THE INFLUENCE OF PLAN INTEGRATION ON COMMUNITY VULNERABILITY AND ECOLOGICAL RESILIENCE TO NATURAL HAZARDS

A Dissertation

by

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ABSTRACT

Coastal areas, which comprise approximately 17 percent of the land area and 52 percent of the population of the United States, regularly contend with flooding threats—especially from hurricanes and coastal storms, which are exacerbated by sea-level rise. Flooding is the most dangerous natural hazard, which poses the greatest threat to property and the safety of human communities. A key driver of increased community vulnerability is the rapid and haphazard expansion of development in flood-prone areas. Poorly designed development in sensitive coastal areas causes wetland loss that further amplifies damage from floods, and empirical research suggests that wetland loss may increase the frequency and magnitude of flood events.

A primary cause of rising vulnerability is that hazard mitigation strategies are isolated from other community planning initiatives that influence development patterns in floodplains in hurricane surge- and rainfall-based flooding events. A variety of plans (e.g. hazard mitigation, land use, transportation, environmental) guide development in hazard areas, and the ways these multiple and independent plans interact can significantly impact community vulnerability. A well-integrated network of plans that safeguards the natural environment – especially wetlands – can significantly aid in building resilient communities and reducing losses from flood events. Yet, a national study by the National Resource Council concluded that hazard mitigation plans are a valuable tool that can significantly reduce community vulnerability, but that such plans are of poor quality and poorly coordinated with local networks of plans.

This study includes three separate, but related, research approaches, which explore these issues by building on the theory and methods of the *Plan Integration for Resilience Scorecard*, a procedure for spatially evaluating local policies as they guide day-to-day planning and development efforts. First, I evaluate the degree to which plan integration addresses flooding impacts and wetlands in Fort Lauderdale, FL and League City, TX. Second, I use hierarchical linear modeling to investigate the influence of a multitude of factors on community plan integration for resilience in six US coastal cities. Third, using the city of Nijmegen, the Netherlands, as a case study, I use the *resilience scorecard* method to analyze how policies in the Dutch national flood mitigation program – "Room for the River" – are integrated into a local network of plans, and the ways this integration affects physical, social, and environmental vulnerability to flooding at the scale of the neighborhood.

This research focuses squarely on problems at the nexus of climate change and urbanization, and seeks to contribute to their resolution by testing and extending the scope of the novel Plan Integration for Resilience Scorecard method. Connecting plan integration to flooding impacts and wetland loss may provide empirical support for the contention that plans and policies must be better aligned to reduce community vulnerability. Investigating the host of factors influencing plan integration in a community may suggest a way forward for communities that struggle with issues of 'siloing' and plan conflict. Using the resilience scorecard method to analyze multi-scale policy integration in the Netherlands may prove to be a useful extension of that evolving methodology and may offer insight into plan integration (or lack thereof) in a country famous for strong planning and water management.

DEDICATION

To my parents

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CHAPTER I

INTRODUCTION

1.1. Background

Coastal communities regularly face threats from natural hazards, including hurricanes and coastal storms, exacerbated by rising sea levels. Coasts in the United States comprise 17 percent of the land area and about 52 percent of the population (Beatley, 2009). Flood vulnerability is growing as development and urbanization continue to occur in flood-hazard areas (Cutter et al., 2008; Douglas et al., 2008; Easterlings et al., 2000; Gallopin, 2006; O'Brien & Leichenko, 2000; Price & Vojinovic, 2008; Vogel, 1996). Floods remain the most deadly hazard, and that which poses the greatest potential to damage the property and threaten the safety of human communities. Total residential flood loss in the United States was more than $26 billion from 1996 to 2007 (Breen & Rigby, 1996). Development and land cover change in flood-prone areas have contributed to increased losses from both surge- and rainfall-based flooding events. A lack of disaster preparedness and predictive alarms has resulted in long-term damage for communities and the natural environment.

Wetland loss amplifies property damage from floods over a larger area. Studies based on empirical observations and field research suggests that loss of wetlands can increase the frequency and magnitude of flood events. Johnston et al. (1994) noted that even a small amount of wetland loss in a watershed can have a long-term impact on flooding damage. Moreover, in a study that controlled for socioeconomic and geophysical factors, Brody et al. (2008) discovered that wetland loss in 37 coastal counties in Texas significantly exacerbated the level of flood damage that occurred between 1997 and 2000. They also found that wetland alterations added over $38,000 in average property damage per event to a city's budget.

Planning can has an important role in influencing development, and ultimately the resilience of the built and natural environments, in areas vulnerable to flood hazards. Communities prepare and adopt a variety of often independent plans (e.g. hazard mitigation, land use, transportation, environmental), each of which potentially impact key issues related to different types of hazard vulnerability and mitigation. The combined impact of multiple and interdependent plans can decrease or increase vulnerability to community hazards. A well-integrated network of plans that guides development guides development away from hazard areas and protects wetlands can significantly aid in building resilient communities and reducing losses from flood events. To date, little is known about the factors that influence coordination in a community's network of plans, though planning capacity and local community context have been identified as key factors that influence both plan quality (Burby, 2003; Lyles, 2014) and the intent to protect the natural environment (Dunlap et al., 2000).

This dissertation includes three separate, but related, research approaches, which explore these issues by building on the concept and method of the Plan Integration for Resilience Scorecard (Berke et al., 2015), a procedure for spatially evaluating local policies as they guide day-to-day planning and development efforts. First, I use hierarchical linear modeling to investigate the influence of a multitude of factors on community plan integration for resilience. Second, I evaluate the degree to which plan integration addresses flooding impacts and wetlands in Fort Lauderdale, FL and League City, TX. Third, using the city of Nijmegen, the Netherlands, as a case study, I use the resilience scorecard method to analyze how policies in the Dutch national flood mitigation program – "Room for the River" – are integrated into a local network of plans, and the ways this integration affects physical, social, and environmental vulnerability to flooding at the scale of the neighborhood.

1.2. Research Questions

The core challenge and public risks of climate change are the uncertainty of impacts of current hazards and future hazards, and the effectiveness of planning approaches to respond to the growing losses resulting from hazards and climate change. The literature shows that weak collaboration between agencies and local plan deficiency result in slow responses to climate change and hazard mitigation (Burby, 2003; Lyles, 2014). However, it remains unclear how networks of plans integrate mitigation policies that advance loss to the built and natural environments.

In this dissertation, I seek to answer three core research questions:

1. **What is the variability in level of integration of hazard mitigation into networks of plans adopted by six coastal cities? What factors influence the level of integration of mitigation in networks of plans in the coastal cities?**
    a. Is the relationship between physical vulnerability and plan integration performance stronger in some cities than in others?
    b. How does socio-economic status, renter population, physical vulnerability, previous hazard experience and local planning capacity influence incorporation of hazard mitigation in local networks of plans?
2. **What is the level of association between wetland alteration, and the degree to which networks of plans in policies that protect wetlands and local contextual factors in Fort Lauderdale and League City?**
    a. How does wetland cover within hazard areas change over time?
    b. How are plan integration, development intensity change, physical vulnerability and socioeconomic status associated with the rate of change in wetland land cover (at both

district and citywide scales)?

3. **How does plan integration affect physical, social and environmental vulnerability to flooding at the neighborhood scale in Nijmegen, the Netherlands?**
    a. How well-integrated are "Room for the River" program policies throughout the Nijmegen network of plans?
    b. How does this integration affect physical, social and ecological vulnerability to flooding at the neighborhood scale?

CHAPTER II

EXAMINING FACTORS INFLUENCING PLAN INTEGRATION FOR RESILIENCE

2.1. Introduction

Flooding poses the greatest threat to property and the safety of human communities compared to all other natural hazards (Breen & Rigby, 1996). Vulnerability is growing as a result of continued development in flood-prone areas and a lack of coordinated hazard mitigation planning (Cutter et al., 2008; Douglas et al., 2008).

The resilience of the built and natural environments is strongly influenced by the development and growth management guidance provided by a community's 'network of plans', which often includes land use, hazard mitigation, and transportation plans, among others. These plans guide development, including in hazard areas. The ways these multiple and independent plans interact can significantly impact community vulnerability (Berke et al., 2015; Berke et al., 2018). A well-integrated network of plans can aid in building resilient communities and reducing losses from flood events. Poorly coordinated plans may lead to conflict and duplication of efforts that can pose significant barriers to creating collaborative planning across different urban planning sectors. For example, a small area plan may suggest increasing density in a district, while a hazard mitigation plan recommends turning the same area into a park due to frequent flooding. To date, little is known about the factors that influence coordination in a community's network of plans, though planning capacity and local community context have been identified as key factors that influence both plan quality (Burby, 2003; Lyles, 2014) and the intent to protect the sensitive environmental areas (Dunlap et al., 2000).

This study investigates the influence of a series of factors on community plan integration for resilience at the district scale in six U.S. coastal cities using Hierarchical Linear Modeling.

We create and compare a set of hierarchical liner models to answer the following research questions: How much do coastal cities vary in their plan integration performance? What factors influence plan integration for resilience in six US coastal cities?

2.2. Prior Research

In the United States, hazard mitigation plans are often poorly integrated with other local plans, leading to development in hazard-prone areas (Berke et al., 2018). In its Sendai Framework for Disaster Risk 2015-2030, the United Nations recognized a similar trend in global hazard contexts, declaring the integration of resilience, hazard mitigation, and disaster risk reduction into land use planning as critical. (United Nations General Assembly, 2015). How well multiple and independent planning efforts are integrated can significantly impact future community vulnerability to hazards; conflicts that result from poor integration may actually increase risk.

To help planners achieve better coordination between multiple planning efforts, Finn, Hopkins and Wempe (2007) created an 'information system of plans' (ISoP) to facilitate the simultaneous access and use of multiple plans. The ISoP tool includes transportation plans, strategic plans for water resource management, comprehensive plans, green infrastructure visions, county zoning ordinances, historic preservation ordinances, solid waste management, and regional framework plans. Designed for use by planning and administration practitioners, the ISoP system offers users an overall picture of where the various overlapping plans conflict and cooperate, helping them address gaps and conflicts in across the various planning documents. It allows planners to simultaneously evaluate multiple plans, giving them a more comprehensive understanding of their communities. The ISoP is limited, however, in that it does not identify the potential positive or negative effects of plans. It focuses exclusively on current plans and projects, and pays no attention to hazard-prone areas or the effects that hazards may have on a community.

Responding to the calls for better integration of natural hazards throughout planning, Berke et al. (2015) designed a resilience scorecard to better analyze a community's networks of plans with respect to hazard vulnerability. The Plan Integration for Resilience Scorecard (PIRS) enables the evaluation of a community's network of plans with respect to its coordination and the degree to which it targets the most vulnerable areas (Berke et al., 2015; Berke et al., 2018). Applying the resilience scorecard in demonstration communities vulnerable to coastal flooding and sea level rise, Berke and colleagues investigated the crucial issue of plan integration and how to more effectively respond to the growing risks posed by hazard events, better inform the public and decision makers, and highlight gaps and conflicts in planning and policy instruments (Berke et al., 2015). Despite the innovation and perspective offered by the PIRS method, the drivers behind plan integration (or lack thereof) remained unexplored.

To date, little is known about the variables that influence coordination in a community's network of plans, though planning capacity and local community context have been identified as key factors that influence both plan quality (Burby, 2003; Lyles, 2014) and the intent to prepare a community for hazards (Dunlap et al., 2000). This study will build on the PIRS method, discussing and identifying the factors that influence plan integration for resilience through an empirical study of six coastal U.S. cities.

2.3. Conceptual Framework

The conceptual framework is to guide the analysis of factors that influence the degree of integration of hazard mitigation policies in networks of plans adopted by communities – the dependent variable. Based on the results of previous studies, several factors were included in the framework to be predictors of integration of hazard mitigation policies in plans. The factors include socio-economic status, renter population, physical vulnerability, previous hazard experience and local planner capacity that are hypothesized to explain the degree of integration of mitigation policies (Appendix Figure A.1).

2.3.1. Plan Integration

The term plan integration refers to the level that a network of plans adopted by a community work together to guide future land use and development patterns to achieve public goals. Goals can include, for example, ecosystem protection, reduction of vulnerability to hazards, and transportation mobility. Communities increasingly are adopting different types of plans for different sectors of urban planning such as land use, housing, emergency management, and environmental protection (Berke et al., 2018). Coordination among different plans has become increasingly complex and requires greater local capability to be aimed at coordination (Innes, 1996; Hopkins, 2001a, b).

In the case of hazard mitigation, communities are adopting a broad range of plans that influence development that can occur in hazard areas. Examples include requirements that local governments adopt consolidated plans that affect the supply and location of affordable housing units required by the U.S. Department of Housing and Urban Development, and hazard mitigation plans that influence land use and development in hazard areas required by the Federal Emergency Management Agency. Since the1990s, urban planning and hazard mitigation scholars have maintained that there is an important linkage between land use planning and community resilience (Burby, 2003, 2009). States like California, North Carolina and Wisconsin have recognized this linkage by mandating local adoption of comprehensive plans that require a hazard mitigation element. Communities also often adopt multiple functional plans (e.g., transportation, environmental) and small area plans (e.g., downtown, neighborhood redevelopment) on their own that can influence the pattern of development in hazard areas.

The combined impact of multiple and interdependent plans can influence the level of vulnerability to hazards. Strong integration of policies in different types of plans can enhance a community's ability to achieve goals. For example, a hazard mitigation plan may suggest buyouts in a high hazard area, while a parks and open space plan designates that same area as a new or expanded riverfront park. The strong integration between these two plans not only reduces the vulnerability, but also improves the livability in the city. Poorly coordinated plans can lead to conflict and duplication of effort that pose significant barriers to creating collaborative planning across different urban planning sectors. For example, a small area plan may suggest increasing density in a district, while a hazard mitigation plan recommends turning the same area into a park due to frequent flooding. In a review of planning for hazard mitigation, the National Resource Council communities concluded that support integrated planning are more resilient since they have improved ability to anticipate, collaborate across agencies and interest groups, adaptively respond to hazard events, and recover in ways that reduce future vulnerability (NRC, 2012).

2.3.2. Influences on Plan Integration for Resilience Scores

2.3.2.1. Planning Staff Capacity

Several scholars argue that local planner capacity contributes to stronger plans and more efficient policy implementation (Burby, 2003; Lyles, 2014). Low capacity indicates that planners may not have the time and resources to be involved in hazard mitigation activities. Thus, lack of capacity is likely to result in neglect of several hazard risks when formulating plans. For instance, decision-makers may emphasize development in central business districts within hazard areas but remain unaware of its consequences.

2.3.2.2. Local Community Context

Local community context dimension includes socioeconomic status, physical vulnerability, percent renters, and previous experience with hazard events.

<u>Socioeconomic status.</u> Several scholars have suggested that people with higher incomes are more likely to undertake hazard adjustment (Lindell and Prater, 2000; Peacock, 2003). Moreover, Lubell et al. (2009) noted that communities with higher socioeconomic status tend to be more supportive of implementing mitigation policies. Improved implementation of hazard mitigation policies would place greater emphasis on high risk areas and foster more resilient communities. In terms of reducing losses from hazard events, socioeconomic status often influences degree to which a community is likely to create a high quality plan and integrate mitigation into multiple plans. Per capita income is included as a measure of socioeconomic status for the above reasons, and because it is suggested as an important factor in prior studies of hazard mitigation (Brody et al., 2010; Peacock, 2003)

<u>Physical vulnerability.</u> Dimensions of physical vulnerability include buildings, structures, infrastructure, level of financial investment and structural integrity (Masterson et al., 2014). Physical vulnerability involves the interaction between geophysical forces and the built environment (Beatley, 2009), and is often the result of human decisions to place property in hazardous locations. Studies suggest that parts of a community that are more physically vulnerable and receive more investment are likely to be the focus of greater policy attention and have better preparation for future hazards (Burby, 1998; Godchalk, 2003). Thus, physical

vulnerability is hypothesized to be a crucial factor linking land use planning and hazard mitigation.

Percentage of households that are renters. Several scholars argue that percent of households in a community that rent is a significant factor for estimating post-disaster population dislocation and recovery (Fussell & Harris, 2014; Masterson, 2014; Peacock et al., 2007, 2014; Van Zandt et al., 2012). Fussell & Harris (2014) point out that renters, particularly those in subsidized housing, had higher vulnerability than homeowners in housing loss after disaster. Homeowners are better prepared for disasters, when compared to renters, as a result of higher investment in the property (Iwata & Yamaga, 2008). It is expected that a similar relationship may be found with respect to renters and the integration of mitigation policies throughout a network of plans. Areas with higher renter populations often receive less policy attention and investment – particularly with regard to hazard mitigation than those with higher rates of homeownership (Peacock et al., 2007). Thus, percentage of households that are renters is hypothesized to be a key factor influencing land use and hazard mitigation.

