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Institutional congruence for resilience management in interdependent infrastructure systems

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ABSTRACT

Institutions are important elements in human systems influencing interactions among organizations that contribute to resilience management in interdependent infrastructure systems (IISs). In particular, the existence of institutional congruence among actors across these complex systems is important for the successful operation of such systems. Institutional congruence is the extent to which organizations have similar, agreed upon, or harmonized institutions. Institutional congruence has remained an understudied aspect of the management of resilience in IISs. This paper assesses three significant aspects of resilience management of IISs through the evaluation of organizational institutions: organizations' involvement in hazard mitigation planning and use of hazard mitigation plans; organizations' view regarding the responsibility of hazard mitigations and contributors to hazard; and organizations' support of policies for hazard risk mitigation. Organizational institutions within a sector and across different sectors that are involved in hazard risk mitigation in the context of the Harris County during Hurricane Harvey were investigated. The impacts of the extent to which organizational institutions were congruent on the cooperative management of resilience and the vulnerability of infrastructures were discussed. Findings show that, although the use of non-structural solutions is supported by most of the organizations, the existing plans did not specifically focus on such solutions. Additionally, the results indicate the existence of congruence across sectors about the importance of responsibility sharing among governments at different levels in mitigating the risk of hazard. Different organizations across sectors have varying perceptions regarding suitable approaches for flood risk mitigation that contribute to the vulnerability of physical infrastructures.

1. Introduction

Modern infrastructure systems, such as power and transportation networks and flood control infrastructures, are no longer independent but interact and coordinate with each other in order to increase service efficiency. Not only do they provide essential services to support the economic growth and prosperity of communities [1], but they also play an imperative role in disaster risk reduction, hazard mitigation, and efficient community recovery efforts [2,3]. Hence, understanding the underlying mechanism influencing such interwoven interdependence remains of great importance.

In an urban system, resilience refers to *"the ability of the urban system and all its constituent socio-ecological and sociotechnical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity"* [4]. In complex coupled systems such as infrastructures, resilience also deals with improving the ability of organizations from public, private, and civic sectors to work together to anticipate hazards and respond and adaptively recover in ways that reduce future risk. A rich body of research focuses on the physical aspect of resilience [1,5–8]. Numerous research studies have been conducted to capture the role of interdependencies among various Interdependent Infrastructure Systems (IISs), all of which have used various analytical and simulation techniques [9–14].

Increasing the robustness of physical infrastructures is critical in building a resilient infrastructure system [15]. Another important

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element is the role of organizations and institutions that govern organizational behaviors and interactions in resilience management of IISs [16–18]. Institutions can be defined as formal and informal procedures, programs, and rules that are established by humans and that engender social practices, set responsibility of actors, and categorize actors' interactions [19]. Organizations, in this context, are formal decision-making structures or entities with specific goals, boundaries, and functions [20]. In fact, organizations are the actors that are involved in the management of hazard risk and resilience management effort. Organizations and their underlying institutions regulate and plan for infrastructure systems' development. They also establish hazard risk mitigation policies that require collective actions, cooperation, and participatory engagement of all stakeholders [21,22]. Organizations are from various urban sectors, which here refers to a group of organizations with similar background and objectives and follow similar processes, such as the transportation sector and the environmental conservation sector. However, organizations across urban sectors and/or within a sector have different objectives, as well as socially constructed values, rules, and norms. The existence of such conflicts and incongruence among institutions that govern the behaviors and interactions of organizations can inhibit effective resilience management [23]. In other words, the presence of these institutions, along with their congruence, which is defined as the existence of an agreement, similarity, or harmony between distinct constructs [24], can help the system in coping with disasters.

