (Table 2) allows a deeper look at the policy approach to flood vulnerability in Feijenoord District. Land use plans have the lowest mean neighborhood score (0.5) as a result of their focus on land use, including (re)development. They also display the highest standard deviation (3.3), likely reflecting their hyper-local focus—each neighborhood has its own land use plan according to its particular needs and goals.

Not surprisingly, the adaptation strategy has the highest mean neighborhood score (8.5) across Feijenoord's network of plans. It is clearly focused on increasing flood resilience throughout the district, though somewhat more so in the unembanked neighborhoods. Scores for the water plan are more modest (mean = 1.4), and are considerably higher in the embanked part of the district than in the unembanked areas.

5.3. Spatial distribution of individual plan scores

Observing the scorecard results disaggregated by plan type *and* at the individual neighborhood scale permits an even more nuanced analysis of the network of plans. Scores are a window onto both existing conditions and spatial differences in plan emphasis. In Feijenoord, land use plans reflect current development pressures as well as individual neighborhood goals, which vary widely across the district (Fig. 6a). The sub-municipal water plan (Fig. 6b) and climate change adaptation strategy (Fig. 6c) both broadly reduce flood vulnerability, but affect Feijenoord's constituent neighborhoods in different ways. As demonstrated below, assessment of neighborhood-level disparities using the Plan Integration for Resilience Scorecard enables a richer understanding of the dynamics of the community's network of plans[2].

5.3.1. Land use plan scores

The unembanked portion of Feijenoord District is currently the focus of substantial public and private attention as part of a city-led push to attract middle- and upper-income residents. Several neighborhoods are undergoing a transition that includes redevelopment and infill as their abandoned port-related facilities are converted to modern residential districts, and this is reflected in their land use plan scores (Fig. 6a). In some places, development pressures challenge the attention given to flood resilience, resulting in land use policies that may increase flood vulnerability. The Katendrecht neighborhood (#5) exemplifies this conflict as it evolves from an industrial brownfield site to a residential and mixed-use community. Katendrecht's two land use plans (one for the 'core', or *kern*, and one for the 'wrist', or *pols*) include multiple policies aimed at increasing density on the peninsula, often noting the proximity of the harbor basins for their amenity value, but not acknowledging the potential hazard (e.g. '[T]he Pols-site is to be … transformed into a mixed, urban residential, working and leisure-district, using the recreational potential of the vicinity of the water'

[2] Selected instead of the conventional red-to-blue color scale (red = bad; blue = good) which, though preferred in social science research for its ease of understanding and colorblind-safe status, is problematic when illustrating flood vulnerability due to the intuitive connection between shades of blue and depth of water (see colorbrewer2.org).

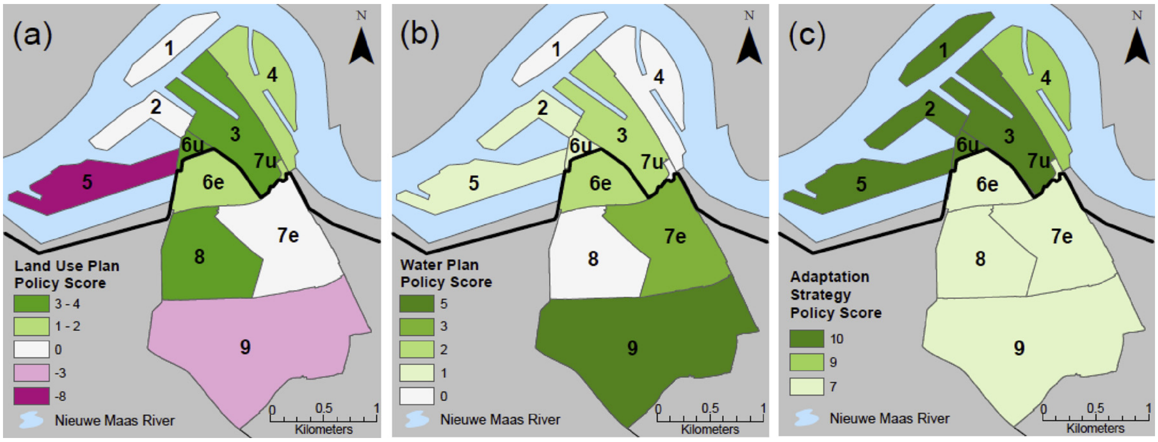

Fig. 6. Policy scores by plan type in Feijenoord District neighborhoods (pink = negative; green = positive): (a) Land Use Plans (all shown on one map); (b) Sub-municipal Water Plan; (c) Rotterdam Climate Change Adaptation Strategy.