Previous hazard experience. A community's previous hazard experience functions as a "two-direction" factor. Some studies found that communities that had previously experienced hazards were more resilient than those with no hazard experience (Burby, 2003; Brody et al., 2003). Brody et al. (2009) noted that flood losses over five years and the adoption of non-structural approaches had positive influences on hazard mitigation output. Other studies, however, have suggested that previous hazard experience negatively influences mitigation outputs (Burby & Dalton, 1994). Disagreement persists over whether previous hazard experience yields positive influence on non-structural approaches to mitigation (Burby, 2003, 2009).

2.4. Design and Methods

2.4.1. Selection of the Cities

The sample selection in this study is based on population size and geographic variation from flood-vulnerable communities in the United States. Sample communities will be categorized into three levels by population size: large community, 250,000–1million; medium size community, 50,000-249,999; small size community, 10,000 – 49,999. Six flood-vulnerable communities in the United States include Asbury Park, NJ; Boston, MA; Fort Lauderdale, FL; League City, TX; Tampa, FL; Washington, NC.

2.4.2. Data and Measurements: Dependent and Independent Variables

The unit of analysis in this study is the sub-jurisdictional districts within the hazard zone (100-year floodplain) in six flood-vulnerable U.S. cities (n = 309). In order to spatially analyze both the vulnerability measures and the applicable plan policies, the community must be divided into sub-jurisdictional areas known as 'Planning Policy Districts'. Each applicable policy affects the vulnerability of the population (or the infrastructure, or the ecology, etc.) in each Planning Policy District differently, depending on the policy language and the land use characteristics in a district (Masterson et al., 2017).

U.S. Census block groups are a convenient and widely utilized sub-jurisdictional spatial unit (Masterson et al., 2017) and thus will form the basis for delineating Planning Policy Districts in most study communities in this research. However, because this analysis is policy- and plan-focused, other specialized sub-jurisdictional units (e.g., 'downtown' or historic neighborhoods) should be used when available—that is, when specifically referenced or mapped in approved community plans. These specialized districts are often the focus of planning initiatives and policies and thus have value as stand-alone districts. Figure 2.1 illustrates the difference between U.S. Census block group boundaries (left) and planning policy districts (right), derived by including the specialized ‘downtown’ as a stand-alone district.

Hazard zones must also be delineated for the community. These zones consist of the spatial extent of the community affected by a particular hazard—in this study, flooding. For the purpose of this analysis, the current 100-year is used for study cities.

Figure 2.1 U.S. Census block groups (left) and Planning Policy Districts (right). Source: Project materials.

A plan integration score (dependent variable) is derived for each hazard zone Planning Policy District in each city. The index measures the degree to which each community’s network of plans is then evaluated to determine the degree to which plans increase or decrease hazard vulnerability. Every Planning Policy District is assigned a score of ‘+1’, ‘-1’, or ‘0’ for every applicable land use policy. A score of ‘+1’ indicates that the policy is expected to positively affect flood vulnerability, while ‘-1’ indicates a negative effect. A score of ‘0’ indicates that the land use policy does not affect flood vulnerability in the Planning Policy District. After scoring each policy for each Planning Policy District in the hazard zone, we sum policy scores for each plan by each Planning Policy District. We then sum the scores for each Planning Policy District across the entire network of plans.

The scoring is performed independently by two researchers. To ensure reliability of rating plan policies inter-coding reliability scores were derived using both percent agreement for each policy (with mean 93.4%) and Krippendorff's Alpha (with mean 0.74) (Berke et al., 2018); Web-based tool "ReCal" (Freelon, 2013) was applied to compute intercoder reliability coefficients.

The five independent variables in this study (Table 2.1), including district-level socioeconomic status and physical vulnerability, and city-level percent renters, local planner involvement, and previous hazard experience. Socioeconomic status is measured by per capita income (Lubell et al., 2009; Grube et al., 2015). Physical vulnerability is tested by improved parcel value (Berke et al., 2015; Patterson & Doyle, 2009; Shi & Yu, 2014). Percent renters is measured by percentage of households that are renters (Fussell & Harris, 2014; Peacock et al., 2007, 2014; Van Zandt et al., 2012). Local planner involvement is measured in terms of the number of local planning staff (Burby, 2003; Lyles et al., 2014). Previous hazard experience is measured as the number of disasters in the five years prior to the date of plan adoption (Burby, 2003; Brody et al., 2003).

Table 2.1 Dependent and Independent Variables

Data Level	Variable	Measurement	Source
District Level	**Plan integration score** *(dependent variable)*	An index of land use-related policy for which the network of plan is assessed in the plans.	Plan Content Analysis Scorecard result
	Socioeconomic status	2010 Per capita income	2010 U.S. Census

Table 2.1 Continued.

Data Level	Variable	Measurement	Source
District Level	**Physical vulnerability**	2010 Improvement parcel value from appraisal records database of each city	2010 Parcel Boundary shapefile with parcel code
City Level	**Percent Renters**	Percentage of households that are renters	2010 U.S. Census
	Local planner involvement	Number of local planning staff	Plan Content Analysis
	Previous hazard experience	Number of disasters in the 5 years prior to the date of plan adoption	Public Entity Risk Institute

2.4.3. Data Analysis

Descriptive statistics are used to compare mean scores for plan integration across the six cities. Hierarchical Linear Modeling is used to evaluate the independent effects of district-level socioeconomic status and physical vulnerability – and city-level percent renters, local planner capacity, and previous hazard experience – on plan integration scores at the scale of Planning Policy Districts. Because Planning Policy Districts are ‘nested’ within cities, overlooking this ‘nested issue’ in our data analysis will cause several problems (Cronbach, 1976; Burstein, 1980): (1) biased estimation of the standard errors of the “Fixed Effects”; and (2) ignoring some important information, such as cross-level interaction effects. Thus, we create and compare a set of hierarchical liner models – random intercept model and random-coefficients regression model – to answer the research questions.

2.5. Findings

2.5.1. Plan Integration Performance across Six Coastal Cities

Results from a random intercept model indicate that plan integration performance is varied across the six coastal cities (Appendix Equation A.1). The estimated value of the variance in the city means, $\tau_{00} = 37.23$, is significantly different from zero (Table 2.2). Model results give a grand mean policy score of 18.03 for the six coastal cities (Table 2.2), which shows how much the coastal cities vary in their average plan integration score. The average correlation between districts within a coastal city is 0.19; therefore, the districts are not independent from each other. Thus, we can estimate a multilevel model.

Table 2.2 Grand Mean Plan Integration Score Across Six Coastal Cities

Variable (Fixed Effect)	**Coefficient**	**Standard error**	***t*-ratio**	***p*-value**
Grand mean plan integration score (γ_{00})	18.0328	0.7967	22.634	**<0.001*****
Between-city Variance Component(τ_{00})	37.2335			
Within-city Variance Component (σ^2)	157.0088			
p-value of the model	0.003***			

Note: n = 309; $^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.
The intra-class correlation is the ratio of city level variance ($\tau_{00} = 37.23$) to the total variance in the dependent variable ***plan integration score***, and shows that the proportion of variance that occurs at the city level is 0.19 (See Appendix Equation A.2).

The broad trends from the random intercept model can be better understood through a closer inspection of the mean plan integration score for plans in each of the six coastal cities. Figure 2.2 displays the mean policy score across all plans in a community. Scores are positive in Boston, MA (0.81), Fort Lauderdale, FL (16.75), League City, TX (29.10), Tampa, FL (17.35), and Washington, NC (6.00). This suggests that the network of plans in each of these cities generally supports vulnerability reduction. However, the mean plan integration score in Asbury Park, NJ, is -4.00. The variability in direction and strength of scores suggests differences across the study cities in terms of emphasis and prioritization of the policy frameworks supporting hazard vulnerability reduction. The question of what *factors* drive these variations remains unresolved, however. The remainder of this section is devoted to examining and discussing the factors influencing plan integration for resilience.

Figure 2.2 Mean Plan Integration Scores in Six Cities (100-year floodplain).

2.5.2. Factors Influencing Plan Integration Score: Hierarchical Linear Model #1

Results from a hierarchical linear model suggest that cities with a larger renter population and less recent hazard experience are less likely to incorporate hazard mitigation into local plans (Appendix Equation A.3). An inverse relationship was also found between the level of physical vulnerability and the degree of support for mitigation policies are integrated into networks of plans at the district scale. According to the first model, temporary population, previous hazard experience, and district physical vulnerability are significant predictors, whereas planning capacity and per capita income are not significant predictors of policy scores at 95% confidence level (Table 2.3). Each of these influential variables will be discussed below.

Table 2.3 Factors Influencing Plan Integration Score by District. (Hierarchical Linear Model 1)

Variable (Fixed Effect)	**Coefficient**	**Standard error**	***t*-ratio**	***p*-value**
Renter population ('Renters')	-0.6163	0.1023	-6.024	**<0.001*** **
Planning capacity ('Staff')	0.0220	0.0428	0.515	0.607
Previous hazard experience ('Previous')	0.4274	0.1834	2.330	**0.020** **
Physical vulnerability ('Physical')	-0.0096	0.0033	-2.951	**0.003*** **
Per capita income ('Percapita')	0.000038	0.000021	1.799	0.073*
Between-city Variance Component(τ_{00})	28.0343			
Within-city Variance Component (σ^2)	119.1244			
p-value of the model	0.005***			

Note: n = 309; *p < .10. **p < .05. ***p < .01.

2.5.2.1. Renter Population

Findings indicate that the percentage of households that are renters is a significant factor affecting plan integration score, and that cities with larger renter populations have lower average district policy scores, controlling for other factors at the city and district scales. The coefficient for the 'renters' variable is -0.62 (t = -6.02, p < .001). For every one percent increase in renter population of the city, other things being equal (controlling previous hazard experience, physical vulnerability, planning capacity, and per capita income), the average district policy score value decreases by 0.62.

This may be the result of less policy attention paid to areas with a higher percentage of renters; such areas tend to have larger transitory populations and/or lower socioeconomic status which often translates to less political power and influence. Long-term investment also tends to be relatively lower in such areas, both from property owners (landlords) and from the city (Van Zandt et al., 2012; Iwata & Yamaga, 2008).

2.5.2.2. Previous Hazard Experience

Previous hazard experience is another significant variable affecting plan integration for resilience; cities with more recent hazard experience have higher average district policy scores, controlling for the other city- and district-level factors. The coefficient for the ‘previous’ variable is 0.43 ($t = 2.33$, $p = .02$). For every one unit increase in previous hazard experience, other things being equal (controlling renters, physical vulnerability, planning capacity, and per capita income), the average district policy score value increases by 0.43.

This finding is consistent with previous studies regarding hazard preparedness (Brody et al., 2003; Burby, 2009), and suggests that previous hazard experience has a positive influence on supporting a policy framework to reduce hazard vulnerability. One potential reason is that recent hazard experience may promote greater ‘institutional memory’ and reinforce hazard awareness, leading to greater incorporation of hazard mitigation in local plans. Previous hazard experience is also influential in combination with physical vulnerability (as will be shown in next section), which is a significant factor in its own right.

2.5.2.3. Physical Vulnerability

District-level physical vulnerability significantly influences community plan integration; controlling for other community context variables, districts with higher physical vulnerability are less likely to have high policy scores. The coefficient for the *physical* variable is -0.01 ($t = -2.95$, $p < .005$). Because physical vulnerability is measured using average improved parcel value in districts as a proxy, this means that for every $100 increase in average parcel value, other things being equal (controlling *previous hazard experience, renters, staff,* and *per capita income*), the average district policy score value decreases by one point.

Districts with high physical vulnerability are typically high-value areas that have been the focus of significant investment. They are also often the focus of policies aimed at further intensification, which exacerbates the situation. Many downtown districts, for instance, are located in a hazard zone because they are near the site of the city's founding, which was often near a river or seaport. They are also economically important for the city, given their centrality and mixture of services, which makes them the focus of additional policies aimed at further densification or redevelopment.

This finding also suggests that more policy attention is being paid to the less physically vulnerable areas, which is consist with results from past studies (Burby, 2009). The analysis of League City's network of plans provides an example. Policies drawn from different plans work together to limit development in areas with low physical vulnerability, and several themes can be seen: (1) public expenditures for expansion of open spaces in undeveloped floodplains; (2) land use regulations that require additional mitigation actions for new development in floodplains; (3) public facilities for parks that reduce impacts of flooding; and (4) development limits linked to evacuation times for all new development in floodplains.

2.5.3. Relationship between Previous Hazard Experience and Physical Vulnerability, and Their Effects on Plan Integration Score: Hierarchical Linear Model #2

The previous section explained how and why different factors influence plan integration scores in the six coastal cities. Critical questions remain unanswered, however, regarding the relationships between factors, and especially how city-level factors interact with district-level factors. A second hierarchical linear model is thus used to clarify the relationship between city-level previous hazard experience, district-level physical vulnerability, and district plan integration scores (Table 2.4). Results from this model indicate that districts in cities with much hazard experience will have higher policy scores, *even if the districts have higher physical vulnerability*, compared to districts in cities with little previous hazard experience (Appendix Equation A.4). By focusing on the relationship between physical vulnerability and previous hazard experience, we see that plan integration performance is stronger in some cities (those with much hazard experience) than in others (those with little).

Table 2.4 Relationship Between Hazard Experience and Physical Vulnerability Factors, Regarding Influence Plan Integration Score (Hierarchical Linear Model 2)

Variable (Fixed Effect)	**Coefficient**	**Standard error**	***t*-ratio**	***p*-value**
Previous hazard experience (‘Previous’)	1.7634	0.2070	8.519	0.001***
Physical vulnerability (‘Physical’)	-0.4534	0.1570	-2.886	0.004***
Physical vulnerability slope (‘Previous*Physical’)	0.0221	0.0078	2.818	0.005***
Between-city Variance Component(τ_{00})	31.6325			
Within-city Variance Component (σ^2)	134.4006			
p-value of the model	0.004***			

Note: n = 309; *p < .10. **p < .05. ***p < .01.

As before, model results indicate that cities with more previous hazard experience have higher average district plan integration scores, controlling for the district’s physical vulnerability. The coefficient for the ‘previous’ variable is 1.76 (t = 8.52, p < 0.001). Also in line with the previous model, Table 2.4 shows that districts with higher physical vulnerability have lower average district plan integration scores, controlling for the city’s previous hazard experience. The coefficient for the ‘physical’ variable is -0.45 (t = -2.89, p = 0.004).

The coefficient for the physical vulnerability slope (‘Previous*Physical’) is 0.02 (t = 2.82, p = 0.005). Physical vulnerability scores across districts range from 0 to 2195.57, with a mean value of 31.19. For every one unit increase in previous hazard experience of the city, the average plan integration score value increases by 1.76 with the lowest physical vulnerability value and increases by 45.67 with the highest physical vulnerability value (Appendix Equation A.5).

Thus, the relationship between district physical vulnerability and district plan integration score is stronger in cities with much previous hazard experience than in cities with little previous hazard experience. This finding provides additional nuance to our understanding of the relationship between physical vulnerability and plan integration scores.

When the variables are viewed together, we find that districts in cities with more hazard experience will have higher plan integration scores, even if the districts have higher physical vulnerability, compared to cities with less hazard experience. Key reasons for this may include: (1) the extent of the vulnerability in such district may have recently been highlighted by the flood event, resulting in a planning and policy reaction with a goal of strengthening resilience; (2) more physically vulnerable parts of the city often receive greater policy attention, anyway – even if it is in the direction of increasing vulnerability – because they tend to be prominent and areas and of investment focus. That attention is more likely to be in the direction of reducing vulnerability if they recently experienced the effects of a flood event; and (3) when planners and policymakers are deciding where to direct resilience-focused hazard mitigation policy – particularly in the wake of a hazard event – they are more likely to focus it on the most physically vulnerable parts of their community—that is, the areas which have received the most previous investment. Therefore, previous hazard experience is a very influential city-level component for integrating and coordinating plans for resilience.

2.6. Conclusions and Implications

The primary conclusion to be drawn from the findings in this paper is that the first research question is generally affirmed. The level of plan integration is highly varied across the six coastal cities in the study, which suggests different policy emphases of the networks of plans in targeting different spatial areas. It also suggests that different cities have different priorities in their policy framework supporting hazard vulnerability reduction.

Communities with a larger “temporary” population and less pre hazard experience are less incentivized to incorporate hazard mitigation in local plans, when accounting for community planning capacity and other context. These findings are consonant with much existing literature; larger rental populations and problems of institutional memory may result in networks of plans that integrate hazard mitigation less effectively than in cities with a larger ‘settled’ population and recent experience with flooding.

The second set of research questions is also addressed by the hierarchical linear modeling analysis. Despite the fact that districts with higher physical vulnerability are less likely to incorporate hazard mitigation in local plans (controlling for other factors), districts in cities with much previous hazard experience have better plan integration performance (higher policy scores), even in districts with higher physical vulnerability, when compared to cities with little hazard experience. That is to say, the relationship between physical vulnerability and plan integration performance is stronger in cities with much hazard experience than in those with little hazard experience, and highly physically vulnerable places that have recently experienced flood events are more likely to have strong policy scores, so as to incorporate hazard mitigation in local plans.