2. Problem statement

In the existing research literature, studies that examine the congruence of organizational institutions in the context of risk mitigation and resilience management of IISs are very limited. To bridge this gap, this study explores the congruence of organizational institutions within and across different urban sectors that are involved in hazard risk mitigation and resilience management of IISs. To this end, this study puts forward specific questions aimed at investigating the similarities and differences of organizational institutions regarding three significant aspects of resilience management: (1) organizations' involvement in hazard mitigation planning and use of the hazard mitigation plan; (2) organizations' view about the level of government that should take the greatest responsibility for mitigation of hazard risk and organizations' view about the main causes of hazard; and (3) organizations' support of policies for hazard risk mitigation. The specific core questions are:

(1) To what extent do organizations in different urban sectors and within a sector use the hazard mitigation plan? What is the relationship between involvement in planning and subsequent use of plans?
(2) Do organizations from different urban sectors have a different understanding of hazards, as well as the proper governance approach to cope with hazard risk? To what extent do the views of organizations in different urban sectors vary regarding the level of government that should take the greatest responsibility for mitigation of hazards risk? And what is the extent of conflicting perceptions among organizations within a sector and across different sectors regarding the factors that have the highest contribution to hazard vulnerability?
(3) What is the extent of variation in preferences of different policies in the hazard mitigation and resilience processes among organizations within and across different urban sectors?

Research questions developed in this research study are also aligned with a set of priorities laid out by the Sendai framework for disaster risk reduction 2015–2030 (SFDRR) [25]. The framework articulates the significance of mechanisms that enable coordination between stakeholders within and across all sectors in all levels. In Sendai framework, Priority 3 is *investing in disaster risk reduction for resilience*, in which the promotion of consistency across sectors and organizations to enable better planning for disaster risk reduction have been emphasized (research question 1). Priority 2 is *strengthening disaster risk governance to manage disaster risk,* which focuses on the importance of governance for the management of disaster risk and highlights the importance of responsibility sharing (research question 2). *Understanding disaster risk*, which is Priority 1 in the Sendai framework, accounts for understanding disaster risk in setting policies and practices. To this end, the framework encourages promoting dialogue and improving cooperation among different stakeholders, which can be viewed as a mean to build consensus in supporting effective policies for hazard mitigation (research questions 3). This part of the framework also emphasizes the significance of understanding disaster risk in all dimensions, such as exposure and vulnerability, and highlights the importance of understanding risk for effective risk management (research question 2).

In the next section, the concept of congruence of organizational institutions and its importance in the management of resilience are discussed. Also, a brief review of literature is conducted to highlight the point of departure regarding the assessment of congruence of organizational institutions in the context of IISs. Then, an empirical study is conducted to explore and analyze the congruence of organizational institutions regarding three abovementioned aspects of resilience management. Then, findings are discussed to examine the similarities and differences in organizations' views and perceptions and the impacts of these similarities and differences on the effectiveness of hazard mitigation efforts, as well as risk and resilience management of IISs during and after a disaster event.

3. Theoretical background

3.1. Resilience management: different perspectives and the role of institutions

Traditionally, studies related to resilience management in IISs have been based on three perspectives: engineering, organizational, and social perspectives. Each of the three perspectives focuses on specific systems and processes (e.g., physical infrastructures and interdependencies, organizations, and people) [23]. Engineering resilience aims to develop tools and techniques to quantitatively analyze the existing condition and design processes to enhance the resilience of physical components (e.g., structures and infrastructures). In the social perspective, resilience management is considered as a process that can be reached/enhanced by collective efforts [26] and by building the capability to self-organize through enforcing rules and norms [27]. An organizational perspective to resilience management highlights the role of socially constructed cultural elements of institutions that are formed inherently and can enable organizational activities of public and corporate organizations [23]. Different organizations follow different sets of institutions (e.g., rules, norms, and values) that form their institutional logic [28]. The organizational perspective helps to explain how adherence to different institutional logics prevents organizations from devising an agreed upon solution or even reaching a shared understanding of a problem [29]. This agreement and shared understanding, which is referred to as congruence of institutions, is the cornerstone of resilience management in complex systems with multiple heterogeneous actors [30]. The existence of institutional incongruences can cause institutional barriers, which prevent the implementation of mitigation policies and recovery actions [31]. These institutional barriers might include institutional fragmentation, lack of a shared understanding, unclear responsibilities, or conflicting policy preferences, thus diminishing the management capabilities of the organizations [32]. In sum, identification and assessment of the organizational institutions and the extent to which these institutions are congruent among various actors involved in resilience management IISs are crucial but are limited in current practices [33–35]. To investigate the congruence of institutional attributes of organizations from different urban sectors, the important

