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A plan evaluation framework for examining stakeholder policy preferences in resilience planning and management of urban systems

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ABSTRACT

The objective of this paper was to create and test a methodological framework for examining the extent to which various plans captured diverse stakeholder policy preferences related to resilience planning and management of interdependent urban systems. Policy preferences represent what were important for stakeholders and determine the priorities of stakeholders in resilience planning of urban systems. Stakeholders in different urban sectors may have conflicts of policy preferences in the resilience planning process. A comprehensive understanding of the extent to which plans incorporated and reflected policy preferences of different stakeholders would greatly improve the quality of resilience planning. Hence, we proposed a plan evaluation framework to examine the extent to which various plans captured diverse stakeholder policy preferences in resilience planning of interdependent infrastructure systems. We showed the application of the proposed framework in the evaluation of four plans affecting flood resilience planning in the Houston area. The proposed tool could help identify conflicted stakeholder policy preferences in planning and enable evaluation of policy consistency in networks of plans.

1. Introduction

Urban systems currently face great challenges related to the increasing frequency and impacts of natural hazards. Hence, resilience planning of interdependent urban systems (IUSs) is an essential process to enable urban systems to adapt to natural hazards (Godschalk, 2003; Berke et al., 2015, 2019). The National Research Council observed that resilience planning is critical to building the capacity of human and physical systems to anticipate, absorb, recover from, or more successfully adapt to actual or potential adverse events (National Research Council, 2012). IUSs are complex systems that comprise both physical and human systems; the performance of physical systems being highly dependent on the behavior of human systems (e.g., actions, decisions, plans, and policies) (Li et al., 2020; Naderpajouh et al., 2018; Srivastava and Mostafavi, 2018; Davis et al., 2018). Therefore, effective resilience planning of IUSs should take into account interactions between human and physical systems, such as actor coordination networks, network of plans, and stakeholder values and norms (Dong et al., 2020).

Resilience planning and management of IUSs involve multiple stakeholders from different urban sectors (e.g., flood control, land use, transportation, environmental conservation) (Berke et al., 2019; Woodruff and Regan, 2019; Farahmand et al., 2020; Li et al., 2019; Lyles et al., 2014a). The involved stakeholders usually have divergent priorities and preferences related to economic/urban development, environmental conservation, flood control, and social equity due to their different values (Campbell, 1996; Coates and Tapsell, 2019). Furthermore, these priorities and preferences in planning are interrelated and cannot be easily steered to one priority (Berke et al., 2015; Campbell, 1996). For example, urban development in flood-prone areas would highly affect the need for greater investment in flood-control infrastructure. Natural resources (e.g., wetland, bayou, and prairie) consumed by urban development would adversely affect environmental conservation and ecosystem management (Endter-Wada et al., 2020). Thus, for resilience planning and management of IUSs, evaluating the level of preferences incorporation and consistency across plans based on the understanding of diverse stakeholder preferences in the planning process is an essential step.

To address this need, we proposed a plan evaluation framework to examine how plans reflected and incorporated diverse stakeholder policy preferences in the resilience planning of IUSs. We designed and

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conducted a stakeholder survey to investigate diverse stakeholder policy preferences in flood-resilience planning of IUSs. The stakeholder survey included a list of flood risk reduction policy actions such as land use policies, engineering policies, and monetary policies. Based on the rates of policy actions by participated stakeholders, we developed a preference satisfaction matrix representing stakeholder policy preferences. Then we selected four important plans in the Houston area and assessed the policies documented in plans using a plan evaluation methodology. The proposed plan evaluation framework enabled answering the following research questions. First, to what extent did different plans incorporate diverse policy preferences of stakeholders? Second, the preferences of what stakeholders from which sectors were more/less captured by plans? Third, what was the level of policy consistency across plans? The results, in the context of the Houston area, indicated that the hazard mitigation plan incorporated the most overall stakeholder preferences to risk reduction policies among the four examined plans. The regional transportation plan, however, incorporated the fewest overall stakeholder policy preferences. The hazard mitigation plan and the regional conservation plan had the highest level of policy consistency, while the hazard mitigation plan and regional transportation plan had the lowest level of policy consistency.

The following sections of the paper were organized as follows. We first discussed the existing literature regarding stakeholder policy preferences in resilience planning of IUSs, stakeholder engagement in the planning process, organizational behavior, and collaborative environmental management in the literature review part. Second, we provided an overview of the flooding history and planning background in the Houston area. We elaborated on five major steps for the proposed plan evaluation framework in the "Methodology and Data" section. Third, the key findings of the application to the four plans in the Houston area and discussion of the insights regarding the resilience planning were presented. Finally, we discussed several limitations of the study.

2. Literature review

2.1. Diverse stakeholder policy preferences in resilience planning of IUSs

In the context of resilience planning, policy preferences represent those policies, institutions, and services that diverse stakeholders from IUSs regard as of importance and worth (El-Gohary and Qari, 2010; Ros et al., 1999). "Planning is a value-laden activity" (Forester, 2013) that caters to diverse needs, capacities, and policy preferences (Sandercock, 2017). Each stakeholder involved in the planning process may have diverse policy preferences (sometimes even conflicted policy preferences) with different degrees of importance (Schwartz, 2012; Jahani and El-Gohary, 2012; Bahadorestani et al., 2020). Existing studies showed that stakeholders from IUSs had different priorities and preferences pertaining to urban development, hazard mitigation, social equity, and environmental conservation (Campbell, 1996; Taeby and Zhang, 2019). In the case of flood resilience planning, stakeholders from the transportation sector were more concerned about improving infrastructure systems, while stakeholders in flood control and environment conservation sectors paid more attention to hazard mitigation and environmental preservation (Li et al., 2020, 2019). Consequently, the validity of plans was influenced by the degree to which they facilitated the dialogue on complex problems (Rittel and Webber, 1973) and navigated pluralistic opinions, and incorporated them into a strategic policy framework (Baer, 1997). Substantial planning literature has theorized different ways to deliberate on value conflicts (Habib, 1979) and improve communication gaps (Forester, 2013; Sandercock, 2017; Healey, 1992; Innes and Booher, 2004). This segment of the literature was based on the argument that a critical step to managing value conflict that would greatly influence stakeholder policy preferences was communication across differences. A small but impactful body of work focused on the sources of value conflict that would greatly influence stakeholder policy preferences across multiple planning domains (e.g., environmental and economic domains) and finding common benefits to bridge conflicts (Campbell, 1996; Godschalk, 2004). Along this line of inquiry, a growing number of assessments evaluated the impact of stakeholder policy preference conflicts across multiple plans on vulnerability to hazards (Berke et al., 2015; Berke et al., 2019). Despite these existing studies, there was a lack of methods for quantitative evaluation of stakeholder policy preference conflicts among diverse stakeholders across multiple plans. Quantitative methods could complement existing plan evaluation methods and are important for developing and implementing consistent networks of plans for hazard mitigation and resilience (Berke et al., 2015, 2019).