The study findings indicate that plan integration performance is varied in six coastal cities. More integrated networks of plans are recommended to help build more resilient communities. Policies from across a community's network of plans should work together to limit development in areas with high physical vulnerability. From the findings, it is evident that greater policy attention should also be given to areas with a higher percentage of renters as such areas, which tend to have larger transitory populations and/or lower socioeconomic status, need additional, deliberate help in preparing adequately for hazard events. Proactively focusing attention and resources on these areas is an effective way increase the city's overall resilience to future flood events.

With this in mind, as well as what has been learned about several influential factors and the relationship between them, the next paper explores how plan integration addresses flooding impacts with respect to naturally occurring wetlands. It digs deeper into two coastal communities – Fort Lauderdale, FL, and League City, TX – to see whether plan integration has an influence on wetland protection and, if so, what types of policy themes and what kinds of policy frameworks are included in the community networks of plans to protect these critical ecosystems.

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CHAPTER III

EXPLAINING THE INFLUENCE OF PLAN INTEGRATION ON ECOLOGICAL RESILIENCE

3.1. Introduction

Coastal areas comprise approximately 17 percent of the land area and 52 percent of the population of the United States (Beatley, 2009) and regularly contend with flooding threats (especially from hurricanes and coastal storms) which are exacerbated by sea-level rise. The amount of vulnerable urban area is growing as development increases in flood-prone locations. Simultaneously, a lack of coordinated hazard mitigation contributes to increased losses from both surge- and rainfall-related flood events (Cutter et al., 2008; Douglas et al., 2008; Price & Vojinovic, 2008).

Coastal wetlands are effective in hurricane protection by absorbing storm energy, weakening storm intensities, and providing a buffer zone between residential areas and storm landfall—to be more specific, absorbing wave energy, decreasing the exposure of open water area to wind, cutting off the wind action on the water, and controlling water motion (Costanza, 2008; Farber, 1987). Wetland loss amplifies damage from floods over a larger area, and empirical research suggests that it may increase the frequency and magnitude of flood events (Brody et al., 2008). Even a small amount of wetland loss in a watershed can have a long-term impact on flood damage (Johnston, 1994).

Planning is also critical; the resilience of the built and natural environments is strongly influenced by the development and growth management guidance provided by a community's 'network of plans', which in many communities may comprise a comprehensive plan, hazard mitigation plan, parks or open space plan, and transportation plan (among others). This variety of plan documents guides development in hazard areas, and the ways these multiple and independent plans interact can significantly impact community vulnerability (Berke et al., 2015). A well-integrated network of plans that safeguards the natural environment – especially wetlands – can significantly aid in building resilient communities and reducing losses from flood events.

This study explores the influence of plan integration – along with several other key factors such as development intensity change, physical vulnerability, and socioeconomic status – on ecological resilience. It compares findings from Fort Lauderdale, FL, and League City, TX. The research questions examined are:

(1) How does wetland cover within hazard areas change over time for Fort Lauderdale and League City?

(2) How do plan integration, development intensity change, physical vulnerability and socioeconomic status affect the rate of change in wetland land cover (at both district and citywide scales)?

3.2. Ecological Resilience and Wetland Alteration

The concept of resilience has its origins in the field of ecology. Holling (1973) defined resilience as an ecosystem's ability to adapt to change; in ecological systems, resilience is rooted in essential functional groups and the accumulation of resources for recovery. Pimm (1984) built on this earlier definition to describe ecological resilience as the speed at which a system returns to its original state after a disturbance. More recently, scholars have begun to coalesce around a definition of resilience as an ecosystem's capacity to absorb perturbation (Holling et al., 1995; Lebel et al., 2006; Walker & Salt, 2006). In particular, Folke et al. (2002) interpreted resilience from the perspective of socioecological systems, manifested by three elements: absorption capacity, self-organization capacity, and adaptation capacity.

Several studies have used wetland alteration to measure ecological resilience (Brody, Peacock & Gunn, 2012; Brody et al., 2011, 2012, 2015; Reja et al., 2017). Brody et al. (2012)

suggest that wetlands function as a key ecological indicator of resilience in terms of flood mitigation, which is consistent with Cutter and colleagues' (2008) community ecological resilience indicators. Studies based on this concept and empirical observations and field research indicate that wetland loss can increase the frequency and magnitude of flood events. In a study that controlled for socioeconomic and geophysical factors, Brody et al. (2008) discovered that wetland loss in 37 coastal counties in Texas significantly exacerbated the level of flood damage, and that wetland alterations added over $38,000 in average property damage per event to a city's budget. Ogawa and Male (1986) applied a simulation model to evaluate wetland protection, finding that growing wetland losses increased stream peak flow.

3.3. Factors Associated With Wetland Alteration

This study draws on four sets of factors that are considered to be associated with wetland loss. They include the level of plan integration; low intensity development; physical vulnerability; and community socio-economic status.

Planning is critical; the resilience of the built and natural environments is strongly influenced by the development and growth management guidance provided by a community's 'network of plans'. Berke et al. (2015) designed a resilience scorecard to better analyze a community's networks of plans with respect to hazard vulnerability, in response to calls for better integration of natural hazards planning. The Plan Integration for Resilience Scorecard (PIRS) enables the evaluation of a community's network of plans to measure the degree coordination in different geographic areas in a community (Berke et al., 2015; Berke et al., 2018). Berke and colleagues applied the resilience scorecard in demonstration communities vulnerable to coastal flooding and sea level rise. They aimed to address the crucial issue of plan integration, and to demonstrate how planning can more effectively respond to the growing losses posed by hazard events, inform the public and decision makers, and highlight gaps and conflicts in planning and policy instruments (Berke et al., 2015). A well-integrated network of plans that safeguards the natural environment – especially wetlands – can significantly aid in building resilient communities and reducing losses from flood events. Plan integration is hypothesized to be an important factor associated with wetland loss.

Land use development patterns are highly related to flooding vulnerability and wetland loss (Arnold and Gibbons, 1996; Brody et al., 2006a). The more development that is concentrated within a flood zone, the more damage will occur, and flooding will affect more people in areas of intense development, such as high-density multi-family residential areas. Low-density development amplifies flooding risk because it increases impervious area, which generates more surface runoff (Brody et al., 2006a). Sprawling-type development in coastal areas leads to often-irreversible environmental damage, including loss of farmland, impervious surfaces replacing natural and open spaces, and a loss of wetlands and other lands that naturally attenuate flooding and act as buffers (Brody et al., 2008). A sprawling land use pattern is mainly due to overconsumption of otherwise functional lands, such as wetlands (Arnold and Gibbons, 1996). Poor understanding of the long-term risks associated with living in high-hazard areas is a key driver of this type of precarious development pattern (Berke and Lyles, 2013; Brody et al., 2008).

It is expected that different intensities of development will affect wetland loss differently (Brody et al., 2006a). Several studies focus on the environmental impacts and consequences of sprawl / low-intensity development (Benfield et al., 1999; Brody et al., 2006a; Kahn, 2000; Kenworthy and Laube, 1999), finding that low-intensity development is strongly related to wetland loss. This study will test the association between low-intensity development and wetland alteration, in particular, also building high- and medium-intensity development into the analysis. Thus, the change in development intensity is included as a key factor associated with wetland loss.

Dimensions of physical vulnerability include buildings, structures, infrastructure, level of financial investment and structural integrity (Masterson et al., 2014). Physical vulnerability involves the interaction between geophysical forces and the built environment (Beatley, 2009), and is often the result of human decisions to place property in hazardous locations. Studies suggest that more physically vulnerable areas, which receive more investment, are often the focus of policy attention aimed at further densification and greater pressure to transfer wetland areas to development (Burby, 1998; Godchalk, 2003; Brody et al., 2008). Thus, physical vulnerability is hypothesized to be associated with wetland loss.

Several scholars have suggested that people with higher incomes are more likely to value the protection of the natural environment (Dunlap et al., 2000). Moreover, Lubell et al. (2009) noted that communities with higher socioeconomic status tend to be more supportive of implementing environmental policies to protect wetland. Improved implementation of environmental policies would ensure greater emphasis on wetland areas and encouragement of ecologically resilient communities. This association will also be tested in this study.

3.4. Methods

This study explores the influence of plan integration, low intensity development, physical vulnerability, and socioeconomic status on wetland alteration in Fort Lauderdale, FL, and League City, TX. The unit of analysis is the sub-jurisdictional district within the hazard zone (100-year floodplain) in Fort Lauderdale (n=111) and League City (n=21) (Figure 3.1). U.S. Census block groups are a convenient and widely utilized sub-jurisdictional spatial unit

(Masterson et al., 2017), and thus form the basis for delineating districts in the study cities in this research. However, because the analysis of plan integration is policy- and plan-focused, other specialized sub-jurisdictional units should be used when available (that is, when specifically referenced or mapped in relevant community plans). These specialized districts are often the focus of planning initiatives and policies, and thus have value as stand-alone districts (e.g. downtown area). They are combined with block groups to form a more context-specific layer of mutually exclusive districts. Given the focus of this study, hazard zones must also be delineated, comprising the spatial extent of the community affected by a particular hazard—in this case, flooding. As a critical driver for land use policy, the FEMA-delineated 100-year floodplain is used, and districts within this hazard zone are examined for each of the study cities (Figure 3.1).

We test the *Pearson's r* to understand the relationships between wetland alteration and four key factors: the level of plan integration, low-intensity development, physical vulnerability, and community socio-economic status (Table 3.1)[1].

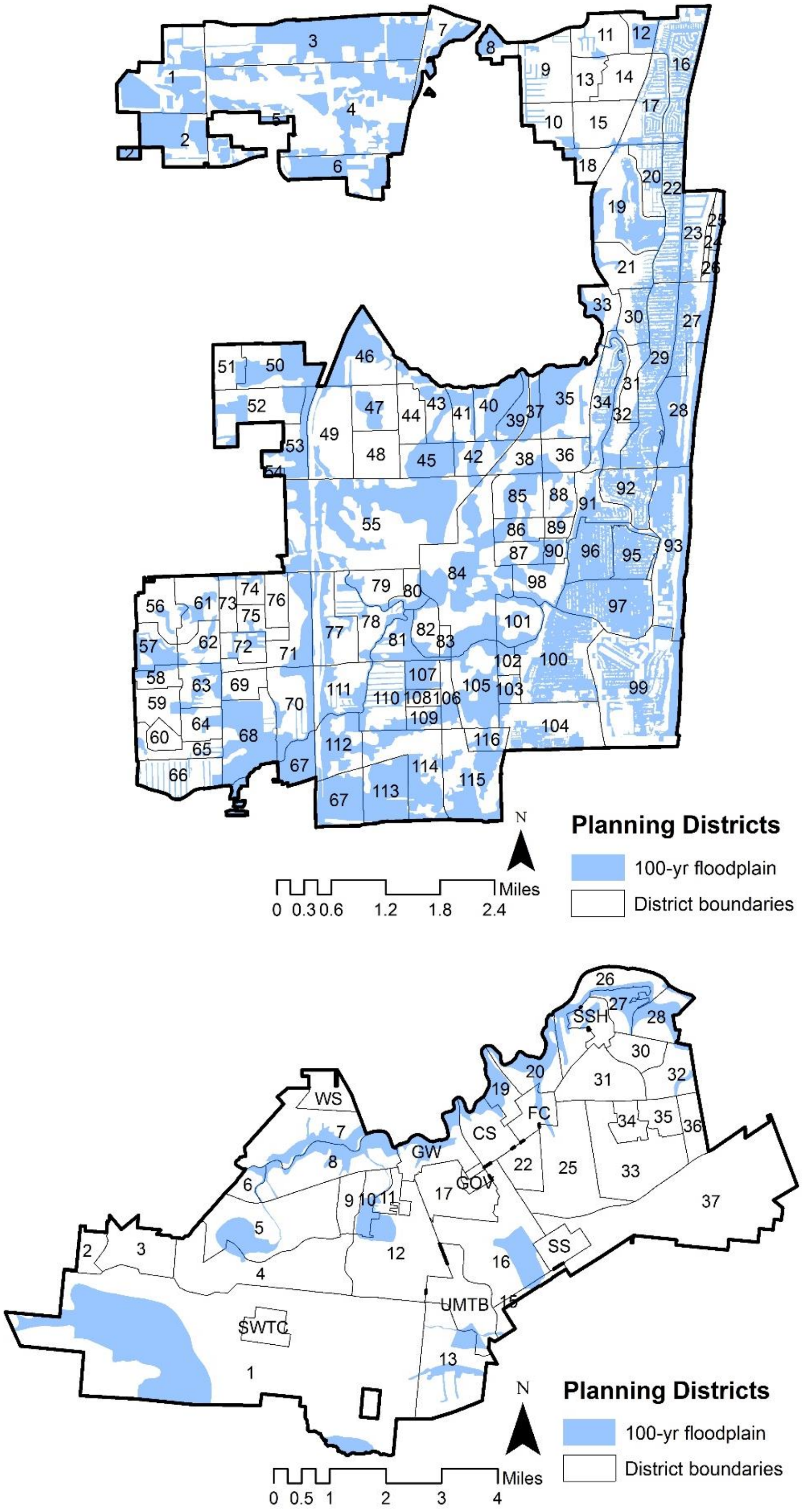

Figure 3.1 Planning districts and hazard zone in Fort Lauderdale, FL, and League City, TX. The 100-year floodplain is shown in blue.

Wetland alteration is measured by proportion of area change in wetland cover from 2006 to 2010 within the 100-year floodplain in each district (Brody, Peacock & Gunn, 2012; Brody et al., 2011, 2015), which is calculated by summing 30m^2 pixels from Landsat Thematic Mapper remote sensing imagery (Table 3.1). District-level plan integration scores are measured via an index derived from applying the Plan Integration for Resilience Scorecard method (Berke et al., 2015, 2018). Development intensity is measured by proportion of area change in low-/medium-/high-intensity development land cover from 2006 to 2010 (Brody et al., 2012; 2015). Low-intensity development is defined as areas with impervious surfaces occupying 20-49% of the total area; these areas typically include single-family housing units. Medium-intensity development is defined as areas with impervious surfaces occupying 50-79% of the total area; these areas also typically include single-family housing units. Finally, high-intensity development is defined as areas with impervious surfaces occupying 80-100% of the total area; these areas typically include apartment complexes, as well as commercial and industrial areas (Homer et al., 2012; Anderson, 1976). Physical vulnerability is ascertained using improved parcel value as a proxy (Berke et al., 2015; Patterson & Doyle, 2009; Shi & Yu, 2014). Socioeconomic status is measured via per capita income (Lubell et al., 2009; Grube et al., 2014).

For the plan integration measure, we evaluate plans adopted in each community that were in place prior to 2010. These plans were used by the community to guide development during the period that we evaluate wetland alteration (change in wetland cover from 2006 to 2010). A plan integration score is generated by spatially evaluating each of the four plans in Fort Lauderdale's network and two plans in League City adopted between 2006 and 2010 (Table 3.2). Every district is assigned a score of '+1', '-1', or '0' for every applicable land use policy in each plan. A score of '+1' indicates that the policy is expected to positively affect flood vulnerability, while

‘-1’ indicates a negative effect. A score of ‘0’ indicates that the land use policy does not affect flood vulnerability in the district. The scoring is performed independently by two researchers. Intercoder reliability was calculated using both percent agreement for each policy (mean = 91.04%) and Krippendorff’s Alpha (mean = 0.78); the web-based tool “ReCal” (Freelon, 2013) was applied to compute intercoder reliability coefficients. After scoring each policy for each district in the hazard zone, we sum policy scores for each plan by each district. We also sum the scores for each district across the entire network of plans.

Table 3.1 Factors Examined in This Study

Factors	**Measurement**	**Source**	**Reference**
Wetland alteration	Proportion area change in wetland cover from 2006 to 2010. Based on summing 30m^2 pixels based from Landsat Thematic Mapper remote sensing imagery.	NOAA, Coastal Change & Analysis Program	Brody, Peacock & Gunn (2012); Brody et al. (2011,2012,2015); Reja et al. (2017)
Plan integration	An index of land use-related policy for which the network of plan is assessed in the plans adopted between 2006 and 2010 in the study cities.	Plan Integration for Resilience Scorecard results	Berke et al. (2015; 2018); Malecha et al. (2018)
Low-/medium-/high-intensity development	Proportion area change in low-/medium-/high-intensity development cover from 2006 to 2010. Based on summing 30m^2 pixels based from Landsat Thematic Mapper remote sensing imagery.	NOAA, Coastal Change & Analysis Program, National Land Cover Database 2011	Brody et al. (2012,2015)
Physical vulnerability	2010 Improvement parcel value from appraisal records database of each city	2010 Parcel Boundary shapefile with parcel code	Berke et al. (2015); Patterson & Doyle (2009); Shi & Yu (2014)
Socioeconomic status	2010 Per capita income	2010 U.S. Census	Lubell et al. (2009); Grube et al. (2014); Aldrich (2012)

Table 3.2 Network of Plans in Fort Lauderdale and League City in This Study

Coastal Community	**Plans**
Fort Lauderdale	City of Fort Lauderdale Comprehensive Plan (2008) Consolidated Downtown Master Plan (2007) Downtown New River Master Plan (2008) Davie Blvd. Corridor Master Plan (2007)
League City	Parks & Open Space Master Plan (2006) Local Mitigation Plan (2010)*

*The 2010 hazard mitigation plan was an update of the prior version (2005). The update does not represent significant change from prior version. Thus, there is confidence that the update can be used to represent the prior version and can be correlated with wetland alteration between 2006 and 2010.
Source: Plan documents.