aspects of risk and resilience management in IISs that are highly influenced by the organizational institutions should be properly identified. In the following sections, the important aspects of risk and resilience management that have been selected to explore the congruence of organizational institutions of involved actors are reviewed. The selected aspects will be further used to collect the data required for the investigation of organizations' perceptions and preferences that can represent their institutional attributes.

3.2. Involvement in planning process and use of hazard mitigation plan

Plans are established to achieve short-term and long-term governance goals through various policies. There are often multiple plans that are designed by various stakeholders (governmental or non-governmental organizations) and implemented by different stakeholders [36]. A community's capability to coordinate plans that guide its development is imperative in gaining and maintaining its resilience [37]. Plans, if appropriately comprehended, can also engender a view to the public that the responsible parties are able to properly organize the existing disaster risk and plans have enough foresight to wisely take into account associated issues and contingencies [38]. These include policies that guide and prioritize decisions on the design of developments such as infrastructures. These policies may include regulatory, incentive, and investment policies that guide stakeholders' actions. In particular, community hazard mitigation plans guide future development with respect to the hazard and the vulnerability of built and natural environments, as well as human vulnerability [39–41].

Resilience management through the use of plans that are not coordinated may result in inadequate preparation for and response to disasters [42–44]. This challenge can be conceptualized as the inadequacy of institutional congruence among organizations involved in the management of resilience. Involvement of an organization in the planning process also potentially increases the tendency of the organization to follow existing guidelines and policies in the plans. Therefore, more involvement of an organization in the planning process could increase the likelihood of the organization to follow the directions that are considered in the associated plan. Besides, plans that are developed through the involvement of more agencies and organizations are of higher quality in terms of stakeholder engagement [45]. Involvement of different organizations would lead to a more collaborative effort since the plans have incorporated various aspects of resilience management and requirements from more diverse perspectives [46]. On the other hand, the involvement of multiple parties in the planning process may lead to inconsistencies and contradictions between plans [47]. Institutional congruence among organizations that are involved in planning may reduce such inconsistencies and contradictions in views, perceptions, and policy preferences. In this case, disorganized use of the plan is prevented and organizations will not work at cross-purposes [48]. Moreover, the acceptability of plans among stakeholders is considered as one of the key factors for effective disaster risk reduction [49].

3.3. The responsibility of mitigation and contributors to hazard

Organizations may have different perception and understanding of various aspects of resilience management. In the absence of shared understanding, actions are defined and understood by fragmented and multi-directional approaches [23]. Moreover, the formation of shared understanding can enhance the performance of organizations [50]. Organizations' view about the governmental agency that should take the greatest responsibility for mitigation of hazard risk and organizations' perception about the factors that significantly contribute to the hazard are two crucial factors that form organizational institutions.

Governments are responsible for coordinating efforts to mitigate hazard risk. They design systems and regulations, including decision-making, legislative processes, and policy instruments [51]. There is a controversial debate about the level of government that should take responsibility for hazard risk mitigation [52]. An organization's recognition of the governance of the disaster risk refers to its expectations from different levels of government (e.g., federal, state, county, city) as well as its attitude about responsibility sharing [53,54] and disaster risk decision-making arrangement [55]. Mutual understanding or perfect recognition in organizations about governmental responsibilities and roles enhances the effectiveness of directed and coordinated actions of multiple agents. In case of a disaster, such understanding helps organizations to predict actions of other actors and allocate resources based on the competency of other organizations [56]. Moreover, different stakeholders may have a different perception of the causes of a disaster [57,58]. For example, in case of an earthquake, to reduce potential human losses a group of stakeholders might believe that the community needs to prioritize actions to increase public awareness about how to survive during the earthquake, while another group of stakeholders may put more effort into increasing hospitals' robustness to enhance the communities' emergency care capability following the earthquake. In this case, the former group recognizes social factors as the main source of human loss generation while the latter group identifies physical vulnerability as the main cause of human loss escalation. Therefore, the formation of a shared understanding of the main sources of risk helps to develop effective and synergic practices.