[*Bestemmingsplan Katendrecht-Pols*, 2011, p. 17]).

Development pressure is less intense in Feijenoord's more established embanked neighborhoods, where opportunities for infill and redevelopment are limited. Variations in land use plan policy scores there are more often driven by priorities for how to improve spatial quality and the built environment. Neighborhoods like Bloemhof (#8) and Afrikaanderwijk (#6e) are made more resilient by policies focused on modernization and the improvement of public spaces and drainage (e.g. 'Sites where green is permitted are to be used for parks, public utilities, playgrounds … and other necessities of water management, like embankments and revetments' [*Bestemmingsplan Bloemhof*, 2007, p. 62]). However, with its 'conservative' land use plan, Vreewijk (#9) is less affected by this positive attention, and several redevelopment-related policies are actually likely to raise vulnerability in the event of a flood (e.g. 'Dordtsestraatweg 603-611, a mixed use site, will be redeveloped into 20 apartments divided over four floors, with a new underground parking lot' [*Bestemmingsplan Vreewijk*, 2010, p. 27]).

5.3.2. Sub-Municipal water plan scores

Results from the scorecard analysis indicate that Feijenoord District's water plan (Fig. 6b) accomplishes its mandated objective – and even strives to do more. Water Authorities are enabled by Dutch law to produce plan documents in collaboration with municipalities that manage water availability, movement, and quality in their jurisdictions (Tromp et al., 2014). With regard to flood resilience, these plans are mainly concerned with water drainage and retention. Unembanked parts of the city have been designed to allow precipitation to drain to the river directly, and thus policies aimed at improving water storage are generally not needed in these areas. Rotterdam's water plans are progressive, however, expanding beyond the mandated intent and pooling staff and fiscal resources; even unembanked neighborhoods are positively affected by some water plan policies.

Still, because the task of managing water is more complicated in areas that cannot naturally drain to the river, Feijenoord's progressive water plan focuses more on the embanked neighborhoods. A greater number of resilience-building policies in the water plan apply to Vreewijk (#9) and the embanked part of Hillesluis (#7e) than anywhere else (e.g. 'The site of the former hospital (*Zuiderzeeziekenhuis*) in [the Vreewijk neighborhood of] Feijenoord will be redeveloped; during development, opportunities to address water challenges are to be included' [*Deelgemeentelijk waterplan Charlois en Feijenoord* 2011-2016, 2010, p. 23Deelgemeentelijk waterplan Charlois en Feijenoord -, 2010*Deelgemeentelijk waterplan Charlois en Feijenoord* 2011-2016, 2010, p. 23Deelgemeentelijk waterplan Charlois en Feijenoord -, 2010*Deelgemeentelijk waterplan Charlois en Feijenoord* 2011-2016, 2010, p. 23]). This may indicate that the water plan is working to fill policy gaps in the land use plans related to flooding—compare Fig. 5b to 5a for these embanked neighborhoods.

5.3.3. Climate change adaptation strategy scores

Finally, it is apparent from the scorecard results that Rotterdam's citywide climate change adaptation strategy (Fig. 6c) offers many innovative approaches for building flood resilience throughout Feijenoord District (again, mean policy score = 8.5), but especially in unembanked neighborhoods (mean = 9.4). Like the water plan, the adaptation strategy is generally concerned with flooding, but it is more focused on the threats posed by impending climate change and from the Nieuwe Maas. Hence, greater policy attention is given to the unembanked part of the district (e.g. 'In order to be able to design and build robust waterproof constructions [in Kop van Feijenoord and Noordereiland], new building regulations are being developed' [City of Rotterdam, 2013, p. 70]). This emphasis on unembanked neighborhoods again represents an attempt to fill policy gaps; Rotterdam is using the adaptation strategy to strengthen flood resilience in the increasingly vulnerable unembanked areas, which receive relatively little attention from the water plan.