3.5. Contextual Conditions: Fort Lauderdale, FL, and League City, TX

In this section, the contextual conditions in each city are profiled. Table 3.3 indicates the areas exposed to the 100-year floodplain, population, average parcel value and average per capita income in these exposed areas in Fort Lauderdale, FL and League City, TX. Maps that illustrate 2006 and 2010 land cover in the 100-year floodplain, Fort Lauderdale, FL (Appendix Figure B.1) and League City, Texas (Appendix Figure B.2). The maps also show locations of wetlands in. 2006 and 2010, and district boundaries for each city.

Table 3.3 Contextual Conditions in Fort Lauderdale, FL and League City, TX (100-year floodplain)

	Fort Lauderdale, FL		**League City, TX**	
Area of Hazard Zone	10,816 acres	46.9%	5,184 acres	15.4%
Population in Hazard Zone	66,514	40.0%	8,488	9.9%
Average Parcel Value	$ 22.0/sq. ft		$2.65/sq. ft	
Average Per Capita Income	$37671.4		$37427.8	

Fort Lauderdale is the county seat and largest municipality in Broward County, with a 2010 population of 165,521 and a projected population of 205,769 by 2035 (U.S. Census Bureau, 2010). Nicknamed the “Venice of America”, due to its 337 miles of coastline, the city faces significant threats from flooding, thunderstorm, and hurricanes. The majority of the land use in Fort Lauderdale is a mix of residential (41%) and commercial (12%), industrial (6%), institutional (3%) and utilities (34%). The entire city is nearly completely built out. Only four percent of the total land area is vacant, most of which has been zoned for industrial, institutional, or commercial land uses (2008 Fort Lauderdale Comprehensive Plan, Volume II). A significant proportion of the land area (10,816 acres, 46.9%) and population (66,514 people, 40%) is located in the 100-year floodplain, including intensely developed locations.

League City is a bedroom suburb located southeast of Houston in low-lying coastal region with significant flooding risk, including from hurricanes (Berke et al., 2018). The city is high income, highly educated, and rapidly growing; its 2013 population of around 80,000 is expected to nearly triple, to a projected 228,000, by 2040 (League City, 2013). Currently, land use is dominated by conventional suburban development, including low- and moderate-density residential neighborhoods, commercial corridors, and retail centers (Berke et al., 2018). A significant proportion of the land area (5,184 acres, 15.4%) and population (8,488 people, 9.9%) is located in the 100-year floodplain. There is considerable potential for increased development in the floodplain; roughly 60% of the privately-owned floodplain remains undeveloped (League City Local Mitigation Plan, 2010). Prior floodplain development fragmented aquatic systems and drained or filled many wetlands along coastal creek and lake shores.

3.6.Findings: Fort Lauderdale, FL and League City, TX

3.6.1. Wetland Alteration

A significant proportion of the naturally occurring wetland areas in floodplains occur in both Fort Lauderdale and League City in 2010 (see Table 3.4). In Fort Lauderdale, wetlands cover 827.31 acres (7.65% of the 100-year floodplain land area), including both palustrine wetland (648.28 acres) and estuarine wetland (179.03 acres). In League City, wetlands include 434.78 acres (8.39% of the 100-year floodplain land area), including 279.11 acres of palustrine wetland and 155.68 acres of estuarine wetland.

Table 3.4 Wetland Alteration in Fort Lauderdale, FL, and League City, TX, from 2006 to 2010 (in the 100-year floodplain)

	Fort Lauderdale, FL			**League City, TX**		
	2006	2010	Change (%)	2006	2010	Change (%)
Palustrine Wetland	680.97	648.28	-32.69 (4.80%)	293.56	279.11	-14.46 (4.92%)
Estuarine Wetland	204.38	179.03	-25.35 (12.41%)	157.23	155.68	-1.56 (0.99%)
Total Area (Acre)	**885.35**	**827.31**	**-58.05** **(6.56%)**	**450.79**	**434.78**	**-16.01** **(3.56%)**

Wetland loss is greater in Fort Lauderdale than League City between 2006 and 2010. In Fort Lauderdale, the total wetland area in 2006 was 885.35 acres, but 58.05 acres (6.56%) of wetlands were lost over 4 years. The loss rate was 4.80% for palustrine wetland and 12.41% for estuarine wetland over 4 years. In League City, the total wetland area in 2006 was 450.79 acres, with 16.01 acres (3.56%) of wetlands lost over 4 years. The loss rate was 4.92% for palustrine wetland and 0.99% for estuarine wetland over 4 years.

However, whether the community's network of plans is critical in protecting wetlands remain unknown. The rest of this study is devoted to (1) examining plan integration performance in Fort Lauderdale and League City and identifying what types of policy themes and what kinds of policy frameworks are built into the community networks of plans to reduce hazard vulnerability and protect wetlands, and (2) testing how plan integration, low-intensity development, physical vulnerability and socioeconomic status affect wetland alteration between 2006 and 2010.

3.6.2. Plan Integration

Overall mean policy scores indicate that the network of plans generally supports vulnerability reduction in the 111 districts within the 100-year floodplain in Fort Lauderdale, FL, and the 21 districts in League City, TX. Overall mean policy scores for districts from the four plans in Fort Lauderdale (5.45) and two plans in League City (10.33) between 2006 and 2010 are positive (Table 3.5). Compared to Fort Lauderdale, plan integration and vulnerability reduction is somewhat stronger in League City, suggesting a difference in flood mitigation priorities between the two communities. These broad trends can be better understood through a closer inspection of the individual plan scores.

Table 3.5 Mean Policy Scores for Plans in League City and Fort Lauderdale (100-year floodplain)

	Multi-District Plan Scores Mean (#districts) [a]	
Plans	**Fort Lauderdale**	**League City**
City of Fort Lauderdale Comprehensive Plan (2008)	5.53 (111)	
Davie Blvd. Corridor Master Plan (2007)	-1.00 (7)	
Parks & Open Space Master Plan (2006)		4.48 (21)
Local Mitigation Plan (2010)		5.86 (21)

Table 3.5 Continued.

	Single-District Plan Scores [b]	
Plans	**Fort Lauderdale**	
Consolidated Downtown Master Plan (2007)	-1.00	
Downtown New River Master Plan (2008)	-2.00	
Overall mean for all plans [c] **(#districts)**	**5.45 (111)**	**10.33 (21)**

a. The mean is the sum of policy scores for each district covered by the plan divided by the total number of districts covered by the plan.
b. The single district score is the sum of policy scores for the district.
c. Overall mean is the sum of all policy scores from all plans for each district in the city divided by the total number of districts covered by all plans in the city.

The city of Fort Lauderdale's network of four plans adopted between 2006 and 2010 is somewhat integrated and generally reduces the vulnerability to hazards. The mean policy score for the 2008 Fort Lauderdale Comprehensive Plan is 5.53 (Table 3.5). The coastal management element in 2008 Fort Lauderdale Comprehensive Plan basically satisfies the requirements of Chapter 163, Florida Statutes that "local coastal governments plan for…[and] restrict development where development would damage or destroy coastal resources and protect human life and limit public expenditures in areas that are subject to destruction by natural disaster" (Fort Lauderdale 2008, p. 4-1). However, mean plan scores are negative for the other three plans in the network, including the 2007 Davie Blvd. Corridor Master Plan (-1.00), the 2007 Downtown Master Plan (-1.00), and the 2008 Downtown New River Master Plan (-2.00). The variability in direction and strength of scores suggests differences across the study plans in terms of emphasis and prioritization of the policy frameworks supporting hazard vulnerability reduction. Throughout the three negative scoring plans, more attention is paid to (re)development in the downtown and corridor plans.

Several notable policy themes work together in reducing existing vulnerability, protecting wetlands, and preventing future vulnerability due to new development or redevelopment. First, we find development regulations explicitly focused on protecting coastal areas and hazard-prone locations. Policies found in multiple chapters of the city’s comprehensive plan encourage adequate and appropriate protection and conservation of existing natural beaches, wetlands, and other kinds of open space, especially in hazardous areas. Second, land acquisition policies and guidelines for land use in hazard-prone areas are often targeted at reducing vulnerability for new developments and redevelopment projects (Masterson et al., 2017). Fort Lauderdale’s comprehensive plan contains policies suggesting that the undeveloped land in the Coastal High Hazard Area should be considered for acquisition as recreation and open space and restoration to its natural state. Moreover, the specific and cumulative impacts of development or redevelopment should be “limited upon wetlands, water quality, water quantity, wildlife habitat, living marine resources and the beach dune system” (Fort Lauderdale, 2008).Finally, many policies are aimed at directing capital expenditures related to coastal and hazard-prone areas.

League City’s Parks and Open Space Master Plan (2006) and Local Mitigation Plan (2010) support a common policy framework aimed at open space protection and hazard mitigation, with a mean plan score of 4.48 for the Park Plan and 5.86 for the Local Mitigation Plan across the 21 districts within the 100-year floodplain (Table 3.5). Both plans include the adopted future land use map, used by the city to guide future development and redevelopment. Areas designated for parks and low-density development generally coincide with flood hazard areas, and are supported by policies within each plan. A core attribute of the two plans is to protect people and structures using smart development and environmental management practices aimed at supporting flood mitigation.

There are several themes in the policies drawn from League City’s two plans that focus on limiting development in low-vulnerability areas and protecting wetlands. First is the suggested designation of public expenditures for expansion of open spaces in undeveloped floodplains. The Parks and Open Space Master Plan specifies that city funds for land acquisition be used to target undeveloped preservation areas (e.g. marshes, wetlands) that offer flood mitigation benefits as well as recreational and other open space benefits, such as wildlife habitats and water conservation. Policies in the Local Mitigation Plan explicitly support public investment in parks and open spaces in the floodplain. Second, land use regulations often require reduction in vulnerability for new development in undeveloped floodplain areas. The implementation elements of both plans indicate that the city revise ordinances to carry out the intentions of the comprehensive plans. Finally, the plans suggest public facilities for parks that will reduce the impacts of flooding. The parks plan proposes investment in a string of flood detention lakes, connected by trails, to be located along a regional drainage corridor with parks integrated in areas adjacent to the lakes.

3.6.3. Associations between Wetland Alteration and Plan Integration, Development Intensity Change, Physical Vulnerability and Income

Findings in the previous section reveal discrepancies in the ways plans affect flood resilience in Fort Lauderdale and League City, most conspicuously in terms of how they target reducing flood vulnerability and protecting wetlands. The questions of how plan integration, low intensity development, physical vulnerability and income are associated with wetland alteration remains unresolved. In Figure 3.2, wetland alteration between 2006 and 2010 is correlated with four different factors (plan integration scores for plans adopted between 2006 and 2010; low intensity development area change between 2006 and 2010; physical vulnerability; and per capita income). Correlation results are shown for Fort Lauderdale and League City, at the district scale, within the 100-year floodplain.

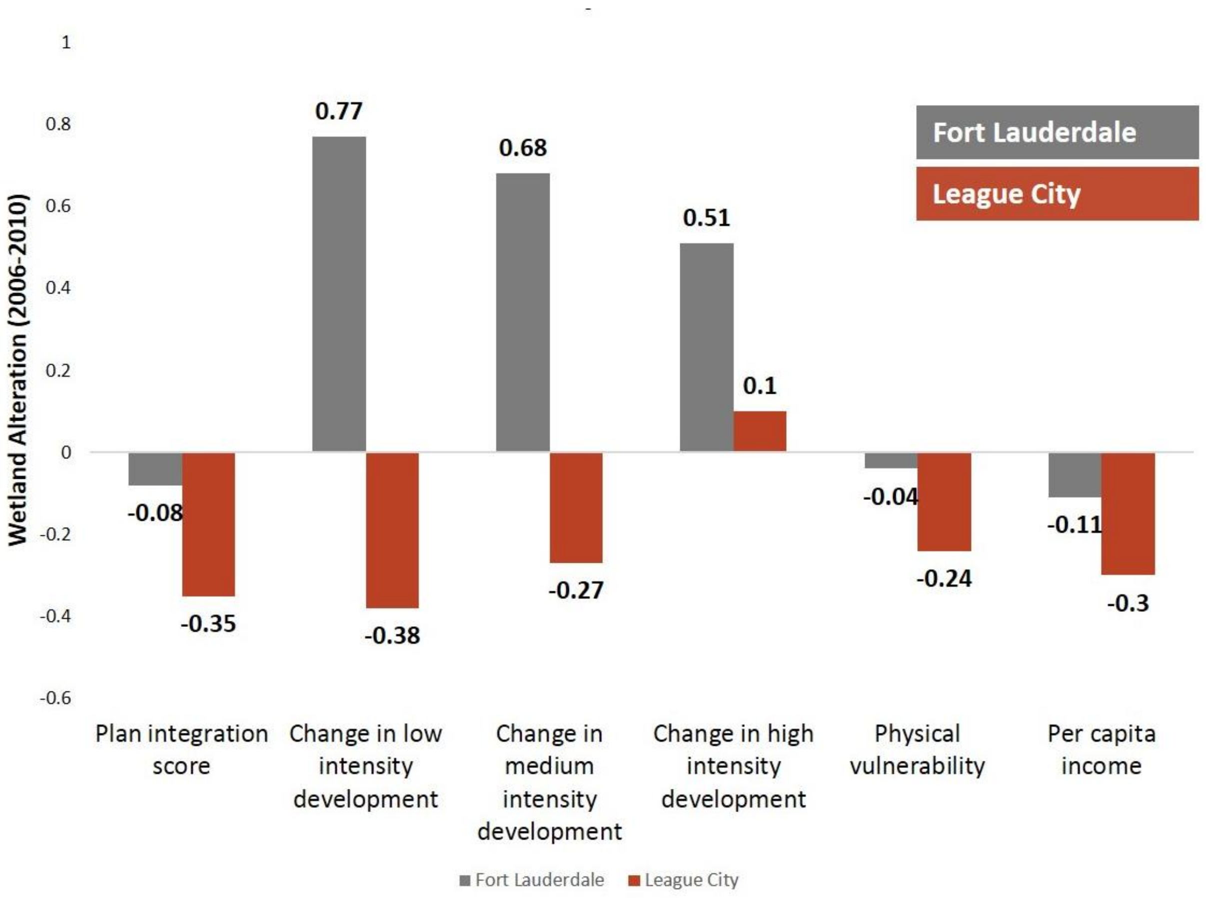

Figure 3.2 Correlations between wetland alteration and plan integration score, change in low-/medium-/high-intensity development, physical vulnerability and per capita income.

The results indicate *an inverse relationship* between wetland alteration and *plan integration scores* in both Fort Lauderdale (-0.08) and League City (-0.35) (Figure 3.2). That is, districts that experience greater wetland loss have higher integration scores. Areas of the community experiencing the greatest wetland loss are the focus of more policy attention. It may be that policies across the network of plans are being adopted to arrest the trend of wetland loss and strengthen resilience, particularly in the areas already experiencing environmental degradation. Variation exists, however, between the two cities. As Fort Lauderdale is a nearly fully built-out city, the level of plan integration appears to have less influence on wetland alteration in Fort Lauderdale than it does in League City—a rapidly developing and densifying community. Appendix Figure B.2 shows that most of the wetland area in League City is along the creek, proximate to intense development. That area has high potential to be densified and also experiences high development pressure. A well-coordinated policy framework to reduce existing vulnerability and protect wetlands for the city as a whole may have been put in place to focus policy attention on wetland loss "hotspots" in League City. This suggests that the network of plans targets areas of higher wetland loss, particularly in League City. Plans may be reacting to such trends in wetland loss and explicitly setting priorities to better conserve wetlands.

Correlation results between *wetland alteration* and change in *low-intensity development* are positive for Fort Lauderdale (0.77) and negative for League City (-0.38) (Figure 3.2). In Fort Lauderdale, a reduction in low-intensity development in an area is associated with more wetland loss. This indicates that wetland areas are not generally transformed into low-intensity development; rather, low-intensity development areas may be densified into medium- or high-density development areas. That is to say, in Fort Lauderdale, low-intensity development area is lost while wetland area is lost between 2006 and 2010 (Figure 3.2). As the comprehensive plan suggests, "…the City is nearly built-out, [so] new development is unlikely to impact threatened and endangered species in the coastal area. Coastal vegetation is not likely to be impacted by development because there are very few vacant development sites and redevelopment sites are already disturbed" (Comprehensive Plan, 2008, Coastal Management Element, Page 4-8). Positive correlations are also found between *wetland alteration* and change in *medium-intensity* (0.68) and *high-intensity development* (0.51) in Fort Lauderdale, but with less magnitude. This may indicate that developed lands of all intensities in Fort Lauderdale's 100-year floodplain are either being further intensified *or* returned to managed open space between 2006 and 2010.