2.2. Importance of diverse stakeholder engagement in resilience planning of IUSs

Diverse stakeholder engagement in the planning process is important to improve the quality of resilience plans. Cities are increasingly guided by networks of plans, such as land use, hazard mitigation, parks and recreation, housing, transportation, environmental conservation, and capital improvement plans, developed by diverse stakeholders both within and outside government (Berke et al., 2019). Resilience planning, therefore, requires collective actions (e.g., communication, coordination) by diverse stakeholders across IUSs. Plan contradictions and inconsistencies would arise in the absence of sufficient coordination among diverse stakeholders (Woodruff and Regan, 2019; Finn et al., 2007). Existing studies showed that the inclusion of diverse stakeholders enhanced defining core values, increased the collective understanding of complex systems (e.g., ecosystems, infrastructure systems, social systems), and helped address and resolve conflicts in the planning process and environmental governance (Nutters and Pinto da Silva, 2012; Graversgaard et al., 2017; Wiesmeth, 2020; Watson et al., 2018). Tompkins et al. (2008) highlighted the importance of incorporating diverse stakeholder preferences to ensure the awareness of inherent trade-offs to obtain long-term stakeholder supports in coastal planning for climate change adaptation. Existing studies also showed that involving local planners who had expertise in land use approaches would greatly improve the quality of hazard mitigation plans and climate change adaptation plans (Lyles et al., 2014a; Woodruff and Stults, 2016; Burby, 2003; Dyckman, 2018). There were multiple studies related to plan evaluation in different domains, such as hazard mitigation (Berke et al., 2015; Lyles et al., 2014b), ecosystem management (Brody, 2003), and sustainability planning (Schrock et al., 2015; Berke and Conroy, 2000). However, little was known about the extent to which plans in different domains incorporated the policy preferences of stakeholders who were affected by the performance of plans. Also, there were limited theoretical (Hopkins and Knaap, 2018) and empirical studies (Berke et al., 2015) to evaluate the level of consistency across plans based on the diverse policies in the planning process. This limitation was in part due to a lack of quantitative methods to evaluate the extent of incorporation and consistency of stakeholder preferences in networks of plans.

2.3. Existing work of examining stakeholder policy preferences

Despite the growing recognition of the importance of congruency among stakeholder policy preferences in resilience planning and management of IUSs, an important dilemma was examining and incorporating different policy preferences of stakeholders. Stakeholder policy preferences were usually not explicitly expressed and were represented or reflected in diverse forms or concepts, such as goals, standards, needs, and attitudes (Barima, 2010). Biesenthal et al. (2018) and Matinheikki et al. (2019) identified the preferences of stakeholders (e.g., institutional logics and demands) in infrastructure projects based on literature review (mainly from the institutional theory) and stakeholder interviewers. Taeby and Zhang (2019, 2018) conducted a comprehensive literature review to understand different disaster resilience practices. Accordingly, they developed a survey to collect stakeholder preferences towards disaster resilience practices in physical, social, environmental, and economic dimensions. In the context of resilience planning of IUSs, to the best of our knowledge, there was no quantitative measure to examine stakeholder policy preferences across different plans. To address this gap, we proposed a quantitative approach and demonstrate its application in the context of hazard mitigation and flood resilience in the Houston area.

3. Planning background in Houston area

Houston is the largest metropolitan without zoning regulations (Fulton, 2020; Qian, 2010). This lack of zoning was often cited as the cause for repetitive and extensive damage after major flood events (Patterson, 2017; Boburg and Reinhard, 2017). However, it is not appropriate to posit 'Houston does not regulate or plan'. Houston supplemented its lack of zoning with a myriad of other regulatory and policy tools. On the one hand, there were policies that managed growth. According to Neuman (Neuman and Smith, 2010), Houston planned growth in primarily three ways- first by developing major institutional projects in close collaboration with the development community; second by building expansive infrastructure networks in partnership with state and federal agencies (Shelton, 2017; Binkovitz, 2020); and third by encouraging neighborhood level planning through Super Neighborhood organizations. Regarding regulatory tools, Fulton (2020) added the use of deed restrictions to regulate land uses on private properties, density bonuses to encourage development in the urban core, a buffering ordinance to impose height restriction outside the urban core, and lot size restrictions. While these policies supported population growth, a laissez-faire development pattern, and affordability (Qian, 2010; Masterson et al., 2014), they also exacerbated vulnerability to flooding (Zhang et al., 2018) and posed environmental justice issues (Neuman and Smith, 2010).

In response to multiple major flood events, Houston also planned for flood risk, restricting growth in flood-prone areas. Blackburn (2020) discussed the critical role of the Bayou Greenways Initiative in protecting and enhancing the network of connected, open spaces along bayous Blackburn (2020). Since 2015, the U.S. Army Corps of Engineers and the Texas General Land Office have explored the efficacy of structural surge infrastructure and coastal ecosystem enhancement (Blackburn, 2017) along the Galveston Bay to protect the city from surge and coastal flooding (Davlasheridze et al., 2019; Bush, 2019). The Harris County Flood Control District invested in the construction and restoration of detention ponds in the city and supported FEMA home buyouts (Harris County Flood Control District, 2017). The City of Houston Office of Emergency Management, through their Hazard Mitigation Plan (Harris County Flood Control District, 2017), focused on retrofitting critical facilities against flood damage, protecting parks, and expanding storm sewer systems throughout the city.