3.4. Support of funding policies, insurance pricing, and hazard mitigation policies

Resilience management requires the implementation of various policy actions, such as policies to mitigate the risk of hazards, funding policy instruments to develop new infrastructures, and insurance pricing policies for households and communities. A policy comprises several practices that seek a certain goal. Incorporation of stakeholders' preferable practices into policy-making processes helps to increase the efficiency of mitigation and recovery activities and facilitates implementing policy options that make practical sense for actors involved in management [59]. Successful implementation of resilience policies requires solicitation of organizations' viewpoints and attitudes [60,61] and investigation of their preferred practices, which also ensures stakeholder engagement [61] and effective collaboration of organizations from different sectors [62]. Evaluation of organizations' preferred policies and actions also help to identify knowledge gaps and eases mutual learning in order to find practical policies [63]. On the other hand, the establishment of diverse and more flexible sets of policies and practices can be limited when stakeholders' institutions are conflicted [63,64].

4. Research design and methods

4.1. Study area and research context

To explore the influence of institutional congruence on resilience management in IISs, this study analyzes institutional congruence among organizations involved in flood resilience management in Harris County, Texas, and in the context of Hurricane Harvey. Harris County is one of the most flood-prone urban regions in the U.S. During past years, the county has experienced several hurricanes and floods such as Memorial Day flood in 2015, Tax Day flood in 2016, hurricane Harvey in 2017, and flooding caused by tropical storm Imelda in 2019. The county has more than 4.37 million population (the third largest county in the U.S.) [65]. Population demographic shows that 63.6% of the residents in the county are minorities and 12.87% are considered as people living in poverty. The social vulnerability of the residents increases the risk of flood in the county. 25.17% of population in Harris County live in areas that are considered as socially vulnerable and more than 50% of those people have been affected by hurricane Harvey in 2017 [65]. The infrastructure in the county is also threatened by the extreme event such as floods. For instance, 1010 miles of major highways in the county are

within a floodplain, which makes the road network highly vulnerable. Hence, Harris County is considered as a proper study area for flood risk management studies. On the other hand, the high risk of flooding has led to a considerable amount of effort by governments, authorities, and stakeholders to cope with flood risk in the county, mitigate the risk, and prepare the community for expected future hazards. For instance, in the aftermath of hurricane Harvey, the City of Houston and Harris county started rethinking the use of 100-year floodplain for new development and flood control standards, Harris County Flood Control District is also updating capital improvement plans for stormwater drainage and flood protection projects.

As one of the most devastating urban flood in the history of U.S., Hurricane Harvey reached the Texas Gulf Coast on August 25, 2017 [66], affecting the region with extreme rainfall and devastating flooding, and causing extensive economic, social, and socioeconomic disruption [67,68]. Estimates shows that Harvey caused over $125 billion loss in Houston, as the main metropolitan area in the Harris county. The losses are mainly from the flooding triggered by the release of two major reservoirs (i.e., Addicks and Baker reservoirs) in the west side of the downtown area in Houston. In many areas, the maximum extent of flooding during hurricane Harvey exceeded the boundaries of 500-year floodplain maps developed by National Flood Insurance Program (NFIP). Different levels of governments, emergency management agencies, local agencies, faith-based organizations, and private sector groups worked together prior, during, and after the event to minimize the impact and meet the needs of people who suffered from storm damage and flooding in the state. Despite the major efforts to reduce the losses occurred by hurricane Harvey, it is argued that the history of planning and development in the region has contributed to the massive losses by the flood following hurricane Harvey. For example, the conflict between the rapid growth of the county population, as well as the expansion of the economy is believed to be underestimated flood control infrastructures planning and investment. Moreover, the lack of a formal zoning policy that may help planning for hazard mitigation and planning for development in the county is not supported by infrastructure investments and land use regulations that consider hazard mitigation requirements [69]. This problem shows that there might be a lack of coordination among urban sectors involved in hazard mitigation and emergency response for hurricane Harvey in the county. Hence, the case study of Harris County in the context of hurricane Harvey can be a proper test bed for assessment of institutional congruence for resilience management in IISs.