Wetland alteration appears to be highly associated with changes in low-, medium- and high-intensity development patterns.

In contrast, in League City, wetland area loss within the 100-year floodplain of a district is correlated with an increase in low-intensity development. This association is also seen with medium-intensity development area (-0.27), but not with high-intensity development area (0.1). This suggests a transfer of wetland areas into low-intensity and medium-intensity development areas between 2006 and 2010 in the 100-year floodplain. Thus, wetland alteration appears to be highly associated with an expansion of low- and medium-intensity development in League City.

For physical vulnerability, correlation results are negative for both Fort Lauderdale (-0.04) and League City (-0.24). This indicates that wetland loss was greater in the highly physically vulnerable areas between 2006 and 2010 in both Fort Lauderdale and League City. Districts with high physical vulnerability are typically high-value areas that have been the focus of significant investment, and are often the focus of policies aimed at further intensification, which exacerbates the situation. They are also economically important for the city, given their centrality and mixture of services, which makes them the focus of additional policies aimed at further densification or redevelopment. Therefore, districts with high physical vulnerability have more potential to transfer wetland areas to development, thereby increasing wetland loss.

For per capita income, correlation results are also negative for both Fort Lauderdale (-0.11) and League City (-0.30). This suggests that wetland loss is greater in wealthier areas between 2006 and 2010 for both cities. Districts with high real estate values usually signal desirable locations, where development pressures are likely to be greater. Thus, districts with high per capita income have greater potential for development, including wetland areas.

3.7. Conclusions and Implications

The rate of change in wetland land cover within the 100-year floodplain was faster in Fort Lauderdale (6.56%) than in League City (3.56%) from 2006 to 2010. The primary conclusion to be drawn from the findings in this paper is that the second hypothesis – that higher 'network of plans' integration will lead to more flood-resilient and robust ecosystems – is largely affirmed. Several prominent themes of policies and policy frameworks are built into the community networks of plans, in order to support and protect the functionality of wetland areas and reduce hazard vulnerability in both Fort Lauderdale and League City. In addition, the network of plans targets areas of higher wetland loss, particularly in League City. Plans may be reacting to such trends in wetland loss and explicitly setting priorities to better conserve wetlands.

Wetland alteration is shown to be strongly associated with high-, medium-, and low-intensity development patterns. Variation exists, however, between the two cities. The area of low-intensity, medium-intensity, and high-intensity development is reduced while wetland area is lost between 2006 and 2010 within 100-year floodplain in Fort Lauderdale, suggesting major development changes in areas of the city that lost wetlands during the time period. In contrast, in League City, the more wetland area is lost in the 100-year floodplain in districts that show an increase in low-intensity and medium-intensity development, indicating that wetland areas are likely to have been transferred into low-intensity and medium-intensity development areas between 2006 and 2010 in League City. Districts with high physical vulnerability are typically high-value areas that have been the focus of significant investment, and are often the focus of policies aimed at further intensification, which exacerbates the situation. Therefore, districts with high physical vulnerability have more potential to transfer wetland areas to development, thereby increasing wetland loss. Also, Districts with high real estate values usually signal desirable locations, where development pressures are likely to be greater. Thus, districts with high per capita income are more likely to experience wetland loss in both Fort Lauderdale and League City.

Naturally occurring wetlands provide various essential ecosystem services to communities, and their loss will amplify property damage from floods over a larger area, especially for coastal communities (Beatley, 2009). Undervaluing these valuable natural ecosystems may have the effect of compromising safety in coastal communities. Thus, effective planning that helps protect naturally occurring wetlands can significantly aid in building resilient communities and reducing the growing losses from hazard events. Improvements in policies for integrating wetland protection with flood mitigation, adopting wetland protection ordinances, and exceeding minimum NFIP requirements are therefore recommended. The process of incorporating wetland protection into the local network of plans not only helps reduce the impact on wetlands, but also enables the setting of priorities to conserve critical wetland “hotspots” (Strommen et al., 2007).

The next paper explores how plan integration affects physical, social, and environmental vulnerability to flooding at the neighborhood scale in Nijmegen, the Netherlands. The study applies a Plan Integration for Resilience Scorecard in a different context—in a community that is the focus of an innovative, large-scale planning effort of national significance: the “Room for the River” program in the Netherlands. Such a massive undertaking carries the potential for conflict with existing plans and policies. The PIRS methodology offers a new perspective and empirical data to evaluate such conflict.

3.8. References

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3.8.1. Endnotes

[1] State-mandated planning is a potentially extraneous factor not controlled by the research design and statistical measurements employed in this study. In particular, during the 2006-2010 study period Florida had state mandated local planning in place since the 1970s, but Texas did not. Since this difference is not accounted for, the analysis could produce spurious results. The presence of a state mandate could create a climate in Florida that is more supportive of planning to support wetland protection than existed in Texas, so that the associations attribute to the Florida mandate could in fact be linked to the mandate rather than the plans that are studied. Nevertheless, the other factor linked to change in low-intensity development creates pressure for supporting wetland protection, which adequately addresses this threat to validity.

CHAPTER IV

EXPLORING THE INFLUENCE OF PLAN INTEGRATION ON COMMUNITY VULNERABILITY

4.1. Introduction

Different community plans (e.g. land use, transportation, environmental) guide growth and development in hazard areas, and the interaction of multiple and independent plans can significantly impact future community vulnerability to hazards. The Netherlands is one of the most flood-vulnerable countries on earth, with 55 percent of housing located in areas subject to flooding (Slomp, 2012). Although large-scale coastal engineering projects have effectively mitigated the threat of flooding from the sea, near- and long-term uncertainties remain with respect to riverine flooding. Dutch government addressed this with a new approach—making more room for water rather than strengthening the dikes.

Given the importance of community plans for spatial development, a lack of coordination between this “Room for the River” initiative and a community’s network of spatial plans may still increase the vulnerability of communities and the built environment. Little is known about the degree to which community plans are coordinated with the “Room for the River” program, or about how this may affect existing physical, social, and environmental vulnerabilities. Plans that pursue conflicting goals, or that fail to adequately focus on the most vulnerable areas in a community, can ultimately exacerbate flood risk (Berke et al., 2015).

This study explores the influence of plan integration on community resilience to flooding in the Dutch city of Nijmegen, the location of the flagship “Room for the River” project in the Netherlands. The goals of the program are to increase the long-term flood safety while simultaneously enhancing spatial quality. In the Dutch context, ‘spatial quality’ is a concept that emphasizes the holistic impact of spatial planning on the living environment (ESPON, 2017). The concept is oftentimes associated with livability and the protection of green space and ecological values (Ibidem). The research questions examined are: (1) How well-integrated are “Room for the River” program policies throughout the Nijmegen network of plans? (2) And how does this integration affect physical, social and environmental vulnerability to flooding at the neighborhood scale?

4.2. Plan Evaluation, Networks of Plans, and the Resilience Scorecard

Plan evaluation is an efficient and feasible way to define plan quality, with the ultimate aim to improve the performance of spatial planning in pursuit of more livable communities. Several scholars have defined the characteristics of high quality plans with regards to the influence of local government decisions and the potential to achieve plan implementation (Lyles, Berke & Smith, 2016; Nelson & French, 2002; Oliveira & Pinho, 2009). Berke and French (1994) specified that high quality plans consist of three general characteristics: (1) a fact basis that can completely define local demands; (2) clear goals to address the local needs; and (3) detailed and executable policies that can fulfill the plan’s goals. Berke & Godschalk (2009) further distinguished between internal and external plan quality, following Baer (1997) and Hopkins (2001a, b). This was subsequently, developed into a larger set of characteristics covering the breadth of elements included in spatial land use plans (Berke & Lyles, 2013; Lyles & Stevens, 2014). Baer (1997) distinguished the five evaluation stages of the planning process: plan assessment, testing, plan critique, comparative study and professional plan evaluation, and post-implementation evaluation. These studies form a strong foundation for evaluating the quality of individual plans, but they do not account for the growing trend of communities being guided by multiple plans – often developed independently by various government and nongovernment stakeholder groups (Hopkins & Knapp, 2016). Gaps remain with respect to evaluating consistency within a network of local plans.

Modern planners are often required to work consistently with multiple plans and different interest groups (Hopkins, 2001a, b; Hopkins, Kaza & Pallathucheril, 2005). To help planners achieve this goal, Finn, Hopkins and Wempe (2007) created an information system of plans (ISoP) to facilitate the simultaneous access and use of multiple plans. The ISoP tool includes transportation plans, strategic plans for water resource management, comprehensive plans, green infrastructure visions, county zoning ordinances, historic preservation ordinances, solid waste management, and regional framework plans. This system offers users an overall picture of 'hotspots' where the various overlapping plans conflict and cooperate, helping users address the gaps and conflicts in the entire planning system of documents. The development of ISoP allows planners and other stakeholders to simultaneously evaluate multiple plans, across the entire regional planning system, giving them a more accurate and comprehensive understanding of their communities.

The ISoP is limited, however, in that it does not identify the potential positive or negative effects of plans – only areas where plans and projects overlap and may conflict. It exclusively focuses on current plans and projects, and does not pay attention to hazard-prone areas or the effects of hazards in a community. The growing emphasis on resilience in response to the pandemonium of natural disasters around the globe (GFDRR, 2017), increases the urgency of explicit and consistent consideration of community vulnerability within networks of plans.

Community disaster resilience should be built upon a thorough understanding of all dimensions of exposure and vulnerability (United Nations General Assembly, 2015), including physical, social, and environmental aspects. According to The United Nations Office for Disaster

Risk Reduction, vulnerability is the “conditions determined by physical, economic, social and environmental factors, which increase the susceptibility of a community to the impacts of a hazard” (UNISDR, 2015, P. 31). Dimensions of physical vulnerability include buildings, structure, infrastructure, level of financial investment and structural integrity (Masterson et al. 2014). Social vulnerability is defined in relation to the capacity of a person or group to anticipate, resist, and recover from the impact of natural hazards, and influenced by features like age, household composition, income, race and ethnicity (Cutter, Boruff & Shirley, 2003; Peacock, Van Zandt, Zhang & Highfield, 2014; Masterson et al., 2014). Environmental vulnerability is defined by Williams and Kapustka (2000) as the potential of an ecosystem to respond to stress and threats across time and space. Approaches for measuring each of these vulnerabilities are described in the Applying the Plan Integration for Resilience Scorecard in Nijmegen section.

4.2.1. Plan integration for resilience scorecard

Most communities in the U.S. have a comprehensive plan, hazard mitigation plan, open space plan, and transportation plan. Unfortunately, these plans often do not integrate and coordinate well (Berke, Malecha, Yu, Lee & Masterson, 2018). For example, a small area plan may suggest increasing density in a district, while a hazard mitigation plan recommends turning the same area into a park due to frequent flooding. In the U.S., local hazard mitigation plans are often poorly integrated with other local plans, leading to development in hazard-prone areas (Berke et al., 2018). In its Sendai Framework for Disaster Risk 2015-2030, the United Nations (UN) recognized a similar trend in global hazard contexts, declaring as critical the integration of resilience, hazard mitigation, and disaster risk reduction into land use planning. (United Nations General Assembly, 2015). In addition, how well multiple and independent planning efforts are integrated can significantly impact future community vulnerability to hazards; conflicts that result from poor integration may actually increase risk.

Berke et al. (2015) designed a resilience scorecard to better analyze a community's networks of plans with respect to hazard vulnerability, in response to calls for better integration of natural hazards planning. The Plan Integration for Resilience Scorecard (PIRS) enables the evaluation of a community's network of plans with respect to its coordination and the degree to which it targets the most vulnerable areas (Berke et al., 2015; Berke et al., 2018). Berke and colleagues applied the resilience scorecard in demonstration communities vulnerable to coastal flooding and sea level rise. They aimed to address the crucial issue of plan integration, and to demonstrate how planning can more effectively respond to the growing losses posed by hazard events, inform the public and decision makers, and highlight gaps and conflicts in planning and policy instruments (Berke et al., 2015).

The PIRS was developed as a method for evaluating local policies as they guide day-to-day planning and development efforts. Our study applies this methodology in a different context—in a community that is the focus of an innovative, large-scale planning effort of national significance: the "Room for the River" program in the Netherlands. Such a massive undertaking carries the potential for conflict with existing plans and policies. The PIRS methodology offers a new perspective and empirical data to evaluate such conflict.

4.3. Dutch Planning and "Room for the River" Program

4.3.1. Understanding Dutch Planning

The Dutch spatial planning system was originally conceived to prevent sprawl, improve efficiency in land use, and protect open space for natural and agricultural purposes (Faludi & Van der Valk, 2013; Van der Valk, 2002). It is built upon consensus-building among political institutions, stakeholders, and experts (Van der Horst, 1996), and is noted for being in genuine pursuit of comprehensive spatial rather than sectoral goals (Nadin & Stead, 2012). Dutch spatial planning follows the nation’s three-tiered administrative system; national, provincial, and municipal government all produce plan documents. The most powerful of these is the municipal land use plan (bestemmingsplan) (Buitelaar & Sorel, 2010; Hobma & Jong, 2016), which is legally binding for citizens and streamlines policy and regulation from municipal, provincial and national authorities. National and provincial plans traditionally focus on so-called ‘above-municipal issues’ (Buitelaar, Bregman, van Ree & de Zeeuw, 2014), with national policies increasingly limiting their focus to infrastructure development, while provinces are expected to address the preservation of open green space and ecological values (Hobma & Jong, 2016; ESPON, 20171). Before 2008, compliance with higher-tier spatial policy was mandatory, and municipal plans were checked for consistency and ratified by the provincial government (Hobma & Jong, 2016; ESPON, 2017). Currently, lower-tier plans need only comply with the regulatory components of higher-tier spatial policy, and ratification is no longer required – although a 2014 study found that compliance with provincial and national spatial plans is still considered as mandatory (Buitelaar et al., 2014).

In terms of dealing with flood safety, the Netherlands is moving from mere regulation to integration of water management policies into strategic spatial plans at different spatial scales (Woltjer & Al, 2007; ESPON, 2017). Traditionally, flood safety is the responsibility of the regional Water Authorities (waterschappen) or the national executive agency of the Ministry for Water and Infrastructure (Rijkswaterstaat). Water Authorities are independent governmental entities that levy taxes and create their own - non-spatial - policies and regulations within the embanked areas. For the unembanked areas – sites outside of the system of primary flood defenses, oftentimes in riparian areas – no safety standards apply and responsibility for flood safety is more ambiguous (Malecha, Brand & Berke, 2018). To encourage streamlining of policies, consultation of water managers during the creation of a land use plan via a water assessment has become mandatory in recent years, often with emphasis on offsetting development with water storage rather than flood safety (Hobma, 2016; Woltjer & Al, 2007). The pursuit of flood safety in the Netherlands traditionally relies on technological interventions like dikes, dams, floodgates and pumps (Wesselink, 2007). Uncertainty about sea level rise and river discharges due to climate change has resulted in the national Delta Program, which is in charge of a series of large-scale interventions that safeguard flood safety on the long-term. The Room for the River-program, with its explicit goal to widen the riverbed while stimulating spatial quality, is part of the Delta Program and was translated in a statutory plan instrument: the National Planning Core Decision (PKB). The use of a PKB implies that compliance in lower-tier plan documents is mandatory, and therefore consistency within Nijmegen's network of plans can be expected. Along with its focus on large-scale (technological) interventions, the Delta Program is increasingly concerned with the coordination of planning for risk reduction in sites where raising dikes would cause unacceptable damage to the living environment—the concept of Multilayered Safety, where the built environment itself is adapted to become less vulnerable to flooding, has been translated in a few pilots (Hoss, Jonkman & Maaskant, 2011).

In sum, despite the sectoral origins of flood safety on the one hand and spatial and environmental planning on the other, the Dutch planning system appears to follow a trend of increased streamlining and coordinating of policies into spatial plans—a trend observed by the European Spatial Planning Observation Network programme (ESPON, 2017). A key question here is if that trend is also recognizable in Nijmegen's network of plans.

4.3.2. Case selection: City of Nijmegen – The flagship “Room for the River” project in the Netherlands

The city of Nijmegen is selected for several reasons, including its location along the Waal River, which makes it naturally exposed to riverine flooding. Also, the project in Nijmegen is the largest and flagship project of the national “Room for the River” program. Nijmegen is a city in the Dutch province of Gelderland with a 2011 population of 164,223. The city’s "Room for the River" plan was given the "Excellence on the Waterfront Honor Award 2011" by the Washington, D.C.-based Waterfront Center, due to its success in combining flood safety and the construction of a park along the riverfront, the development of which included close collaboration with the local community (Waterfront Center, 2011). The twin goals of the “Room for the Waal” program are (1) to protect the City of Nijmegen from future floods and (2) to enhance spatial quality. At Nijmegen, river dikes are not simply raised or strengthened: instead, the northern river dike is relocated to create a wider floodplain that gives future floodwaters more room to flow, reducing the threat to the city (Figure 4.1). Additionally, all engineering projects were designed to do more than control flooding; parks and nature areas were included in the designs as co-benefits of the initial flood safety goal.