Therefore, Houston planned, but planned incrementally and (till 2015) without the broad institutional framework and vision of a comprehensive city plan (Neuman and Smith, 2010). Policy responses to flood risk were numerous, varied in scope, and involved stakeholders from different planning sectors and geographical scales. Holistic resilience planning, therefore, would require plans to find synergies between the different planning approaches and incorporate diverse policy preferences of different stakeholders from diverse urban sectors in the Houston area.

4. Methodology and data

The proposed plan evaluation framework comprised five major steps to examine how plans reflected and incorporated diverse stakeholder policy preferences in resilience planning and management of IUSs: (1) identify stakeholder policy preferences in flood-resilience planning of IUSs, (2) develop a policy preference satisfaction matrix, (3) assess policies documented in plans using plan evaluation methodology, (4) policy preference aggregation, and (5) evaluate policy consistency across plans. Fig. 1 illustrated the five steps of the proposed framework, and we explained each step in detail in the rest of this section. In this study, we focused on the flood resilience planning prior to Hurricane Harvey involving diverse urban sectors, including flood control, emergency response, transportation, community development, and environmental conservation.

4.1. Identify stakeholder policy preferences

We conducted a stakeholder survey in Texas, Harris County, to understand diverse stakeholder policy preferences in flood resilience planning of IUSs. The survey collected stakeholder preferences with regards to policy actions that could be taken to reduce the risks of future flooding in the Houston area (for detailed survey information, please refer to the supplemental documents).

Table 1 listed the policy actions included in the survey. The flood risk reduction policy actions included land use policies (e.g., limit new development, protect wetland/open space, temporarily prohibit development after disasters, limit the development of public facilities), engineering policies (e.g., elevating buildings, strengthen infrastructure, build dams, build levees, improve drainage systems), and monetary policies (e.g., charge impact fees, buyout/acquire property). The policy actions were selected based on the discussion of strategies for urban resilience in the literature (Godschalk, 2003; Burby et al., 1999; Burby, 1998; Brody et al., 2009, 2013; Berke and Smith, 2009).

We classified survey respondents into five urban sector categories based on organizations and departments they represented. These five urban sectors were flood control (FC), emergency response (ER), transportation (TT), community development (CD), and environmental conservation (EC) (Farahmand et al., 2020; Li et al., 2019). We further classified respondents in each urban sector into governmental organizations (Gov) and non-governmental organizations (NGOs). Table 2 showed examples of involved organizations and departments in classified urban sectors. Here, we would like to note the intersections of governmental and non-governmental organizations. Some non-governmental organizations, such as the Texas Floodplain Management Association, Bayou Preservation Association, and Houston Wilderness, are professional organizations consisting of related government officials or have long-term collaborations with governmental organizations. Therefore, these professional non-governmental organizations could provide both governmental and non-governmental perspectives toward surveyed policy actions. Also, in this study, we defined stakeholders as "identifiable groups who take an active role in making decisions that affect the planning process (Reed, 2008; Johnson et al., 2013)" instead of "those who are affected by or can affect a decision in the planning process (Freeman, 2010)." Reed (2008) and Johnson et al. (2013) argued that, although individuals can be stakeholders based on Freeman's definition, studies were suggested to focus on "identifiable groups united by shared interests who hold a stake (whether directly or indirectly) in the scope of their initiative." Thus, following the insights from Reed (2008) and Johnson et al. (2013), we excluded the wider public in survey participants.

4.2. Develop policy preference satisfaction matrix

To analyze survey responses, we developed a policy preference satisfaction matrix. The matrix was structured to compare support for policies (rows) described by urban sectors represented by respondents (columns) (Please see Table S1 in Supplemental documents). The goal of this study was to analyze how sectors and types of organizations influence stakeholder policy preferences in resilience planning. For example, did respondents from the emergency response sector, on average, show more support for engineering solutions such as P6: *build protective dams*, compared to land use solutions such as P9: *protect wetlands and open*

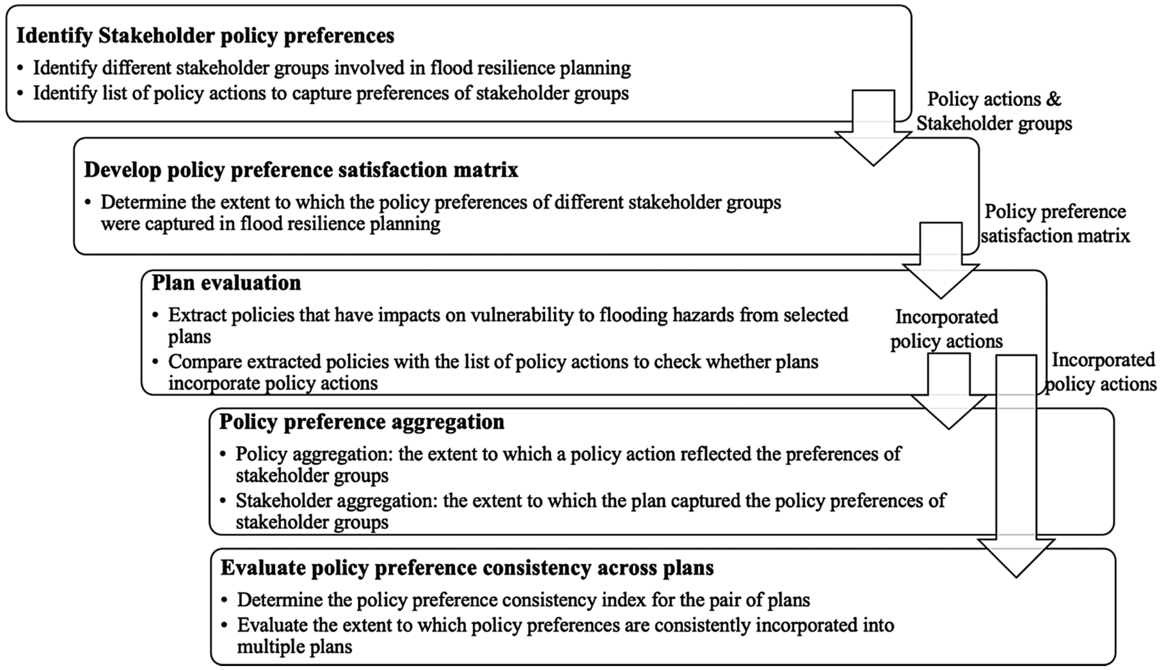

Fig. 1. Five steps of the proposed plan evaluation framework.