6. Conclusions & implications

The scorecard findings reveal conflicts and patterns in Feijenoord's network of plans that have implications for flood resilience in the district and in Rotterdam, more generally. Despite positive overall policy scores, the neighborhood- and plan-specific results are inconsistent. Some neighborhoods focus on development with insufficient attention to flood safety—to such a degree that their land use plan scores are negative. This mirrors findings from the U.S. (Berke et al., 2015; Berke et al., 2018) and reflects tensions between development and flood mitigation, which often lead to increases in population and building density in vulnerable areas without adequate focus on resilience. Resolving such tensions is critical to reducing vulnerability.

The larger-scale plans unsurprisingly score higher on average and are more consistent—evidence of their strong focus on flood risk and an indication that they may, in fact, be making up for policy gaps in some of the land use plans. The strategy of water plans assuming greater responsibility for water resilience, particularly in embanked neighborhoods (and of the adaptation strategy doing the same in unembanked areas) may be expedient, as long as the plans and agencies are truly working together. When this is not the case, though, which plan's guidance will win out? It is thus advisable to integrate resilience-building policies as thoroughly as possible, 'mainstreaming' them in the most influential plans. This is especially true for policies in the adaptation strategy, which is more of a visionary than a regulatory document. Integrating its many progressive recommendations in the more prescriptive elements of the network of plans – the water plans and, especially, the land use plans – will help Rotterdam reach its ambitious resilience goals.

From a research perspective, completing a Plan Integration for Resilience Scorecard analysis in a new policy and hazard context, quite unlike that in which the scorecard method was originally developed, provides support for its external validity. Methodological adjustments (e.g. delineating planning districts and hazard zones, determining which plans and policies to include) were relatively straightforward and should also be in future studies, provided that local experts are involved in the design and conduct of the research. The scorecard permitted an in-depth assessment of plan integration for flood resilience in Feijenoord District and offered new insight into the dynamics of its network of plans.

Finally, the scorecard evaluation of Feijenoord raised unanticipated questions about flood resilience in Rotterdam. Ambiguity appears to exist with respect to responsibility for flood safety in unembanked areas. Given the non-committal nature of national requirements like *Beleidslijn Grote Rivieren*, it seems that Dutch municipalities are still trying to identify their obligations in unembanked areas. The extent of their responsibility for flood damages and spatial provisions in land use plans remains unclear—a problem resulting in part from (and exacerbated by) a lack of experience with large flood events over recent decades. This is somewhat troubling, especially when combined with the policy inconsistencies identified using the scorecard. Whether existing provisions will suffice in the case of a very large flood event remains to be seen.

7. Limitations

This process was limited in several ways that should be improved in future applications, which may include evaluations of additional locations, comparative analyses, and translation to planning and flood risk management practice. As in Berke et al. (2015), this initial proof-of-concept scorecard evaluation was conducted in a community with a relatively small number of sub-jurisdictional districts (neighborhoods), which limited the statistical power for analysis of spatial relationships. A larger study area with more individual neighborhood hazard zones would provide a higher n-size, greater confidence, and better insight. Thus, having been demonstrated at the scale of the district (Feijenoord), small city (Washington, NC), and large city (Berke et al., 2018), the scorecard process may benefit from testing at the regional or even national scale.

Another way to strengthen the potency of conclusions, with respect to both Feijenoord's network of plans and the efficacy of the scorecard method, would be to repeat the study after some time has elapsed. A longitudinal study would track changes in the integration and responsiveness of the network of plans. It would allow greater insight regarding, for example, whether the suggestions in the adaptation strategy are eventually mainstreamed and whether low land use plan scores for Katendrecht and Vreewijk merely reflect an uncharacteristically development-centric time period. We would emphasize, however, that sufficient consideration should always be given to flood resilience, regardless of what other policy drivers exist.

Funding

This work was supported by the National Science Foundation (NSF), Award Number 1545837. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the NSF.

Declaration of conflicting interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgements

The authors wish to thank Nick van Barneveld, Winnie Pang, Stijnie Lohof, and Roeland van der Gugten for providing important information and clarifications in the early stages of this research. Siyu Yu and Jaekyung Lee also offered helpful critiques on early drafts.