4.4. Applying the Plan Integration for Resilience Scorecard in Nijmegen

Plan integration and hazard vulnerability analysis in Nijmegen follows the three-phase procedure developed by Berke et al. (2015) (Figure 4.2). This study expands the ‘network of plans’ to administrative documents beyond local plans, because the main focus is the national flood safety program ‘Room for the River’.

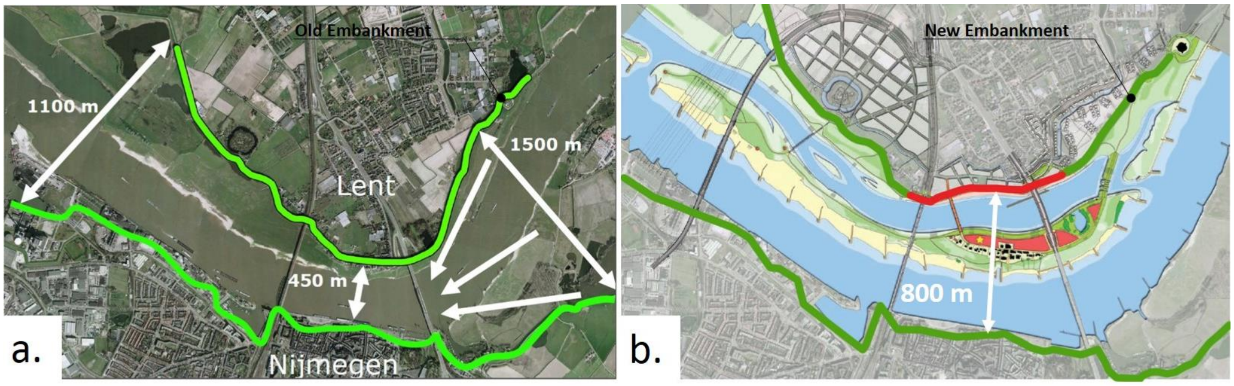

Figure 4.1 “Room for the River” Program in Nijmegen. **a.** Riverfront before implementation. **b.** Riverfront after implementation. Note that a large portion of the dike (bold green lines) has been moved 350 meters inland (red line in ‘b’); a channel has been dug in order to give the River Waal more room to flow, creating an island; and three new bridges have been added to enhance connectivity between the island and riverfront neighborhoods.
Source: Adapted from “Room for the River” project material.

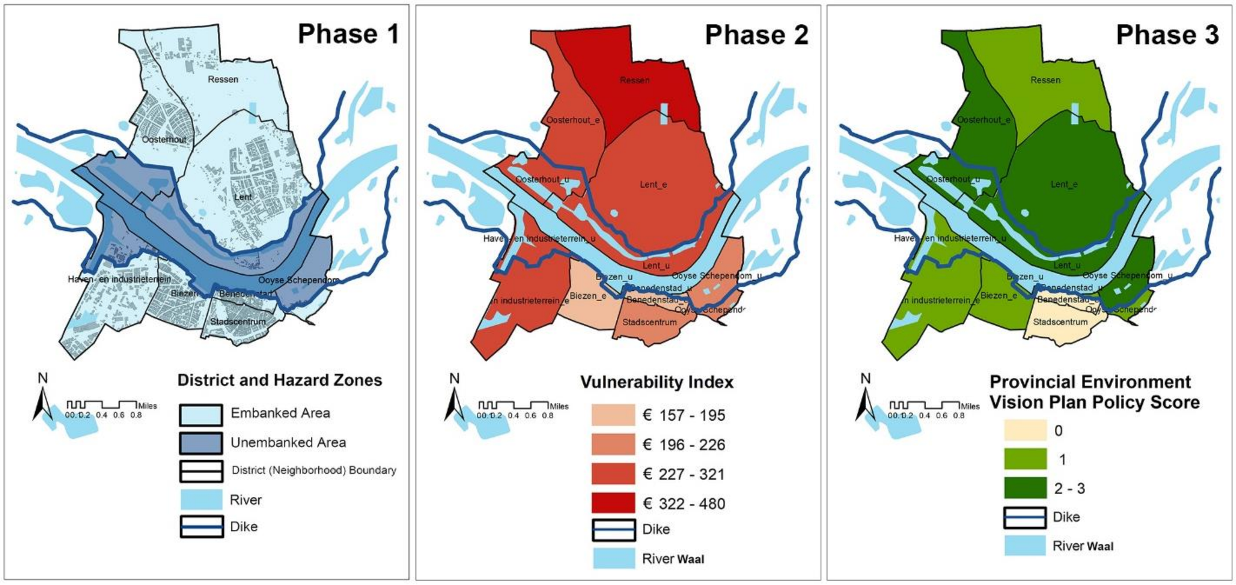

Figure 4.2 Three-phase Plan Integration for Resilience Scorecard Method. **Phase 1.** Delineate Planning district (neighborhoods) and hazard zones after the “Room for the River Waal” program in Nijmegen. **Phase 2.** Determine vulnerability. **Phase 3.** Evaluate network of plans. Location: Riverfront neighborhoods in Nijmegen.

4.4.1. Delineate Planning Districts and Hazard Zones

In order to spatially analyze both the vulnerability measures and the applicable plan policies, the city of Nijmegen is divided into sub-jurisdictional areas known as ‘Land Policy Districts (Neighborhoods)’. Each applicable policy may affect the social vulnerability of the population, the physical vulnerability of the built environment, or the environmental vulnerability in each district differently, depending on the land use characteristics in that district (Masterson et al., 2017). There are 44 planning districts (neighborhoods) in the city of Nijmegen, and the hazard zones in the city of Nijmegen have been defined according to the difference between ‘embanked’ and ‘unembanked’ areas (Figure 4.2 phase 1). Both are vulnerable to flood hazards, but in very different ways. The embanked areas are protected by a long dike that runs between them and the river, and flood safety in these areas is primarily the responsibility of the regional Water Authority (Rivierenland). Unembanked areas are directly exposed to the river, making flooding more likely, despite their relative high elevation. Administrative responsibility for flood safety in the unembanked areas is comparatively ambiguous, with no leading responsible authority (de Moel, van Vliet & Aerts, 2014). As the spatial unit of analysis for this study, the hazard zones within the 44 planning districts (neighborhoods) were used.

4.4.2. Determine Vulnerability

Earlier studies have developed methods for measuring physical, social, and environmental vulnerability which are followed, with slight adjustments, in this study. Berke and colleagues (2015) utilized improved tax value for land parcel data (U.S. dollars per square foot) as a proxy for physical vulnerability, consistent with other studies focused on the impact of land use policies on land development (Patterson & Doyle, 2009; NOAA, 2015; Shi & Yu, 2014). For our study, physical vulnerability is determined using the mean housing value (Woningwaarde or

‘WOZ’), a statistical unit used by the Dutch Centraal Bureau voor de Statistiek at the neighborhood scale.

Cutter et al. (2003) developed the Social Vulnerability Index (SoVI) as a first step toward rectifying the ‘vulnerability paradox’ of hazards research—that social vulnerability has largely been ignored because it is difficult to quantify (Peacock et al., 2008; 2014). The U.S. Centers for Disease Control (CDC) developed its own Social Vulnerability Index for Disaster Management (SVI), which utilizes a ‘flag score’ procedure and census data to assess social vulnerability (Flanagan et al., 2011). This study adapts the Flanagan et al. ‘flag score’ indexing procedure to the Dutch context, measuring social vulnerability using 11 indicators, comprising four domains of social vulnerability: household composition, socioeconomic status, minority status, and housing and transportation (Table 4.1). The top 25% of districts for a given indicator are ‘flagged’ and the total number of flags is used to identify the most vulnerable planning districts (neighborhoods) in the city of Nijmegen.

Table 4.1 Indicators that Comprise Social Vulnerability

Domain	**Social Vulnerability Indicators**
Household composition	% persons 65 years of age or older
	% persons 14 years of age or younger
Socioeconomic status	% households under or around minimum income
	General assistance benefits (per 1000 households)
	Average per capita income
Minority status	% non-Western immigrants
Housing/transportation	% multi-family structures
	% homes built before 2000
	Number of vehicles per household
	% rentals
	% housing units occupied

Source: Data from Centraal Bureau voor de Statistiek (http://www.weetmeer.nl/buurt/Nijmegen/0268) and indicator names adapted from ACS 2006–2010 (5 year estimates) from the U.S. Census Bureau (2015).

Studies have suggested that the act of measuring environmental vulnerability requires basic knowledge about the most important feature of a particular community: the likelihood of ecosystem exposure (Villa & McLeod, 2002; De Lange, Sala, Vighi & Faber, 2010). Villa and McLeod (2002) used the percentage of protected area as an indicator of environmental exposure in their study. Our study follows this procedure exactly, determining the percentage of protected area in each hazard zones within each of Nijmegen's 44 districts. 'Protected areas' include the national and provincial nature networks, valuable open space, and fauna habitat areas, as identified in the Gelderland Province plans (2017).

4.4.3. Evaluate Network of Plans

A plan integration for resilience scorecard is then generated by spatially evaluating each of the 14 documents in Nijmegen's network of plans – comprised of national, provincial and municipal scale plans created between 2010 and 2017 (Table 4.2), as all three tiers of government in the Netherlands produce spatial plans that can affect local decisions. In some cases, integration of (elements of) spatial plans of higher tiers of government is a mandatory legal requirement (ESPON, 2017).

Every land policy district (neighborhood) is assigned a score of '+1', '-1', or '0' for every applicable land use policy. A score of '+1' indicates that the policy is expected to positively affect flood vulnerability, while '-1' indicates a negative effect. A score of '0' indicates that the land use policy does not affect flood vulnerability in the land policy district. The scoring is performed independently by two researchers. Intercoder reliability was calculated using both percent agreement for each policy (with mean 90.38%) and Krippendorff's Alpha (with mean 0.84); Web-based tool "ReCal" (Freelon, 2010) was applied to compute intercoder reliability coefficients.

Table 4.2 Network of Plans in the City of Nijmegen

Tiers of Administrative Systems	**Plans**
National	Delta Plan: Room for the River Waal (2012)
Provincial	Provincial Environment Vision Plan (2017)
Municipal	Comprehensive plan | Structure vision (2010), Waterfront Master plan (2014), Land use plan of Kanaalhavens (2015), Centrum Binnenstad (2012), Verbreding Waalbrug (2015), Mercuriuspark (2015), Ooyse Schependom (2015), Woenderskamp (2017), Kern Lent-Visveld (2012), De Stelt (2014), Hof van Holland (2017), Woonpark Oosterhout (2013)

Source: Plan documents.

4.5. Plan Integration Findings

This section first reports overall policy scores for Nijmegen's network of plans for the embanked and unembanked neighborhoods. Policy scores for plans at different administrate scales (national, provincial, and municipal) are then examined.

4.5.1. Overall Policy Scores

Overall policy scores indicate that the network of plans generally supports vulnerability reduction in the 44 neighborhoods in Nijmegen. Composite policy scores for neighborhoods from 14 plans collected at the national, provincial, and local level are all positive, ranging from +1 (Neighborhood *Bottendaal*, *Galgenveld*, *Altrade*, *Hengstdal*, *St. Anna*, *Hatertse Hei*, *Heseveld*, *Wolfskuil*, and *Hazenkamp*) to +64 (the embanked portion of Neighborhood *Lent*) (Figure 4.3). Compared to findings in six U.S. cities (Berke et al., 2018), plan integration and vulnerability reduction is generally stronger and more consistent in Nijmegen, suggesting a difference in flood mitigation priorities between the two countries. However, there is high variability in overall mean policy scores between the embanked and unembanked neighborhoods; the overall mean policy score is 5.18 for embanked neighborhoods and 13.00 for unembanked neighborhoods (see Table 4.3 for means and standard deviations of the 14 individual plans). This suggests different policy emphases of the network of plan documents in targeting different spatial areas in Nijmegen, with unembanked neighborhoods receiving more attention in reducing risk, on average, than their embanked counterparts. Scores are also somewhat more consistent in the unembanked neighborhoods, with a standard deviation of 5.61 compared to 9.26 in embanked neighborhoods. These broad trends can be better understood through a closer inspection of the individual plan scores.

Table 4.3 Policy Scores for Plans in Nijmegen

	Multi-Neighborhood Plan Means and Standard Deviations (# of affected neighborhoods)				
Plan (Year Adopted)	Embanked Neighborhoods		Unembanked Neighborhoods		Difference
	Mean	Std. Dev.	Mean	Std. Dev.	Mean
National					
Delta Plan: Room for the River Waal (2012)	1.21 (44)	1.10	3.50 (6)	2.02	2.29
Provincial					
Provincial Environment Vision Plan (2017)	0.91 (44)	0.95	2.00 (6)	0.78	1.09
Municipal (Multi-neighborhood)					
Nijmegen Comprehensive Plan (2010)	1.48 (44)	0.99	-0.17 (6)	0.26	-1.65
Waterfront Master Plan (2014)	3.50 (2)	1.50	3.00 (2)	3.00	-0.50
Kanaalhavens Land Use Plan (2015)	1.00 (3)	1.41	1.33 (3)	1.89	0.33
Centrum Binnenstad Land Use Plan (2012)	2.00 (2)	1.00	0.50 (2)	0.50	-1.50
Verbreding Waalbrug Land Use Plan (2015)	2.00 (6)	0	2.00 (6)	0	0
Municipal (Single-neighborhood)	Embanked Neighborhoods		Unembanked Neighborhoods		Difference
Mercuriuspark Redevelopment Plan (2015)	-4.00		1.00		5.00
Ooyse Schependom Land Use Plan (2015)	0		6.00		6.00
Woenderskamp Land Use Plan (2017)	9.00		0		-9.00
Kern Lent-Visveld Land Use Plan (2012)	4.00		0		-4.00
De Stelt Land Use Plan (2014)	15.00		16.00		1.00
Hof van Holland Land Use Plan (2017)	20.00		0		-20.00

Table 4.3 Continued.

Municipal (Single-neighborhood)	Embanked Neighborhoods		Unembanked Neighborhoods		Difference
Woonpark Oosterhout Land Use Plan (2013)	0		0		0
Mean for the ten Land Use Plans	7.88 (8)	7.47	6.67 (6)	3.08	-1.21
Overall Mean for all Plans	**5.18 (44)**	**9.26**	**13.00 (6)**	**5.61**	**7.82**

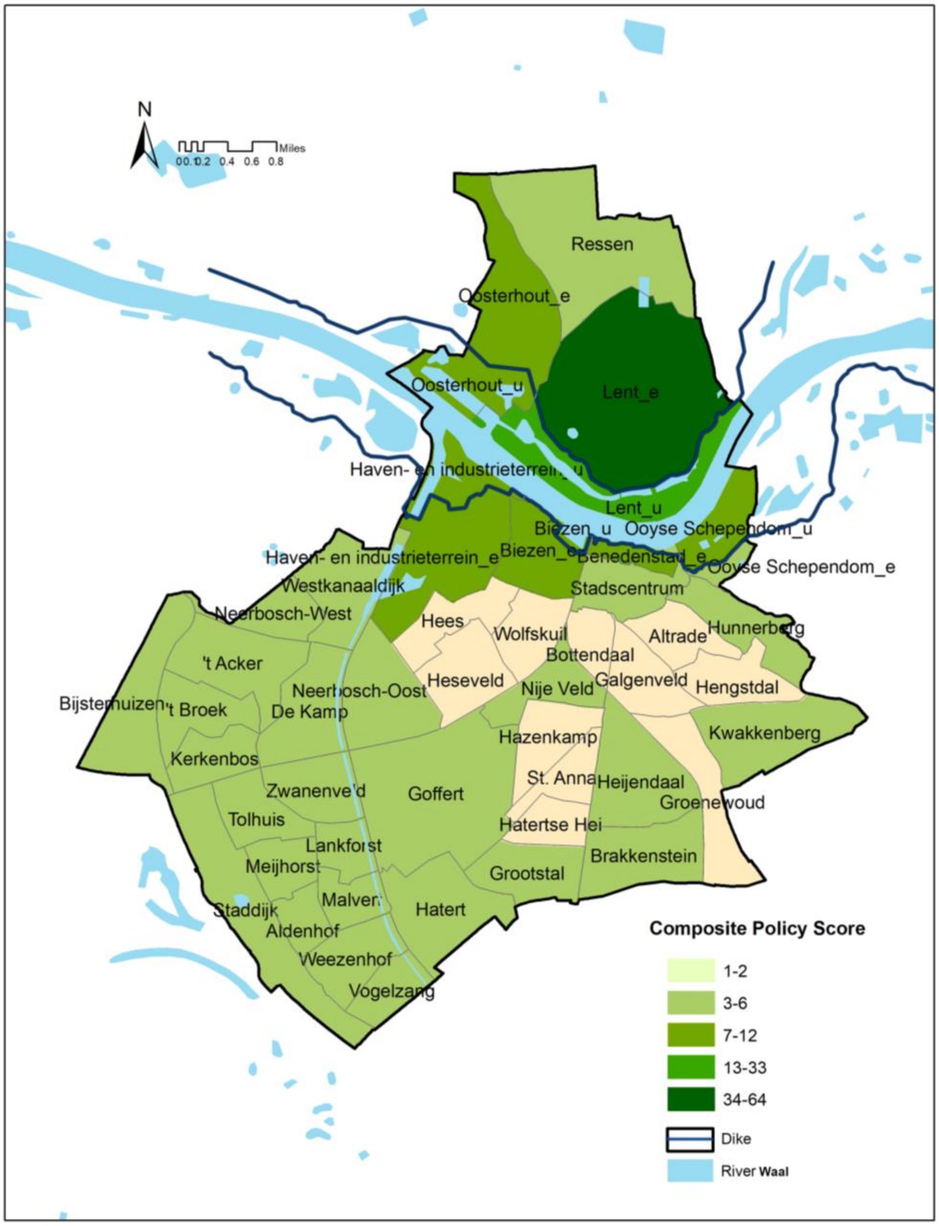

Figure 4.3 Composite policy scores in neighborhoods of Nijmegen

4.5.2. Plan Scores by Administrative Scale

4.5.2.1. National Scale -- Delta Plan: Room for the River Waal

Scorecard results indicate that Delta Plan: Room for the River Waal (2012) accomplishes its pursuit of flood safety. This plan was adopted to accommodate the relocation of the dike in response to the decision taken by the Dutch national parliament following the 1993 and 1995 near-flood events to “make more room for the river”. With regard to flood resilience, Nijmegen’s ‘plan-study’, associated with the Delta Plan, aspires to a high-water reduction of 34 centimeters (more than the national mandatory standard of 27 centimeters), anticipating future increases in River Waal discharges until 2050. The plan’s core strategy to widen the riverbed by moving the dikes inland results in enlarged unembanked areas. Thus, the mean policy score for the enlarged unembanked neighborhoods that are at greater risk to riverine flooding is 3.50, compared to a mean policy score of 1.21 for embanked neighborhoods that are at lower risk to riverine flooding (Figure 4.4). Of particular significance is the unembanked part of Neighborhood Lent, for which the policy score of the Delta Plan: Room for River Waal is 13, the highest score among 44 neighborhoods in Nijmegen under this plan. Policy tools targeting Neighborhood Lent’s unembanked area include, for example, permitted land use (thus prohibiting the most vulnerable uses), land acquisition (removing hazardous areas from consideration for development), and capital improvements (such as infrastructure strengthening).