Table 1
Flood Risk Reduction Policy Actions in the Survey.

Policy Description
P1: limit new development in flood-prone areas
P2: elevate buildings
P3: strengthen infrastructure design standards
P4: establish and implement infrastructure resilience program
P5: minimize additional impervious surfaces, such as parking lots
P6: build additional protective dams
P7: build additional protective levees
P8: build more catchment reservoirs and retention ponds
P9: protect wetland and open space
P10: improve stormwater systems
P11: build additional floodwater drainage systems
P12: temporarily prohibit development in the period immediately after a disaster event
P13: charge impacts fees for development in flood-prone areas
P14: limit the development of public facilities and infrastructure in flood-prone areas
P15: limit rebuilding in frequently flooding areas
P16: buyout or otherwise acquire damaged property

space? Is there a preference consensus for certain policies by all respondents, regardless of sector and type of organization? To this end, we averaged the level of policy support (Table 1) of respondents in each sector and type of organization. Then we conducted a linear transformation to map the level of policy support to the 0–10 scale (Equation S1 in the supplemental documents). Also, to capture the extent of congruency that respondents preferred to the listed policy actions, we calculated the variances in the level of policy support of respondents in categories.

Each cell in the policy preference satisfaction matrix, therefore, represented the average level of policy support of respondents in categories. We also developed a second matrix for variances in the level of support by urban sectors. The average level of policy support can represent a measure of opposition or support toward this policy action, reflecting the policy preferences of stakeholders in this category. Variances in the level of policy support could indicate the level of congruency for this policy action among stakeholders in the category. A high variance in the level of policy support indicated that stakeholders in this category had divergent preferences towards this policy action, while a

Table 2
Examples of Departments and Organizations in Classified Urban Sectors.

Category	Example of involved departments	Example of involved organizations
Flood Control (F. C.)	Water departments and institutions, drainage and floodplain management	The Texas Floodplain Management Association (NGO), Harris County Flood Control District (Gov), City of Houston Floodplain Management Office (Gov)
Emergency Response (E.R.)	Disaster management, disaster relief, fire department, police department, resilience offices	Harris County Office of Emergency Management (Gov), Texas Department of Public Safety (Gov), Federal Emergency Management Agency (FEMA) (Gov)
Transportation (T. T.)	Transportation strategic planning, design, construction, and management departments	METRO (Gov), Houston TranStar (Gov), Port of Houston Authority Texas Department of Transportation (TxDOT) (Gov)
Community Development (CD)	Business and economic services, Academic institutions, public work departments, recreational departments	Houston Real Estate Council (NGO), United Way of Greater Houston (NGO), Harris County Community Economic Development Department (Gov), Bay Area Houston Economic Partnership (Gov)
Environmental Conservation (E. C.)	Pollution control, waste management	Bayou Land Conservancy (NGO), Bayou Preservation Association (NGO), Houston Wilderness (NGO), Urban Land Institute (NGO), The Nature Conservancy (NGO)

low variance of policy support indicated that stakeholders tended to have a shared preference towards this policy action.

4.3. Plan evaluation

We selected four plans that reflect diverse policy preferences of different stakeholders in resilience planning and management of IUSs. The selected plans included the 2016–2020 Capital Improvement Plan (CIP), the 2017 Gulf-Houston Regional Conservation Plan (RCP), the 2040 Regional Transportation Plan (RTP), and the 2017 Hazard Mitigation Plan (HMP).

We compared the extracted policy list from the plan analysis with the 16 flood risk reduction policy actions in the survey (Table 1) and identified content overlaps across lists. Please see the supplemental documents for the detailed plan description and evaluation, and policy extraction process. We interpreted overlaps between policy tools in plans and stakeholder surveys as a policy in a plan successfully capturing the preference of stakeholders. We then assigned to that policy numerical values in the policy preference satisfaction matrix—the average level of support of stakeholders from all the categories. If a policy from a plan did not overlap with survey policies, that policy got a zero. Table 3 showed examples of extracted policies from selected plans and obtained scores for the policies.

4.4. Policy preference aggregation

The fourth step was to compare the policy tool in plans with stakeholder support for that policy from surveys. After we extracted the policies from plans and obtained the average level of support scores for the extracted policies, we aggregated the scores by policy actions (rows in the matrix) and by stakeholder categories (columns in the matrix). Therefore, there are two types of policy preference aggregation—policy aggregation and stakeholder aggregation. The policy aggregation indicated the extent to which a policy action reflected the preferences of all the stakeholders involved in flood resilience planning, and the stakeholder aggregation indicated the extent to which the evaluated plan captured the policy preferences of stakeholders from one urban sector within or outside government. Table S2 in the supplemental showed the calculation of two aggregations based on the obtained scores by the evaluation of each plan.

Table 3
Examples of Extracted Policies and Scores for the Policies.

Plan	Extracted Policy	Included survey policy action	Score
CIP	Buffalo Bayou Detention Basin: street & traffic control & storm drain dedicated drainage and street renewal fund; Project addresses watershed stormwater quantity and quality requirements. It includes the design and construction of a detention basin	P10: improve stormwater systems, P11: improve drainage systems	Level of support for P10 and P 11
RCP	Protect acreage along riparian corridors in a holistic approach for each of the four Galveston bay sub-watersheds and develop habitats to develop plans to improve habitat for birds, preserving and protecting the ecological value of land/water ecosystems and habitats	P9: protect wetland and open space	Level of support for P9
RTP	Enhance State of Good Repair Adequate maintenance (includes bridges, roadways, transit facilities, port facilities, railroads) will extend the life and ensures the safety of current facilities at a fraction of the cost of constructing new ones. Improve existing infrastructure, which makes it safer and more resilient.	P4: establish infrastructure resilience program	Level of support for P4
HMP	Acquisition or mitigation reconstruction of repetitive loss properties: Acquisition or mitigation reconstruction	P16: buyout or acquire property	Level of support for P16

4.5. Evaluate policy consistency across plans

We also wanted to evaluate if certain policies were consistently incorporated into multiple plans. Therefore, we proposed a policy consistency index: D_{AB} that would indicate the level of policy consistency in two plans (Please refer to Equation S2 in the supplemental information). The policy consistency index D_{AB} was not only influenced by the number of same policy actions incorporated in plans A and B but also affected by the number of incorporated policy actions in the evaluated plans. Therefore, a high D_{AB} would imply that a large proportion of policies in both plans A and plan B reflected the same preference. Conversely, a low D_{AB} indicated inconsistent policy integration across the pair of plans.