Appendix

Appendix A. Policy scores and descriptive statistics for Feijenoord District, by plan type and hazard zone

		Plan Scores			
	Neighborhood	Land Use Plan	Water Plan	Adaptation Strategy	Total
Unembanked	(1) Noordereiland	0	0	10	10
	(2) Wilhelminapier	0	1	10	11
	(3) Kop van Feijenoord	3	2	10	15
	(4) Feijenoord	1	0	9	10
	(5) Katendrecht	−8	1	10	3
	(6u) Afrikaanderwijk (Unembanked)	4	1	10	15
	(7u) Hillesluis (Unembanked)	2	0	7	9
	Unembanked Neighborhoods Mean	*0.3*	*0.7*	*9.4*	*10.4*
	Unembanked Neighborhoods Std. Dev.	*3.7*	*0.7*	*1.0*	*3.8*
Embanked	(6e) Afrikaanderwijk (Embanked)	2	2	7	11
	(7e) Hillesluis (Embanked)	0	3	7	10
	(8) Bloemhof	4	0	7	11
	(9) Vreewijk	−3	5	7	9
	Embanked Neighborhoods Mean	*0.8*	*2.5*	*7.0*	*10.3*
	Embanked Neighborhoods Std. Dev.	*2.6*	*1.8*	*0.0*	*0.8*
	Overall Mean	*0.5*	*1.4*	*8.5*	*10.4*
	Overall Standard Deviation	*3.3*	*1.5*	*1.4*	*3.1*

References

Alexander, D.E., 2013. Resilience and disaster risk reduction: an etymological journey. Nat. Hazards Earth Syst. Sci. 13 (11), 2707–2716. http://dx.doi.org/10.5194/nhess-13-2707-2013.

Alexander, E.R., Faludi, A., 1989. Planning and plan implementation: notes on evaluation criteria. Environ. Plan. B Plan. Des. 16 (2), 127–140. http://dx.doi.org/10.1068/b160127.

Baer, W.C., 1997. General plan evaluation criteria: an approach to making better plans. J. Am. Plan. Assoc. 63 (3), 329–344. http://dx.doi.org/10.1080/01944369708975926.

Berke, P.R., 1996. Enhancing plan quality: evaluating the role of state planning mandates for natural hazard mitigation. J. Environ. Plan. Manage. 39 (1), 79–96. http://dx.doi.org/10.1080/09640569612688.

Berke, P., Godschalk, D., 2009. Searching for the good plan: a meta-analysis of plan quality studies. J. Plan. Lit. 23 (3), 227–240. http://dx.doi.org/10.1177/0885412208327014.

Berke, P.R., Stevens, M.R., 2016. Land use planning for climate adaptation: theory and practice. J. Plan. Educ. Res. 36 (3), 283–289. http://dx.doi.org/10.1177/0739456X16660714.

Berke, P., Godschalk, D., Kaiser, E., Rodriguez, D., 2006. Urban Land Use Planning, 5th ed. University of Illinois Press, Urbana-Champaign, IL.

Berke, P., Newman, G., Lee, J., Combs, T., Kolosna, C., Salvesen, D., 2015. Evaluation of networks of plans and vulnerability to hazards and climate change: a resilience scorecard. J. Am. Plan. Assoc. 81 (4), 287–302. http://dx.doi.org/10.1080/01944363.2015.1093954.

Berke, P.R., Malecha, M.L., Yu, S., Lee, J., Masterson, J.H., 2018. Plan integration for resilience scorecard: evaluating networks of plans in six US coastal cities. J. Environ. Plan. Manage. http://dx.doi.org/10.1080/09640568.2018.1453354.

Bestemmingsplan Afrikaanderwijk, 2011. Rotterdam, the Netherlands. Retrieved from. http://www.robedrijf.nl/DSV/Document/Bestemmingsplannen%20in%20procedure/Feijenoord/Afrikaanderwijk_onherroepelijk.pdf.

Bestemmingsplan Bloemhof, 2007. Rotterdam, the Netherlands. Retrieved from. http://www.ikkendoe.com/DSV/Document/Bestemmingsplannen%20in%20procedure/Feijenoord/Feijenoord/Bloemhof%20april%2007.pdf.

Bestemmingsplan Katendrecht-Pols, 2011. Rotterdam, the Netherlands. Retrieved from. http://www.ikkendoe.com/DSV/Document/Bestemmingsplannen%20in%20procedure/Feijenoord/Katendrecht-Pols.pdf.

Bestemmingsplan Vreewijk, 2010. Rotterdam, the Netherlands. Retrieved from. http://docplayer.nl/46891475-Vreewijk-bestemmingsplan-opgesteld-door.html.