4.5.2.2. Provincial Scale -- Environment Vision Plan

Scorecard results indicate that the provincial-level Environment Vision Plan sets up a comprehensive framework to accomplish the twin goals of the “Room for the River” Program - to protect the city of Nijmegen from flooding and preserve the ecological values in the natural network. The natural network in the enlarged unembanked areas are particularly important because the ecological values in this area offer significant flood reduction benefits, as well as other recreational and wildlife habitat protection benefits. The plan offers approaches to delineate an Ecological Main Structure within the “Gelders Nature Network” and the “Green Development Zone”, and sets requirements for new development within those two areas, thereby reinforcing the integration between hazard mitigation and environmental protection. Result shows that more policy attention is paid to the unembanked neighborhoods (mean policy score = 2.00) than to the embanked neighborhoods (mean policy score = 0.91) (Figure 4.4). This finding indicates that the Provincial Environment Vision Plan is more focused on increasing flood resilience in the enlarged unembanked areas.

4.5.2.3. Municipal Scale Plans

The City of Nijmegen has adopted three types of municipal plans with each giving more attention to flood reliance in embanked areas compared to unembanked areas. The Nijmegen Comprehensive Plan suggests many progressive policies for building flood resilience across the embanked neighborhoods in Nijmegen (mean policy score = 1.48). However, some policies in this plan aim to increase flood vulnerability in unembanked areas (mean policy score= -0.17) by proposing to increase density and economic development in neighborhoods that are already directly exposed to the river (Figure 4.4). Nijmegen’s Waterfront Master Plan targets the neighborhoods of Biezen and Haven-en industrieterrein, both of which contain embanked and unembanked portions; again, greater attention is given to the embanked areas (mean policy score = 3.50) than to the unembanked areas (mean policy score = 3.00), despite the fact that unembanked areas are more likely to deal with occasional flooding. For the ten local land use plans, results indicate that they generally support flood risk mitigation. Figure 6-4 shows that, consistent with the other municipal plans, greater attention is paid to embanked neighborhoods (mean policy score = 7.88) than to unembanked neighborhoods (mean policy score = 6.67)[2]. In the Netherlands, most land use planning occurs at the local level, thus these plans are especially detailed and focused, resulting in a higher number of total policies (and higher mean scores) than plans at the national and provincial level.

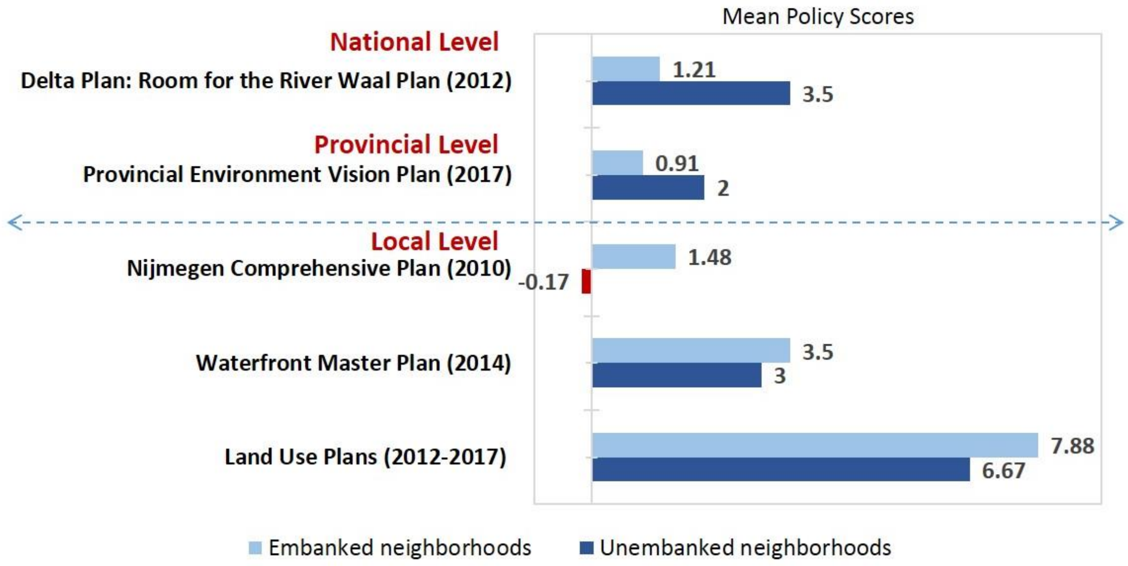

Figure 4.4 Mean Policy Scores for Plans in Nijmegen

In summary, the plan integration scorecard findings reveal patterns – and sometimes inconsistencies – in Nijmegen's network of plans, which impact flood resilience in relation to the impact of the "Room for the River" program. Despite the overall plan scores being positive, significant differences exist in the results for embanked and unembanked neighborhoods. National and provincial level plans generally give greater attention to unembanked neighborhoods by protecting natural riparian networks and focusing on safeguarding flood resilience in the enlarged unembanked areas resulting from the "Room for the River Waal"

Program. Municipal plans place greater emphasis on embanked areas, focusing on building flood resilience to accompany development. Thus, it appears that higher-tier plans are, in fact, making up for policy gaps in the local, development focused plans. This pattern across administrative scales may be significant; it compares to a speculative finding from a previous resilience scorecard analysis for the City of Rotterdam, where a new type of policy-document (the Rotterdam Adaptation Strategy) 'fills in' the lack of flood resilience policies in the unembanked areas within the established land use and comprehensive plans (Malecha et al., 2018). It suggests that flood resilience is a relatively young policy concern, which is still finding its way within the Dutch planning system.

4.5.3. Association between Plan Integration Scores and Level of Vulnerability

Findings in the previous section reveal discrepancies in the ways plans at different administrative levels affect flood resilience in the city of Nijmegen, most conspicuously in terms of how they target embanked and unembanked areas. The question of whether plan policies target the most vulnerable areas – in terms of physical, social and/or environmental vulnerability – remains unresolved. The correlation between policy scores and different flood vulnerabilities is the focus of remainder of this section. In Table 4.4, policy scores for individual plans (grouped by administrative tier, and also totaled in a composite) are correlated with three types of community vulnerability (physical, social and environmental). Correlation results are further divided into embanked and unembanked areas at the neighborhood scale.

Generally, the higher the physical vulnerability in a neighborhood, the higher the policy scores it receives, thus indicating that the network of plans prioritizes vulnerability reduction in physically vulnerable areas (Table 4.4). The correlations between physical vulnerability and summed policy scores from all plans are positive, albeit low, for the embanked neighborhoods

(0.09) and somewhat higher for the unembanked neighborhoods (0.23). Positive correlation results between policy scores and physical vulnerability in both the embanked and unembanked neighborhoods indicate that Nijmegen’s network of plans consistently pursues the ‘flood safety’ goal of the “Room for the River Waal” program in terms of physical vulnerability.

In contrast, the overall correlation among three tiers of plans indicates an inverse relationship between policy scores and social vulnerability in both embanked (-0.18) and unembanked (-0.20) neighborhoods. This suggests that vulnerability reduction is not prioritized in highly socially vulnerable neighborhoods. This resembles findings in the U.S. (Berke et al., 2018), where PIRS-analyses reveal a structural pattern of lesser policy attention to socially vulnerable neighborhoods. Variation however, exists between the different hazard zones and among the different tiers of plan. Within the unembanked neighborhoods, the Provincial Environment Vision Plan (-0.60), the Land Use Plans (-0.37) and the Delta Plan: Room for the River Waal (-0.34) have inverse relationships. Among embanked neighborhoods, all plans except the Waterfront Master Plan (0.04) have negative correlations. This suggests that the network of plans targets socially vulnerable neighborhoods less, particularly in the unembanked part of the city. In general, plans do not explicitly mention any prioritization of flood resilience with respect to social vulnerability.

For environmental vulnerability, the correlation results are negative for the embanked (-0.24) neighborhoods and positive for the unembanked (0.35) neighborhoods (Table 4.4). This indicates that the Nijmegen network of plans supports environmental vulnerability reduction in the unembanked neighborhoods, but fails to do so in the embanked neighborhoods. For the embanked neighborhoods, all plans except the Provincial Environment Vision Plan have negative correlations between policy scores and environmental vulnerability, which suggests that the plans do not pay much attention to flood vulnerability reduction in the most environmental vulnerable areas. For the unembanked neighborhoods, plans like the Delta Plan (0.43), the Provincial Environment Vision Plan (0.98), and the Land Use Plans (0.33), largely enhance nature preservation in the most environmentally vulnerable areas (Table 4.4). Plans that have more of a (re)development focus, such as the Nijmegen Comprehensive Plan (-0.68) and the Waterfront Master Plan (-0.45), do not prioritize flood vulnerability reduction in the highly environmentally vulnerable areas. Therefore, the Nijmegen network of plans successfully pursues nature preservation – associated with the second goal, spatial quality – of the "Room for the River Waal" Program in the enlarged unembanked areas, but fails to holistically prioritize flood vulnerability reduction with respect to the environment throughout the city.

Table 4.4 Correlation Between Vulnerability and Policy Scores for Plans in Nijmegen (*Pearson's r*)

	Vulnerability Type					
Plans (Year Adopted)	Physical		Social		Environmental	
	Embanked	Unembanked	Embanked	Unembanked	Embanked	Unembanked
National						
Room for the River Waal Plan (2012)	0.10	0.27	-0.21	-0.34	-0.31	0.43
Provincial						
Provincial Environment Vision Plan (2017)	0.37	0.35	-0.11	-0.60	0.08	0.98
Municipal						
Nijmegen Comprehensive Plan (2010)	0.07	0.07	-0.10	0.37	-0.33	-0.68
Waterfront Master Plan (2014)	-0.05	-0.66	0.04	0.94	-	-0.45
Land Use Plans (2012-2017) *	0.05	0.36	-0.17	-0.37	-0.23	0.33
Overall correlation for all plans	**0.09**	**0.23**	**-0.18**	**-0.20**	**-0.24**	**0.35**

*Land use plans include 10 neighborhood land use plans: Kanaalhavens Land Use Plan (2015), Centrum Binnenstad Land Use Plan (2012), Verbreding Waalbrug Land Use Plan (2015), Mercuriuspark Redevelopment Plan (2015), Ooyse Schependom Land Use Plan (2015), Woenderskamp Land Use Plan (2017), Kern Lent-Visveld Land Use Plan (2012), De Stelt Land Use Plan (2014), Hof van Holland Land Use Plan (2017), Woonpark Oosterhout Land Use Plan (2013).

4.6. Conclusions and Implications

Overall, the policies of the “Room for the River” initiative are well-integrated throughout Nijmegen’s network of plans, both in terms of flood safety and protection of the natural environment, which generally has positive effects on flood vulnerability among different neighborhoods in the city. However, the plans currently assume complete protection from flooding, provided by engineered solutions in the form of flood retention facilities and the widening of the riverbed. What happens when flood waters exceed the capacity of these solutions is not considered in Nijmegen’s network of plans. Per our analysis, dry- and/or wet-proofing strategies do not occur, suggesting that new development plans assume that the built environment will not flood—that is, that the combined effects of other flood-control policies will suffice to prevent flooding from entering built-up areas. A possible explanation for this is that the success of the innovative Room for the Waal project has reduced incentives for alternative, multilayered safety policies (Hoss, Jonkman & Maaskant, 2011), that do consider the built environment as a critical factor in flood resilience.

Our analysis also suggests that place matters when it comes to community plans and flood vulnerability reduction, and that physically, socially, and environmentally vulnerable areas should be carefully considered and targeted. Policies aimed at increasing density and improving land use efficiency in hazardous areas increase the physical vulnerability of the densified neighborhoods. With respect to social vulnerability, even though social equality is addressed in the plans, this is not translated in a consistent policy target in policies in neighborhoods that are considered socially vulnerable. Finally, Nijmegen’s network of plans supports flood vulnerability reduction in the environmentally vulnerable unembanked areas – again, enlarged as a result of the Room for the River program – but does not holistically prioritize such reductions throughout the city.

The Plan Integration for Resilience Scorecard provides scholars and planning practitioners with a new method to assess in detail how networks of plans influence community vulnerability, and to determine the degree to which plans target the most vulnerable geographic areas in terms of physical, social and environmental vulnerability. In this case, it can be used to support the “Room for the River” program’s goal of aligning with local development priorities while expanding the floodplain to reduce flood risk at the national scale. The resilience scorecard is therefore a useful tool for communities to self-evaluate their plans in order to improve vulnerability reduction in the face of increasing threats from natural hazards.

4.7. References

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4.7.1. Endnotes

[1] For this study, the authors had access to the raw material of the country reports that were the basis of the overall ESPON-publication: Comparative Analysis of Territorial Governance and Spatial Planning Systems in Europe.

[2] Mercuriuspark Redevelopment Plan is the only local land use plan to receive a negative score (-4.00) in the embanked portion, a result of an ambitious push for redevelopment of the area, without much explicit consideration of offsetting this with flood resilience policies.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

5.1. Conclusions

The level of plan integration is highly varied across the six coastal cities in the study, which suggests different policy emphases of the networks of plans in targeting different spatial areas. It also suggests that different cities have different priorities in their policy framework supporting hazard vulnerability reduction. The primary conclusion to be drawn from the findings in the first study is that the first research question is generally affirmed: communities with a larger “temporary” population and less previous hazard experience are less incentivized to incorporate hazard mitigation in local plans, when accounting for community planning capacity and other context. These findings are consonant with much existing literature; larger rental populations and problems of institutional memory may result in networks of plans that integrate hazard mitigation less effectively than in cities with a larger ‘settled’ population and recent experience with flooding. The second set of research questions is also addressed by the hierarchical linear modeling analysis. Despite the fact that districts with higher physical vulnerability are less likely to incorporate hazard mitigation in local plans (controlling for other factors), districts in cities with much previous hazard experience have better plan integration performance (higher policy scores), even in districts with higher physical vulnerability, when compared to cities with little hazard experience. That is to say, the relationship between physical vulnerability and plan integration performance is stronger in cities with much hazard experience than in those with little hazard experience, and highly physically vulnerable places that have recently experienced flood event(s) are more likely to have strong policy scores, so as to incorporate hazard mitigation in local plans.

The primary conclusion to be drawn from the findings in the second study is that the second hypothesis – that higher ‘network of plans’ integration will lead to more resilient and robust ecosystem to floods – is largely affirmed. Several prominent themes of policies and policy frameworks are built into the community networks of plans, in order to support and protect the functionality of wetland areas and reduce hazard vulnerability in both Fort Lauderdale and League City. However, plans do not explicitly set priorities to conserve wetland “hotspots”. Wetland alteration is highly associated with low-intensity development patterns. Also, districts with high physical vulnerability and high per capita income are more likely to experience wetland loss.