4.2. Survey design and implementation

The data used to assess the congruence of organizational institutions comes from a stakeholder survey aimed to collect data regarding infrastructure needs, risks, and vulnerabilities resulting from the interconnections between five different urban sectors (i.e., flood control, emergency response, transportation, community development, and environmental conservation) in the face of Hurricane Harvey. Organizations within each sector that were involved in hazard mitigation activities, emergency response, and recovery efforts following the hurricane were identified by a research team, which included experts in civil engineering, urban planning, and sociology. Individuals in each organization were identified and listed as the potential respondents that were asked to complete the survey form based on their organizational point of view. On January 31, 2018, a pilot test of the stakeholder survey was conducted to get feedback and comments on the survey instrument. The pilot test randomly selected a group of 15 individuals from the existing sample. The test received 4 respondents and was closed on February 12, 2018. The stakeholder survey instrument was refined based on the received feedback. The survey officially started on February 15, 2018. The survey team had a follow-up procedure to maximize the response rate. Each respondent received at least 3–4 reminder emails (unless they completed the survey before receiving all 4 reminders). After multiple reminders were sent, survey team members would call the respondent and/or his/her organization to persuade them to complete the survey. The survey was closed on April 10, 2018; 198 out of 795 invited individuals completed the survey. The sample includes responders from 109 organizations and 160 distinctive departments completing the survey. The organizations were classified based on the departments in which the respondents were employed. Organizations in the flood control sector are mainly organizations that are responsible for managing and operating flood control infrastructures such as Harris County Flood Control District (HCFCD), and departments that are involving in watershed management as well as water infrastructure operation and management. The emergency response organizations include police and fire departments, emergency medical service providers, as well as departments in governmental organizations that are involved in post-disaster emergency operations. Transportation sector mainly includes departments of transportation such as Texas Department of Transportation (TXDOT) and institutes (such as MPOs) that are involved in strategic planning for transportation development and transportation infrastructure development. Examples of community development organizations are City management such of City of Houston, NGOs, departments of public works, and recreational and business departments. Finally, environmental conservation organizations are mainly working on the environmental consequences and risks of flood hazard such as waste management departments and pollution control institutions. The organizations participated in the survey were from different levels such as local, regional, and federal. Examples of organizations within different urban sectors and divisions/departments that fall in each urban sector category are shown in Table 1.

Table 2 shows the number of participants in each sector. Out of 198 participants, 70 individuals (35.35%) had more than 7 years of experience in their current positions and 40 (20.20%) individuals had 4–7 years of experience in their current positions. The survey questionnaire included questions to collect basic information such as name of the organization and department/division that the respondent is working at, respondent's position in the organization, and respondent's experience in his/her current position and his/her previous experiences in related

Table 1
Overview of the different urban sectors and examples of organizations in each sector that are involved in flood risk mitigation and resilience management of IISs in Harris County region.

Category	Example of Divisions/ Departments in the Category	Examples of Organizations in the Survey
Flood control	Water Departments & Institutions, Drainage and Floodplain Management	The Texas Floodplain Management Association, Harris County Flood Control District, City of Houston Floodplain Management Office
Emergency Response	Healthcare Organizations, Disaster Management, Police, Fire Department, Disaster Relief, Disaster Recovery, Resilience Offices	City of Houston Fire Department, FEMA Emergency Corps, Texas Department of Public Safety, Harris County Office of Emergency Management
Transportation	Transportation Departments	HGAC Transportation Policy Council, Houston TranStar, METRO, Port of Houston Authority
Community Development	Recreational Departments, Business and Economic Services, City Management, Academic Institutes, Public Work Departments, NGOs	City of Houston, H-GAC Community and Environmental Planning, City of Houston Parks Board, Bay Area Houston Economic Partnership
Environmental Conservation	Pollution Control, Safety and Health, Waste Management	Texas Water Development Board, Bayou Land Conservancy, Conservation Fund, The Nature Conservancy

Table 2
Distribution of participants in different sectors.