Brody, S.D., 2003. Are we learning to make better plans? A longitudinal analysis of plan quality associated with natural hazards. J. Plan. Educ. Res. 23 (2), 191–201. http://dx.doi.org/10.1177/0739456X03258635.

Buitelaar, E., Sorel, N., 2010. Between the rule of law and the quest for control: legal certainty in the Dutch planning system. Land Use Policy 27, 983–989. http://dx.doi.org/10.1016/j.landusepol.2010.01.002.

Burby, R., May, P., Berke, P.R., Dalton, L.C., French, S.P., Kaiser, E.J., 1997. Making Governments Plan. Johns Hopkins University Press, Baltimore.

Burby, R.J., Beatley, T., Berke, P., Deyle, R., French, S., Godschalk, D., et al., 1999. Unleashing the power of planning to create disaster-resistant communities. J. Am. Plan. Assoc. 65 (3), 247–258. http://dx.doi.org/10.1080/01944369908976055.

[dataset] Centraal Bureau voor de Statistiek [CBS] (2016). Retrieved from http://statline.cbs.nl/Statweb/.

City of Rotterdam, 2013. Rotterdam Climate Change Adaptation Strategy. Rotterdam, the Netherlands. Retrieved from. http://www.deltacities.com/documents/20121210_RAS_EN_lr_versie_4.pdf.

Correljé, A., Broekhans, B., 2015. Flood risk management in the Netherlands after the 1953 flood: a competition between the public value(s) of water. J. Flood Risk Manage. 8 (2), 99–115. http://dx.doi.org/10.1111/jfr3.12087.

de Moel, H., Bouwer, L.M., Aerts, J.C., 2014a. Uncertainty and sensitivity of flood risk calculations for a dike ring in the south of the Netherlands. Sci. Total Environ. 473, 224–234. http://dx.doi.org/10.1016/j.scitotenv.2013.12.015.

de Moel, H., van Vliet, M., Aerts, J.C., 2014b. Evaluating the effect of flood damage-reducing measures: a case study of the unembanked area of Rotterdam, the Netherlands. Regional Environmental Change 14 (3), 895–908. http://dx.doi.org/10.1007/s10113-013-0420-z.

Deelgemeentelijk waterplan Charlois en Feijenoord 2011-2016, 2010. Rotterdam, the Netherlands. Retrieved from. https://www.rotterdam.nl/wonen-leven/waterplan-2/DGWP_Charlois_en_Feijenoord-ontwerp-eindrapport.pdf.

Di Gregorio, M., Nurrochmat, D.R., Paavola, J., Sari, I.M., Fatorelli, L., Pramova, E., et al., 2017. Climate policy integration in the land use sector: mitigation, adaptation and sustainable development linkages. Environ. Sci. Policy 67, 35–43. http://dx.doi.org/10.1016/j.envsci.2016.11.004.

Faludi, A., van der Valk, A., 1994. Rule and Order Dutch Planning Doctrine in the Twentieth Century, vol. 28 Springer Science & Business Media.

Fidelman, P.I., Leitch, A.M., Nelson, D.R., 2013. Unpacking multilevel adaptation to climate change in the Great Barrier Reef, Australia. Glob. Environ. Change 23 (4), 800–812. http://dx.doi.org/10.1016/j.gloenvcha.2013.02.016.

Finn, D., Hopkins, L.D., Wempe, M., 2007. The information system of plans approach: using and making plans for landscape protection. Landsc. Urban Plan. 81 (1), 132–145. http://dx.doi.org/10.1016/j.landurbplan.2006.11.006.

Godschalk, D., Beatley, T., Berke, P., Brower, D., Kaiser, E.J., 1998a. Natural Hazard Mitigation: Recasting Disaster Policy and Planning. Island Press, Washington, DC.

Godschalk, D.R., Kaiser, E.J., Berke, P.R., 1998b. Integrating hazard mitigation and local land use planning. In: Burby, R. (Ed.), Cooperating with Nature: Confronting Natural Hazards With Land-Use Planning for Sustainable Communities. Joseph Henry Press, Washington, DC, pp. 85–118.

Hobma, F.A., Jong, P., 2016. Planning and Development Law in the Netherlands. An Introduction. Instituut voor Bouwrecht, The Hague, Netherlands.

Hopkins, L.D., 2001. Urban Development: The Logic of Making Plans. Island Press, Washington, DC.

Intergovernmental Panel on Climate Change, et al., 2014. Summary for policy makers. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY Retrieved from. http://www.ipcc.ch/report/ar5/wg2/.