5. Results

5.1. Policy preference satisfaction matrix and results of policy preference aggregation

Table 4 showed the policy preference satisfaction matrix of the average level of policy support and the results of policy preference aggregation. We can observe from Table 4 that 16 flood risk reduction policy actions included in the survey satisfied the fewest policy preferences for stakeholders from the transportation sector, with 68.6 % and 65.1 % for stakeholders from government organizations and NGOs, respectively. The 16 policy actions satisfied the highest policy preferences for stakeholders from government organizations in the environmental conservation sector (81.2 %), while stakeholders from NGOs in the flood control sector showed the second-highest level of support towards the policy actions (76.8 %).

The results of policy aggregation also showed that P15 (limit rebuilding in flood areas) gained the highest overall level of support by stakeholders from different categories (81.2 %), while P3 (strengthen infrastructure), P1 (limit new development), and P10 (improve stormwater systems) gained a relatively high level of support too, with ratings of 79.4 %, 79.4 %, and 79.0 %, respectively. This result indicated that P15, P3, P1, and P10 could reflect shared stakeholder policy preferences. P12 (temporarily prohibit development after disasters) gained the least overall support from the stakeholders from different categories (54.2 %), while P6 (build dams) gained the second least support from the stakeholders. Therefore, policy actions P12 and P6 reflected few policy preferences of stakeholders from different sectors.

Furthermore, we observed that NGO stakeholders in the flood control sector indicated the lowest level of support (score 3.33) towards P12 while they showed the highest level of support (full score 10) towards P8 (build reservoirs and retention ponds) and P10 (improve stormwater systems). NGO stakeholders in the environmental conservation sector showed the highest level of support towards P4 (establish infrastructure resilience program), while they showed the lowest level of support towards P6. This result indicates that P4, P8, and P10 could highly reflect the shared preferences of NGO stakeholders in the environmental conservation and flood control sectors.

Fig. 2 illustrated the results of variances in levels of policy support. For more detailed information regarding the calculated variances in the level of policy support of stakeholders in each category, please see Table S3 in the supplemental documents.

Fig. 2 illustrated that stakeholders from different sectors indicated an overall high level of congruency towards P2 (elevate buildings) with the lowest overall variance of P2. Because the average rating for P2 was relatively low (68.8 %, Table 4), the high level of congruency here indicated that most stakeholders showed a low level of support towards P2. On the other hand, P14 (limit the development of public facilities)

Table 4
Policy Preference Satisfaction Matrix and Results of Policy Preference Aggregation.

Policy	F.C. /Gov	FC /NGO	ER /Gov	ER /NGO	TT /Gov	TT /NGO	CD /Gov	CD /NGO	EC /Gov	EC /NGO	Sum	Percent
P1. Limit new development	7.50	8.33	7.61	8.08	8.44	5.83	8.22	7.92	9.50	8.00	79.43	79.4%
P2. Elevate buildings (Engineering policy)	8.33	8.75	6.68	6.15	5.36	5.00	7.84	6.42	7.50	6.75	68.78	68.8%
P3. Strengthen infrastructure (Engineering policy)	7.33	8.75	7.61	7.50	7.19	8.33	7.96	7.50	9.00	8.25	79.42	79.4%
P4. Establish infrastructure resilience program (Engineering policy)	7.14	8.75	7.34	7.50	7.50	6.67	7.96	7.58	8.50	9.00	77.94	77.9%
P5. Minimize impervious surfaces (Land use policy)	5.54	6.67	5.71	5.96	6.43	6.67	6.35	6.75	8.50	6.50	65.07	65.1%
P6. Building dams (Engineering policy)	5.63	5.00	6.39	6.73	6.07	5.83	6.21	6.77	6.50	5.25	60.39	60.4%
P7. Building levees (Engineering policy)	5.42	7.50	6.19	7.50	5.71	7.50	5.96	7.12	6.00	7.25	66.15	66.2%
P8. Building reservoirs/retention ponds (Engineering policy)	6.73	10.00	7.45	8.08	7.14	6.67	7.43	7.65	7.50	7.25	75.90	75.9%
P9. Protect wetlands/open space (Land use policy)	7.14	8.33	7.61	7.31	7.14	5.83	7.24	7.34	9.00	8.50	75.45	75.4%
P10. Improve stormwater (Engineering policy)	7.83	8.33	8.24	8.08	7.81	7.50	8.09	7.95	8.13	7.00	78.97	79.0%
P11. Improve drainage systems (Engineering policy)	7.32	10.00	7.93	8.08	7.14	7.50	7.83	8.18	7.50	7.00	78.48	78.5%
P12. Temporarily prohibit development after disasters (Land use policy)	5.71	3.33	5.34	5.96	5.63	5.00	6.09	6.25	5.63	5.28	54.22	54.2%
P13. Charge impact fees (Monetary policy)	6.25	5.83	6.59	6.92	6.43	6.67	6.62	6.41	8.13	6.39	66.23	66.2%
P14. Limit development of public facilities (Land use policy)	7.86	6.67	7.34	7.29	7.81	5.83	7.57	6.81	10.00	7.25	74.43	74.4%
P15. Limit rebuilding in frequent flooding areas (Land use policy)	9.11	8.33	7.99	7.31	7.19	7.50	8.29	7.26	10.00	8.25	81.22	81.2%
P16. Buyout or acquire property (Monetary policy)	8.00	8.33	7.22	6.35	6.79	5.83	7.70	6.67	8.50	7.50	79.43	79.4%
Sum	112.8	122.9	113.2	114.8	109.8	104.2	117.4	114.6	129.9	115.4		
Percent	70.5%	76.8%	70.8%	71.7%	68.6%	65.1%	73.4%	71.6%	81.2%	72.1%		

Notes: Green marks showed the highest rates, and red marks showed the lowest rates among urban sectors.