Sector	Number of participants
Transportation	13
Flood Control	19
Emergency Response	68
Environmental Conservation	18
Community Development	80
Sum	198

positions were asked. The survey questionnaire also asked respondents about the frequency of interaction between the organizations that they work at with other organizations that are involved in hazard mitigation and resilience management. Moreover, the respondents were asked about the involvement of their organizations in various activities related to hazard mitigation and emergency response as well as resilience management. Examples of these activities are involvement in planning for hazard mitigation and participation in stakeholder forums for hazard mitigation effort. In this part, the perception and preferences of respondents from their organizations' point of view regarding different aspects of hazard mitigation and resilience management were also investigated. Examples of such perceptions and preferences are perception about the contributors to flood, perception about the responsible government for hazard mitigation, policy preference for hazard mitigation, and preference for funding means that are used for new infrastructure projects. In order to comprehensively assess the respondents' attitude, it was required to compare their perception and preferences regarding different potential options, and therefore, a list of different options should be prepared. To this end, for such questions, a list of possible options was prepared by reviewing the related literature. Specifically, to investigate how the hazard mitigation plan had been used by organizations, a list of possible uses of the plan were prepared and included in the survey (U1 to U12 in Table 5). For the possible funding sources for new infrastructure projects, six potential sources were selected and included in the survey form (Fig. 3). Moreover, considering that there are various potential contributors to flooding such as contributors related to land use, contributors related to flood protection and stormwater drainage infrastructures, social contributors, and budgetary contributors, 20 potential contributors of different types were included (C1 to C20 in Table 6). In terms of the policies that can help mitigating the risk of flood, various potential policies were reviewed and 16 major policies included in the survey. These policies include policies for infrastructure development, establishment of programs for resilience enhancement, and establishment and strengthen regulations for aligning development with hazard mitigation goals among others (P1 to P16 in Table 8). The questions used in the analysis presented in this study were selected from the survey form based on their relevance to examining institutional congruence. Table 3 summarizes the questions in the survey form.

5. Results

5.1. Involvement in planning process and use of hazard mitigation plan

Table 4 shows involvement in the hazard mitigation planning process and the use of plans during recovery. Results show that organizations from flood control (73.68%) and emergency response (70.59%) sectors had the greatest involvement in the hazard mitigation planning process. Community development organizations had a moderate level of involvement in the process (55.00%). On the other hand, relatively low involvement of transportation (30.77%) and environmental conservation (38.89%) sectors can be observed. In addition, the high percentage of "Not Sure" responses from transportation organizations (53.85%) is an indication of the lack of awareness and knowledge about the involvement of survey participants' organizations in tasks related to

Table 3
Research questions, associated questions in survey questionnaire, and answer choices.

Resilience Management Aspect	Research Question	Question in the Survey Form	Answer Choices
Involvement in Planning Process and Use of Hazard Mitigation Plan	Involvement in the planning process	Has your organization been involved in your community's hazard mitigation planning process?	Yes/No/Not Sure/No Response
	Use of plan during recovery	Is your organization using the hazard mitigation plan during the process of recovering from Hurricane Harvey?	Yes/No/Not Sure/No Response
	Application of plan	How is the hazard mitigation plan being used by your organization during the recovery process?	list of uses[a]
The Responsibility of Mitigation and Contributors to Hazard	Responsible Level of Government	Which level of government has the greatest responsibility for the mitigation of long-term flooding risks?	City/County/ State/Federal/ All Shared/ None/No Response
	Potential Causes of Flooding	Below is a list of potential contributors to flooding from Hurricane Harvey. From your organizational standpoint, please rate how strongly each factor contributes to flooding.[b]	No Effect/ Weak/ Somewhat Strong/Strong/ Very Strong/No Response
Support of Funding Policies, Insurance Pricing, and Hazard Mitigation Policies	Appropriate Means of Funding	please rank the following means of funding sources for new infrastructure projects from 1 to 6, with 1 being the most preferred source and 6 being the least preferred source.[c]	From 1 (most preferred) to 6 (least preferred)
	Appropriate Household Insurance Setting	In the realm of insurance policies, actuarial pricing is used to develop premiums that are intended to cover losses from underwritten risks and provide future benefits payable to beneficiaries. Do you support actuarial pricing for setting household flood insurance rates?	Yes/No/Not Sure/No Response
	Appropriate Infra. Projects Insurance Setting	Do you support community-based flood insurance programs in which local governments carry flood insurance and rate reductions flow to the local government based on the level of	Yes/No/Not Sure/No Response