Jonkman, S.N., Kok, M., Vrijling, J.K., 2008. Flood risk assessment in the Netherlands: a case study for dike ring South Holland. Risk Anal. 28 (5), 1357–1374. http://dx.doi.org/10.1111/j.1539-6924.2008.01103.x.

Kashem, S.B., Wilson, B., Van Zandt, S., 2016. Planning for climate adaptation: evaluating the changing patterns of social vulnerability and adaptation challenges in three coastal cities. J. Plan. Educ. Res. 36 (3), 304–318. http://dx.doi.org/10.1177/0739456x16645167.

Kaufmann, M., Mees, H., Liefferink, D., Crabbé, A., 2016. A game of give and take: the introduction of multi-layer (water) safety in The Netherlands and Flanders. Land Use Policy 57, 277–286. http://dx.doi.org/10.1016/j.landusepol.2016.05.033.

Kim, S., Rowe, P., 2013. Are master plans effective in limiting development in China's disaster-prone areas? Landsc. Urban Plan. 111, 79–90. http://dx.doi.org/10.1016/j.landurbplan.2012.12.001.

Klein, R.J.T., Nicholls, R.J., Thomalla, F., 2003. Resilience to natural hazards: how useful is this concept? Environ. Hazards 5 (1), 35–45. http://dx.doi.org/10.1016/j.hazards.2004.02.001.

Klein, R.J., Schipper, E.L.F., Dessai, S., 2005. Integrating mitigation and adaptation into climate and development policy: three research questions. Environ. Sci. Policy 8 (6), 579–588. http://dx.doi.org/10.1016/j.envsci.2005.06.010.

Klijn, F., van Buuren, M., van Rooij, S.A., 2004. Flood-risk management strategies for an uncertain future: living with Rhine river floods in the Netherlands? AMBIO J. Hum. Environ. 33 (3), 141–147. http://dx.doi.org/10.1579/0044-7447-33.3.141.

Kousky, C., 2014. Informing climate adaptation: a review of the economic costs of natural disasters. Energy Econ. 46, 576–592. http://dx.doi.org/10.1016/j.eneco.2013.09.029.

Macintosh, A., 2013. Coastal climate hazards and urban planning: how planning responses can lead to maladaptation. Mitig. Adapt. Glob. Change 18 (7), 1035–1055. http://dx.doi.org/10.1007/s11027-012-9406-2.

Moser, S.C., Davidson, M.A., Kirshen, P., Mulvaney, P., Murley, J.F., Neumann, J.E., Petes, L., Reed, D., 2014. Ch. 25: coastal zone development and ecosystems. climate change impacts in The United States: the third national climate assessment. In: Melillo, J.M., Richmond, Terese (T.C.), Yohe, G.W. (Eds.), U.S. Global Change Research Program, pp. 579–618. http://dx.doi.org/10.7930/J0MS3QNW.

Nadin, V., Stead, D., 2008. European spatial planning systems, social models and learning. disP-The Plan. Rev. 44 (172), 35–47. http://dx.doi.org/10.1080/02513625.2008.10557001.

National Research Council, 2012. Disaster Resilience: A National Imperative. National Academies Press, Washington, DC.

Needham, B., 2005. The new Dutch spatial planning act: continuity and change in the way which the Dutch regulate the practice of spatial planning. Plan. Pract. Res. 20 (3), 327–340. http://dx.doi.org/10.1080/02697450600568662.

Neuvel, J.M.M., van den Brink, A., 2009. Flood risk management in Dutch local spatial planning practices. J. Environ. Plan. Manage. 52 (7), 865–880. http://dx.doi.org/10.1080/09640560903180909.

PBL Netherlands Environmental Assessment Agency [PBL], 2010. Correction Wording Flood Risks for the Netherlands in IPCC Report. Bilthoven, Netherlands. Retrieved from. . http://www.pbl.nl/en/dossiers/Climatechange/content/correction-wording-flood-risks.html.

Piantadosi, S., Byar, D.P., Green, S.B., 1988. The ecological fallacy. Am. J. Epidemiol. 127 (5), 893–904.

Roodbol-Mekkes, P.H., van der Valk, A.J., Altes, W.K.K., 2012. The Netherlands spatial planning doctrine in disarray in the 21st century. Environ. Plan. A 44 (2), 377–395. http://dx.doi.org/10.1068/a44162.