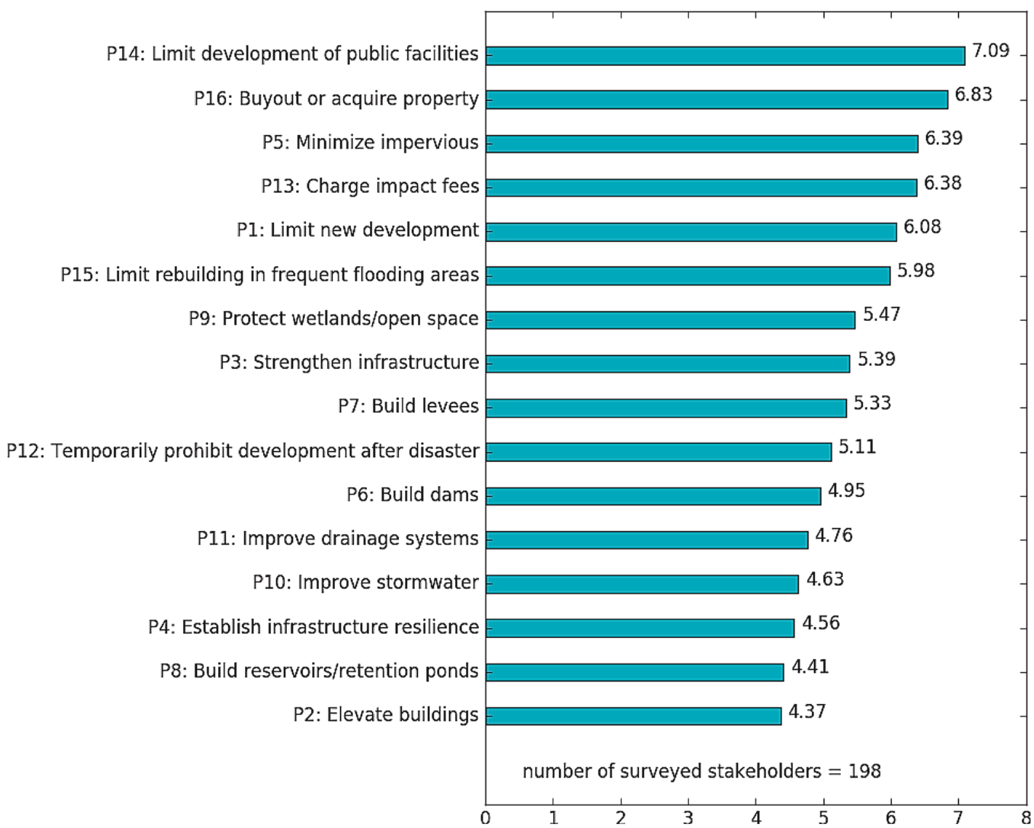

Fig. 2. Results of variances in the level of policy support.

had the lowest level of congruency due to the highest variance of policy satisfaction rating. Stakeholders from different urban sectors had a highly divergent preference towards P14. Stakeholders from NGOs in the flood control and community development sectors showed the lowest two congruencies towards P14 (with variances 1.56 and 1.17, respectively), while stakeholders from government organizations in the environmental conservation sector showed the highest congruency (with zero variance). These examples showed how the variance in the policy preference ratings could be used to evaluate preference congruence among stakeholders within each urban sector.

Based on the results in Table 2 and Fig. 2, we can conclude that engineering policy actions (P2, P3, P4, P6, P7, P8, P10, P11) have the highest average supports, while monetary policy actions (P13, P16) have the lowest average supports by all the urban sectors. Furthermore, engineering policy actions have the highest support by the non-governmental organizations in the flood control sector and have the lowest support by governmental organizations in the transportation sector. Land use policy actions and monetary policy actions gain the highest supports by governmental organizations in the environmental conservation sector and gain the lowest support by non-governmental organizations in the transportation sector. Also, engineering policy actions have the lowest overall variance of rates, and monetary policy actions have the highest overall variance of rates. This means that monetary policy supports are polarized while actors from different urban sectors have more consistent attitudes towards engineering policy actions.

5.2. Results of plan evaluation

Fig. 3 illustrated the results of plan evaluation and policy preference aggregation for selected plans. Detailed results of plan evaluation and policy preference aggregation calculation for each plan were shown in Tables S4–S7 in the supplemental documents.

In the CIP, the preferences of stakeholders from NGOs in the flood control sector were captured the most (37.8 %), while the stakeholder policy preferences of NGOs in the transportation sector were captured the least (29.3 %). It is worth noting that most NGOs that participated in the stakeholder survey were professional organizations that included related governmental officials or have a long-term collaboration with governmental organizations. This could be the reason why the preferences of stakeholders from NGOs in the flood control sector were captured the most in the CIP. Also, different types of NGO stakeholders may have distinctive policy preferences in the planning process. To illustrate, professional NGOs such as the Texas Floodplain Management Association and West Street Recovery may have different preferences in resilience planning, although they both worked on flood resilience in Houston. We found that this plan favors the preferences of stakeholders in the flood control and environmental conservation sectors because the CIP included many projects, such as drainage system improvement and ecosystem enhancement, enhancing flood risk reduction and resilience in the region.

Fig. 3 illustrated that the RCP was the most effective in capturing the preferences of stakeholders from government organizations in the environmental conservation sectors. In contrast, the RCP was least effective in capturing the preferences of stakeholders in NGOs in the transportation sector. We found that the RCP reflected more preferences of stakeholders in the environmental conservation and flood control sectors. This was because the policies in the RCP focused on ecosystem enhancement, open space requirements, and land acquisition, and these policies also indicated the high preferences of stakeholders in the flood control sector.

The RTP addressed only one policy action (P4). Therefore, the RTP captured the fewest overall stakeholder preferences among the four examined plans. The RTP focused mainly on the maintenance and improvement of the transportation system. Most policies in the RTP are related to transportation infrastructure development (e.g., expand the roadway system) and cannot capture diverse stakeholder policy preferences related to flood risk reduction and resilience.