Overall, the policies of the “Room for the River” initiative are well-integrated throughout Nijmegen’s network of plans, both in terms of flood safety and protection of the natural environment, which generally has positive effects on flood vulnerability among different neighborhoods in the city. However, the plans currently assume complete protection from flooding, provided by engineered solutions in the form of flood retention facilities and the widening of the riverbed. What happens when flood waters exceed the capacity of these solutions is not considered in Nijmegen’s network of plans. Per our analysis, dry- and/or wet-proofing strategies do not occur, suggesting that new development plans assume that the built environment will not flood—that is, that the combined effects of other flood-control policies will suffice to prevent flooding from entering built-up areas. A possible explanation for this is that the success of the innovative Room for the Waal project has reduced incentives for alternative, multilayered safety policies (Hoss, Jonkman & Maaskant, 2011), that do consider the built environment as a critical factor in flood resilience.

Our analysis also suggests that place matters when it comes to community plans and flood vulnerability reduction, and that physically, socially, and environmentally vulnerable areas should be carefully considered and targeted. Policies aimed at increasing density and improving land use efficiency in hazardous areas increase the physical vulnerability of the densified neighborhoods. With respect to social vulnerability, even though social equality is addressed in the plans, this is not translated in a consistent policy target in policies in neighborhoods that are considered socially vulnerable. Finally, Nijmegen's network of plans supports flood vulnerability reduction in the environmentally vulnerable unembanked areas – again, enlarged as a result of the Room for the River program – but does not holistically prioritize such reductions throughout the city.

5.2. Implications

This research explores theoretical and practical problems at the nexus of climate change and urbanization, and seeks to contribute to their resolution by testing and extending the scope of the novel Plan Integration for Resilience Scorecard method. Investigating the host of factors influencing plan integration suggests a way forward, both for research and for communities struggling with issues of 'siloing', conflicting plan guidance, and disaster preparedness. Deeper knowledge about the key drivers of plan integration for resilience can inform more effective approaches as practitioners reevaluate their plans and work to foster a more coordinated strategy. More integrated networks of plans are recommended to help build more resilient communities. Policies from across a community's network of plans should work together to limit development in areas with high physical vulnerability. From the findings, it is evident that greater policy attention should also be given to areas with a higher percentage of renters as such areas, which tend to have larger transitory populations and/or lower socioeconomic status, need additional, deliberate help in preparing adequately for hazard events. Proactively focusing attention and resources on these areas is an effective way increase the city's overall resilience to future flood events.

Connecting plan integration to flooding impacts and wetland loss provides empirical support for the contention that plans and policies must be better aligned to reduce community vulnerability. Improvements in policies for integrating wetland protection with flood mitigation, adopting wetland protection ordinances, and exceeding minimum NFIP requirements are therefore recommended. The process of incorporating wetland protection into the local network of plans not only helps reduce the impact on wetlands, but also enables the setting of priorities to conserve critical wetland "hotspots" (Strommen et al., 2007).

Using the resilience scorecard method to analyze multi-scale policy integration in the Netherlands is a useful extension of that evolving methodology and offers insight into plan integration (or lack thereof) in a country famous for strong planning and water management. In this case, Plan Integration for Resilience Scorecard method can be used to support the "Room for the River" program's goal of aligning with local development priorities while expanding the floodplain to reduce flood risk at the national scale. Such a massive undertaking carries the potential for conflict with existing plans and policies. The PIRS methodology offers a new perspective and empirical data to evaluate such conflict.

The Plan Integration for Resilience Scorecard provides scholars and planning practitioners with a new method to assess in detail how networks of plans influence community vulnerability, and to determine the degree to which plans target the most vulnerable geographic areas in terms of physical, social and environmental vulnerability. The resilience scorecard is therefore a useful tool for communities to self-evaluate their plans in order to improve vulnerability reduction in the face of increasing threats from natural hazards.

5.3. Limitation

This study is somewhat limited by its singular focus on planning documentation. The regulatory and implementation aspects of planning and policy, while important to broader questions about plan integration and efficacy, were beyond the scope of this preliminary investigation. Specifically, the Provincial Ordinance, the regulatory component, was not analyzed for conformity with the plans – though such correspondence is highly likely in the Dutch planning and policy system. That being said, future studies should include a thorough evaluation of the community regulations, which would offer a more complete empirical picture of the overall integration of flood – resilience- related policies.

The cross- sectional nature of this study also prevented any inspection of policy implementation. Revisiting this study with a focus on implementation would strengthen the conclusions in this study by analyzing how the implemented zoning ordinance on the ground, rather than the planning potential, affects different types of community vulnerabilities and ecological resilience with respect to flooding.

APPENDIX A

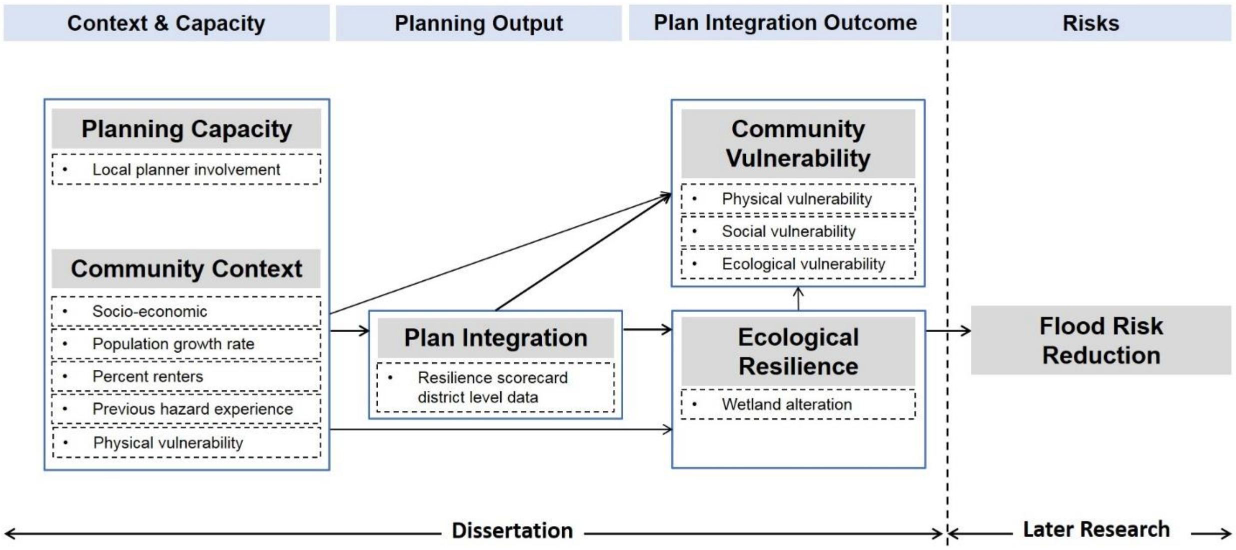

Figure A.1 Conceptual Framework for Investigating the Influence of Plan Integration on Community Vulnerability and Ecological Resilience to Natural Hazards.

Random Intercept Model:

Level-1 Model: $\boldsymbol{PSCORE}\text{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + u_{0j}$

Mixed Model: $\boldsymbol{PSCORE}\text{ij} = \gamma_{00} + u_{0j} + r_{ij}$

Equation A.1

Intraclass Correlation Coefficient (ICC) Equation:

Intra-class correlation: $\rho = \tau_{00} / (\tau_{00} + \sigma^2)$

$= 37.23/ (37.23+157.01) = 0.19$

τ_{00}: between-city variation
σ^2: within-city variation

Equation A.2

Hierarchical Linear Model #1:

Level-1 Model: $\boldsymbol{PSCORE}_{ij} = \beta_{0j} + \beta_{1j}*(\boldsymbol{PHYSICAL}_{ij}) + \beta_{2j}*(\boldsymbol{PERCAPIT}_{ij}) + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + \gamma_{01}*(\boldsymbol{STAFF}_j) + \gamma_{02}*(\boldsymbol{PREVIOUS}_j) + \gamma_{03}*(\boldsymbol{RENTERS}_j) + u_{0j}$
$\beta_{1j} = \gamma_{10}$
$\beta_{2j} = \gamma_{20}$

Mixed Model:
$\boldsymbol{PSCORE}_{ij} = \gamma_{00} + \gamma_{01}*\boldsymbol{STAFF}_j + \gamma_{02}*\boldsymbol{PREVIOUS}_j + \gamma_{03}*\boldsymbol{RENTERS}_j + \gamma_{10}*\boldsymbol{PHYSICAL}_{ij} + \gamma_{20}*\boldsymbol{PERCAPIT}_{ij} + u_{0j}+ r_{ij}$

Equation A.3

Hierarchical Linear Model #2:

Level-1 Model: $\boldsymbol{PSCORE}_{ij} = \beta_{0j} + \beta_{1j}*(\boldsymbol{PHYSICAL}_{ij}) + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + \gamma_{01}*(\boldsymbol{PREVIOUS}_j) + u_{0j}$
$\beta_{1j} = \gamma_{10} + \gamma_{11}*(\boldsymbol{PREVIOUS}_j)$
PHYSICAL has been centered around the grand mean.

Mixed Model:
$\boldsymbol{PSCORE}_{ij} = \gamma_{00} + \gamma_{01}*\boldsymbol{PREVIOUS}_j + \gamma_{10}*\boldsymbol{PHYSICAL}_{ij} + \gamma_{11}*\boldsymbol{PREVIOUS}_j*\boldsymbol{PHYSICAL}_{ij} + u_{0j}+ r_{ij}$

Equation A.4

Physical vulnerability slope Equation:

When the physical vulnerability value is 0, the equation is:

$\boldsymbol{PSCORE} = -15.07 + 1.76\boldsymbol{PREVIOUS}$.

When the physical vulnerability value is 2195.57, the equation is:

$$PSCORE = -893.3 + 45.67 PREVIOUS.$$

For every one unit increase in previous hazard experience of the city, the average policy score value increases by 1.76 with the *lowest* physical vulnerability value and increases by 45.67 with the *highest* physical vulnerability value.

$$PSCORE_{ij} = \gamma_{00} + \gamma_{01}*PREVIOUS_{j} + \gamma_{10}*PHYSICAL_{ij} + \gamma_{11}*PREVIOUS_{j}*PHYSICAL_{ij} + u_{0j} + r_{ij}$$

Equation A.5

APPENDIX B

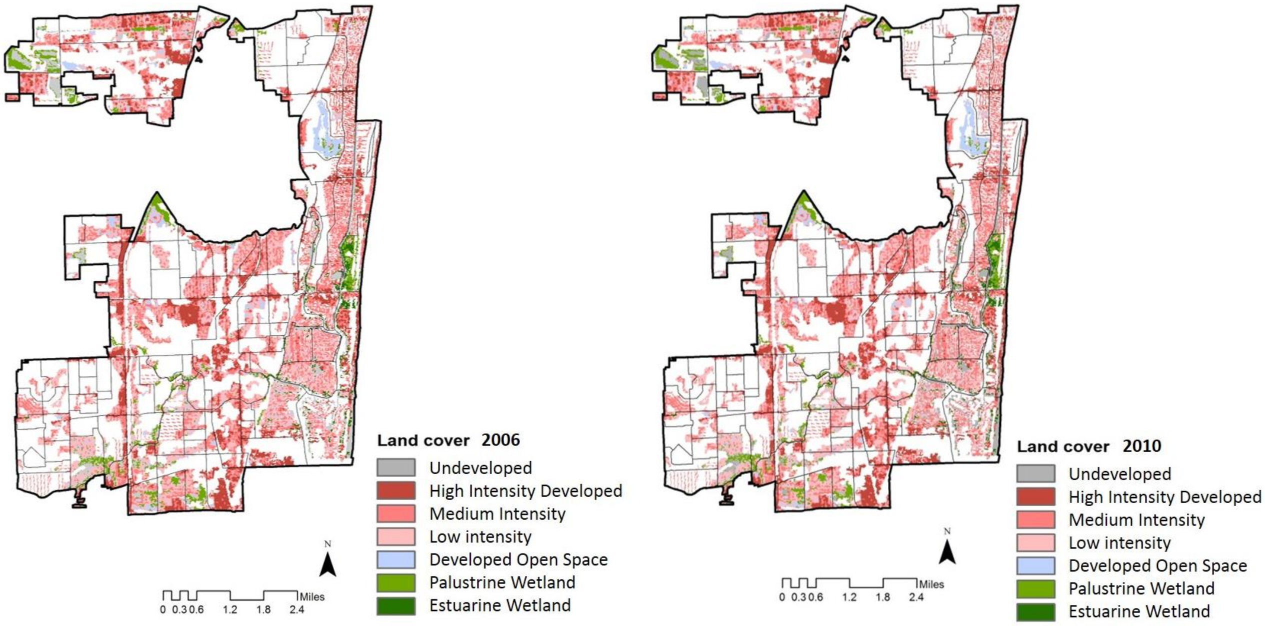

Figure B.1 2006 and 2010 land cover in the 100-year floodplain, Fort Lauderdale, FL. Wetlands shown in green. District boundaries are also shown (gray lines).

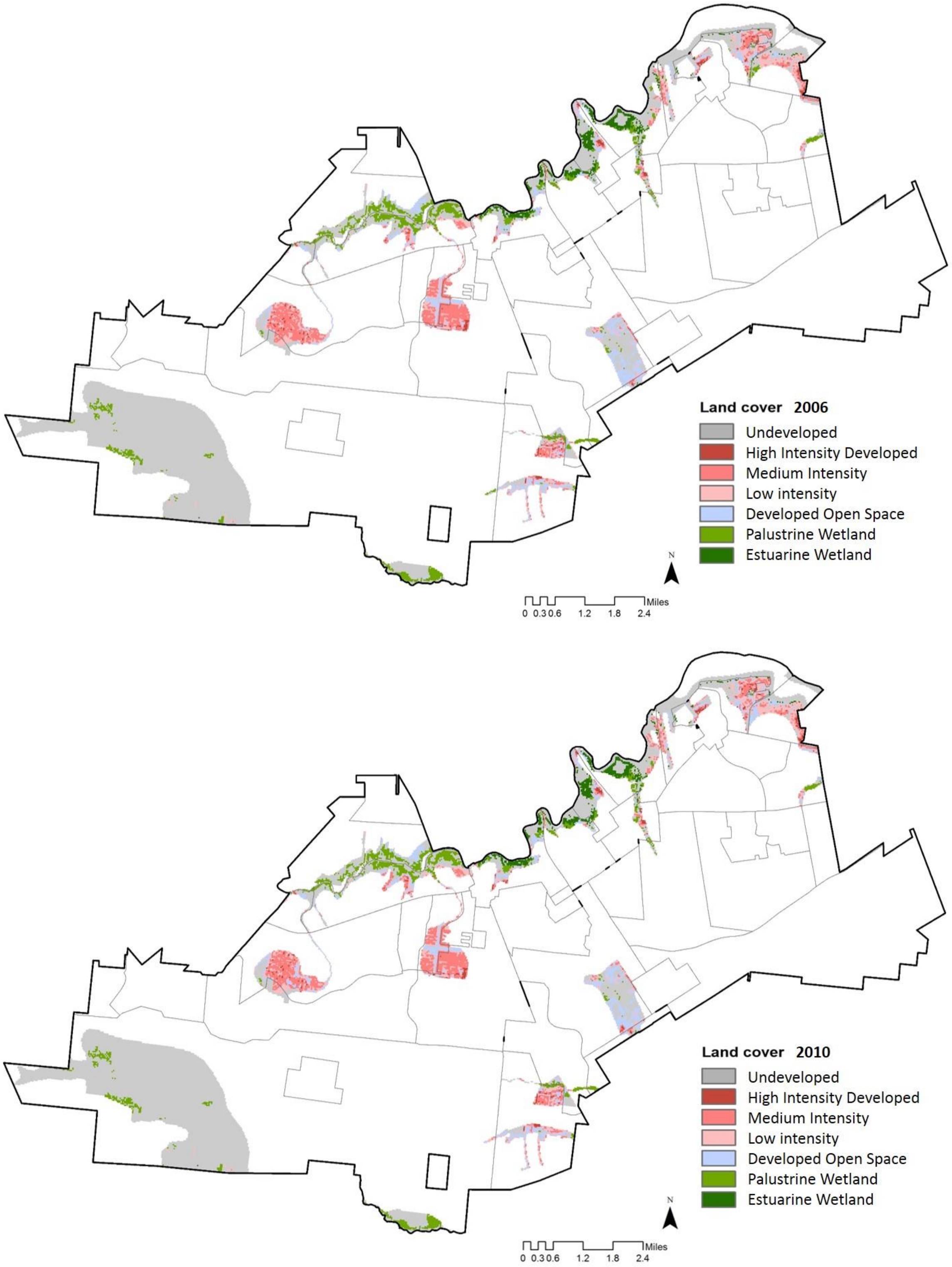

Figure B.2 2006 and 2010 land cover in the 100-year floodplain, League City, TX. Wetlands shown in green. District boundaries are also shown (gray lines).