Runhaar, H., Mees, H., Wardekker, A., van der Sluijs, J., Driessen, P.P., 2012. Adaptation to climate change-related risks in Dutch urban areas: stimuli and barriers. Reg. Environ. Change 12 (4), 777–790. http://dx.doi.org/10.1007/s10113-012-0292-7.

Stichting Toegepast Onderzoek Waterbeheer [STOWA], 2014. Multi-Level Safety: Water Resilient Urban and Building Design. Amersfoort, Netherlands. Retrieved from. http://deltaproof.stowa.nl/upload/publicatie2014/2014_12_EN.pdf.

Torrens Resilience Institute, 2015. A Way to Measure Community Disaster Resilience: Community Disaster Resilience Scorecard Toolkit, Version 2. Retrieved from. http://www.flinders.edu.au/fms/documents/NP1314_Revised_TRI%20Toolkit%20and%20Scorecard%20Version%202.pdf.

Tromp, E., Rengers, J., van den Berg, H., Pelders, E., 2014. Levees in a changing environment (conference paper). 6th International Conference on Flood Management (ICFM6). 16-18 September 2014.

United Nations General Assembly, 2015. Sendai, Japan. United Nations World Conference on Disaster Reduction—Sendai Framework for Disaster Reduction 2015–2030 Author. Retrieved from. http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf.

United Nations Office for Disaster Risk Reduction [UNISDR], 2015. Disaster Resilience Scorecard for Cities. Retrieved from. http://www.unisdr.org/2014/campaign-cities/Resilience%20Scorecard%20V1.5.pdf.

Van Alphen, J., 2016. The Delta Programme and updated flood risk management policies in the Netherlands. J. Flood Risk Manage. 9 (4), 310–319. http://dx.doi.org/10.

1111/jfr3.12183.
Van Buuren, A., Ellen, G., Leeuwen, C.V., Popering-Verkerk, J.V., 2015. Die het water deert die het water keert: overstromingsrisicobeheer als maatschappelijke gebiedsopgave: opbrengsten en lessen uit de pilots meerlaagsveiligheid. Erasmus University Rotterdam, Rotterdam.
Van Buuren, A., Ellen, G.J., Warner, J.F., 2016. Path-dependency and policy learning in the Dutch delta: toward more resilient flood risk management in the Netherlands? Ecol. Soc. 21 (4) Retrieved from. http://www.jstor.org/stable/26270023.
Van der Valk, A., 2002. The Dutch planning experience. Landsc. Urban Plan. 58 (2), 201–210. http://dx.doi.org/10.1016/S0169-2046(01)00221-3.
Van Zandt, S., Peacock, W.G., Henry, D.W., Grover, H., Highfield, W.E., Brody, S.D., 2012. Mapping social vulnerability to enhance housing and neighborhood resilience. Hous. Policy Debate 22 (1), 29–55. http://dx.doi.org/10.1080/10511482.2011.624528.
Vermont Natural Resources Council, 2013. Resilient Communities Scorecard. Montpelier, VT. Retrieved from. http://vnrc.org/wp-content/uploads/2013/06/Cover-and-Credits.pdf.
Ward, P.J., Pauw, W.P., Van Buuren, M.W., Marfai, M.A., 2013. Governance of flood risk management in a time of climate change: the cases of Jakarta and Rotterdam. Environ. Polit. 22 (3), 518–536. http://dx.doi.org/10.1080/09644016.2012.683155.
Wesselink, A.J., 2007. Flood safety in the Netherlands: the Dutch response to hurricane Katrina. Technol. Soc. 29 (2), 239–247. http://dx.doi.org/10.1016/j.techsoc.2007.01.010.
Wiering, M., Winnubst, M., 2017. The conception of public interest in Dutch flood risk management: untouchable or transforming? Environ. Sci. Policy 73, 12–19. http://dx.doi.org/10.1016/j.envsci.2017.03.002.
Woltjer, J., Al, N., 2007. Integrating water management and spatial planning. J. Am. Plan. Assoc. 73 (2), 211–222. http://dx.doi.org/10.1080/01944360708976154.
Woodruff, S.C., Stults, M., 2016. Numerous strategies but limited implementation guidance in US local adaptation plans. Nat. Clim. Change 6, 796–802. http://dx.doi.org/10.1038/nclimate3012.