Fig. 3 illustrated that the HMP captured the most overall stakeholder preferences among the examined plans. The preferences of stakeholders from government organizations in the environmental conservation and stakeholders from NGOs in the flood control sector were captured the most (nearly 59 %), while the stakeholder preferences of NGOs in the transportation sector were captured the least (45.3 %) in the HMP. The goal of HMP was to develop mitigation strategies for potential natural hazards in the City of Houston and thus included mitigation policies such as land requisition, infrastructure enhancement or weatherproofing drainage improvement, and flood control.

5.3. Policy consistency across plans

We also examined the level of policy consistency across four plans in terms of the extent to which they captured diverse stakeholder policy preferences. Fig. 4(a) illustrated the 16 policy actions in the survey included in the four plans. Circles represented four plans, and the sizes of circles were proportional to the number of incorporated surveyed policy actions. Policy actions in the overlaps indicated that they were incorporated in multiple plans. Fig. 4(b) illustrated the results of the policy consistency index among evaluated plans. Detailed calculation of the index was shown in Table S8 in the supplemental documents.

We observed from Fig. 4(a) that only P4 was addressed in all four plans. This implies that four plans all paid much attention to policies related to improving infrastructure resilience. P9 (protect wetlands/open space), P10 (improve stormwater systems), and P16 (buyout) were addressed in three plans, but not the RTP. These three plans included diverse types of policies: P9 is the land use policy, P10 is the engineering policy, and P16 is the monetary policy. The HMP included all the policy actions that the RCP and CIP incorporated except for P5 in the CIP. P6 (build dams), P7 (build levees), P12 (temporarily prohibit development after a disaster), and P13 (charge impact fees) were not included in any examined plans. Although P6 and P7 as typical structural resistance policies were widely used before (Godschalk, 2003; Beatley, 2012) and gained overall support (60.39 % and 66.15 %, respectively), the plan examination results indicated that P6 and P7 were not clearly addressed in the examined plans. As illustrated in Fig. 4(b), the HMP and RCP had the highest level of policy consistency (77.7 %), while the HMP and RTP had the lowest level of policy consistency (16.7 %) in terms of incorporating policy preferences of diverse stakeholders.

6. Discussion

Based on the above results, we can answer the three research questions. To what extent did different plans incorporate diverse policy preferences of stakeholders? The preferences of what stakeholders from which sectors were more/less captured by plans? What was the level of

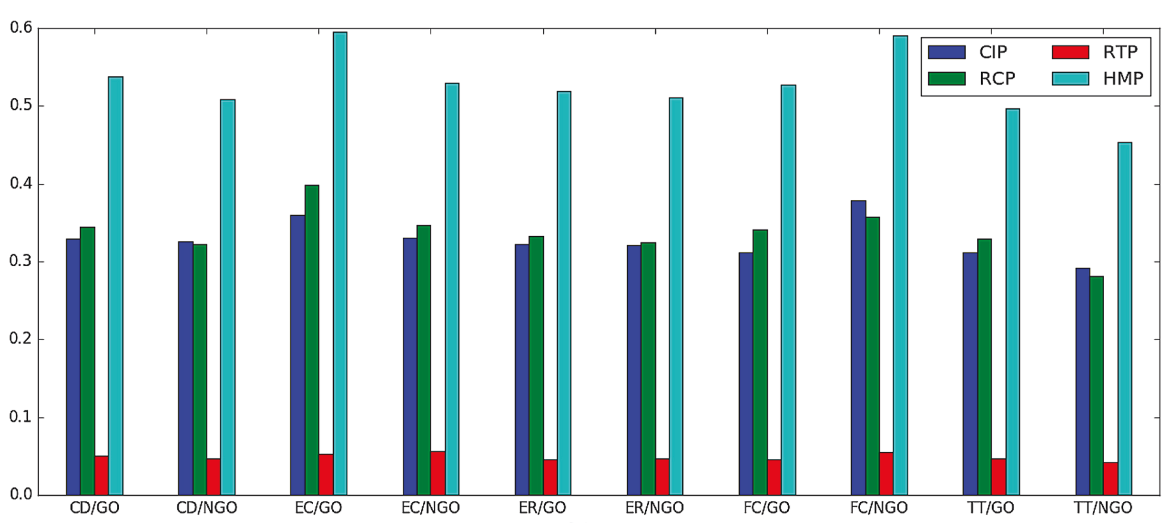

Fig. 3. Stakeholder aggregation for four plans.

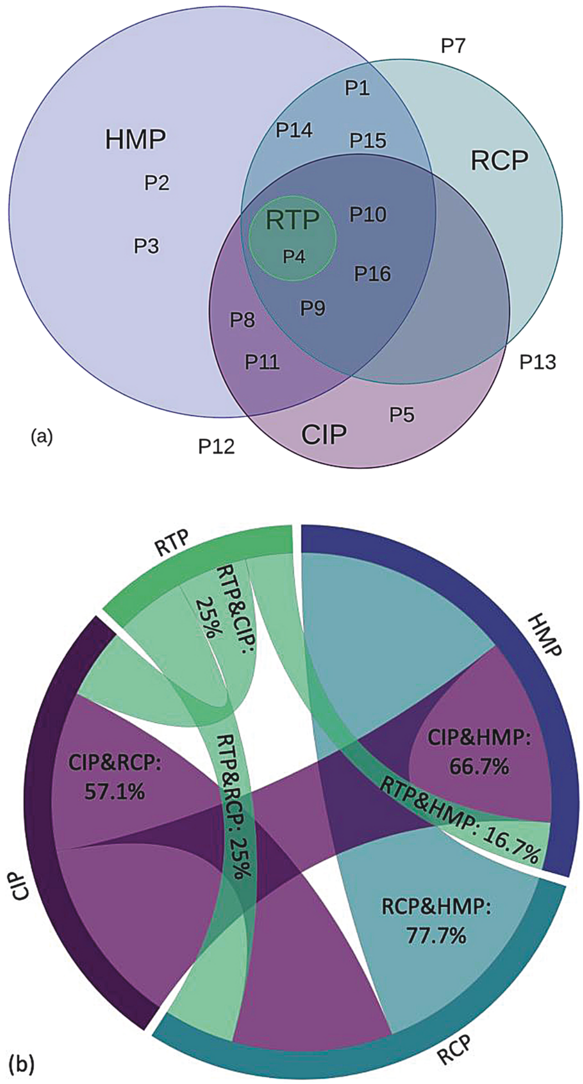

Fig. 4. Policy consistency across plans: (a) policy actions incorporated in four plans (b) policy consistency index.

policy consistency across plans in terms of incorporating policy preferences of diverse stakeholders? For the first research question, among four plans, the HMP incorporated the most policy preferences of stakeholders (52.7 %), while the RTP captured the fewest stakeholder policy preferences (4.9 %) in policy actions for flood risk reduction. HMP incorporated 11 out of the 16 policies that stakeholders supported—-with the most support shown for P15: "limit rebuilding in flooding areas." HMP did not, however, include policies to reduce impervious cover (P5), engineering policies to build new structural protection, such as dams (P6) and levees (P7), and financial tools (P13) to discourage development. This suggested that stakeholders and HMP consistently preferred avoiding floods over resisting through infrastructure. In fact, a few engineering policies (P6, P7) and finance tools (P13) were excluded from all four plans. Among these, "charge impact fees for development in flood-prone areas" was consistently less preferred (66 % support) by stakeholders compared to land-use policies (73 % mean support). This potentially undermined the effectiveness of other highly preferred policies, such as enforcing development restrictions (81.2 % support) or encouraging resilience through green infrastructure (79 % support) in Houston.

The RTP, on the other hand, contained only one policy, "establish and implement infrastructure resilience." Thus, while failed to capture diverse policy preferences, the one policy reflected the preference held by 79 % of stakeholders. Given that RTP played a pivotal role in infrastructure growth by extension urbanization and runoff in Houston, however, it is concerning that the plan did not incorporate policies to address impervious cover or to improve stormwater systems.

Second, we asked if plans captured more/fewer preferences of certain urban sectors and types of organizations? Policy preferences of stakeholders from both government organizations and NGOs in the environmental conservation sector were captured the most in the examined plans, while preferences of stakeholders from NGOs in the transportation sector were captured least effectively. Furthermore, the plans also captured the preferences of stakeholders from NGOs in the flood control sector the second most effectively. The HMP did the best job of addressing both governmental and NGO policy preferences.

Finally, we asked what was the level of policy consistency among plans? The transportation plan and the hazard mitigation plan had the lowest level of policy consistency, while the hazard mitigation plan and the environmental conservation plan had the highest level of policy consistency. This siloed approach to resilience was consistent with past assessments of plans in cities across the United States. For instance, Berke et al. (2019) evaluated policies from six flood-prone cities in the United States and recommend that comprehensive plans further integrated land use based–hazard mitigation. Woodruff and Regan (2019) found that involving diverse stakeholders from different urban sectors both within and outside government would greatly improve the quality of resilience plans. These findings reiterated the need for more collaboration across plans (Godschalk, 2003; Godschalk et al., 1999), and further argued in favor of incorporating diverse policy preferences that were shared by a large number of stakeholders. The capital improvement plan and the hazard mitigation both had relatively high levels of policy consistency. This finding is encouraging as the capital improvement plan could function as a medium for implementing policies in hazard mitigation plans.

The results provided a complementary perspective of networks of plan analysis. Cities are increasingly guided by multiple plans. However, if diverse stakeholders involved in the planning process acted only in pursuit of their own interests and values that influence their policy preferences, the networks of plans would be less integrated and inclusive (Finn et al., 2007). Berke et al. (2015) found that local plans were not well integrated (e.g., land use and hazard mitigation), and some local plans surprisingly increased the physical and social vulnerability in the target areas. The proposed plan evaluation framework can complement existing approaches to better examine networks of plans related to environmental hazards and urban resilience in a perspective of stakeholder policy preference incorporation. Based on the results above, we found that the transportation plan captured the diverse stakeholder policy preferences least effectively and had the lowest level of policy consistency with the hazard mitigation plan. If transportation plans and transportation planners are not aligned with other plans and planners in either values or policies, we may end up perpetuating a transportation system that exacerbates rather than mitigates climate change-related flooding. One good example is the increase in flood risk due to the developed upstream of Addicks and Barkers reservoirs. The development caused the loss of green land and subsequently contributed to water release from the reservoirs in Hurricane Harvey. The release of water led to unprecedented flooding in the west Houston area. The release of water from the reservoirs was to protect the reservoirs from breaching that may lead to catastrophic losses. However, the high water level in the reservoirs was not only due to the rainfall by Hurricane Harvey but also due to the triggered urban growth and development because of the newly constructed segment of State Highway 99 (SH-99) (Li et al., 2019). The inconsistent transportation plans and flood control plans led to increased development and urban sprawl near the segment of SH-99 and around reservoirs. Such development led to more paved areas and eliminated the wetlands that could store and absorb the water without increasing the burden of the reservoirs.

The results also highlighted the divergent policy preferences of diverse stakeholders in the resilience planning process. The environmental conservation plan and the hazard mitigation plan captured the preferences of stakeholders in the transportation sector the least. The transportation plan also did not incorporate the preferences of stakeholders from other sectors. Resilience planning, however, requires collective actions (e.g., communication, coordination) among diverse stakeholders across IUSs. Plan contradictions and inconsistencies would arise due to insufficient coordination among diverse stakeholders. Evaluation of diverse stakeholder policy preferences in networks of plans would effectively facilitate stakeholder preference incorporation across plans and improve the level of collective actions among stakeholders across IUSs in the resilience planning process.

7. Limitations and future directions

We would like to note some limitations in this study. First, we did not consider citizen participation in the planning process. Existing studies showed that citizen participation has been playing an increasingly important role in community development, policy analysis, and public management (Mannarini and Talò, 2013). Future research could account for citizen participation in the planning process due to various policy preferences based on the examination of developed indicators of citizen participation (Morrissey, 2000). While we did not consider citizens' policy preferences in this study, the proposed methodology could be used in future studies to examine the extent to which citizens' policy preferences were incorporated across various plans and to what extent their policy preferences differed from other stakeholder groups. Second, stakeholder policy preferences are not static but evolve over time (Johnson et al., 2013; Iii et al., 2011; Willigers et al., 2009). This study, however, did not consider the evolutions of stakeholder policy preferences based on the survey results. Future research could conduct a longitudinal study to account for the evolutions of stakeholder policy preferences.

Author statements

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2021.06.015.

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