(continued on next page)

Table 3 (*continued*)

Resilience Management Aspect	Research Question	Question in the Survey Form	Answer Choices
		community adoption of flood risk reduction policies and projects?	
	The effectiveness of Potential Solutions	Here are some policy actions that could be taken to reduce the dangers of future flooding in the Houston area. To the best of your knowledge, please indicate your organization's level of opposition or support for each of the following policy options.[d]	Strongly Oppose/ Oppose/ Neutral/ Support/ Strongly Support/No Response

[a] List of possible uses of the plan can be found in Table 5.
[b] List of potential contributors can be found in Table 6.
[c] List of sources of funding can be found in Fig. 3.
[d] List of policy actions can be found in Table 8.

hazard mitigation. Table 4 also shows that during the recovery phase hazard mitigation plans had been used more frequently by organizations from the emergency response (58.82%) and flood control (57.89%) sectors. However, the use of plans by transportation organizations was relatively less frequent (46.15%). These findings are consistent with their high level of involvement in the planning process. In other words, involvement in the planning processes can lead to greater use of hazard mitigation planning during recovery.

Table 5 shows the frequency of the various uses of plans by organizations in different urban sectors. Column U3 (To implement previously prioritized hazard mitigation policies, programs, projects and other actions during recovery) is among the three most used across all sectors. On the other hand, the hazard mitigation plan is not frequently used by the respondents in informing long-term, non-structural decisions, such as land use planning (U6). In addition, the use of the plan to inform short-term and long-term decisions is infrequent across sectors. Although the use of the plan to inform short-term, non-structural decisions (U5) is generally low, it is relatively more frequent used by environmental conservation (11.43%) and flood control (11.59%). Organizations in the transportation sector use hazard mitigation plan to implement previously prioritized policies, programs, projects, and other actions during recovery (U3 @ 16.67%) and to remember implementation details, such as responsible agencies, timelines, and expected costs more frequently (U9 @ 13.33%).

5.2. The responsibility of mitigation and contributors to hazard

Results regarding the organizations' view about the greatest responsibility for the mitigation of long-term flooding risks are shown in Fig. 1. All urban sectors agree that different levels of government should share the responsibilities in flood risk mitigation. In addition, among different urban sectors, flood control and community development sectors show the highest variation in their attitude about the responsible level of government. In flood control sector, 33.33% of the responders supported the necessity of relying on local governments (i.e., city and county level) as being responsible for the mitigation of long-term flooding risk.

Fig. 2 shows the distribution of responses among all respondents. As can be seen, overall, Insufficient capacity of storm water system (C11), building in areas prone to flooding (C1), Funding shortage to build appropriate flood protection infrastructures (C19) are potential contributors that are believed by most of the respondents to have strong contribution on flooding. Table 6 shows the potential contributors to flooding, as listed in the survey, and summarizes participants' views on different contributors to flooding in the region. A score was assigned to each choice ("No Effect" = 1 to "Very Strong" = 5) and the means and variance were calculated in each urban sector. The percentage of participants that answered this question has also been determined. For each urban sector, contributors with the highest and lowest scores are shown. As shown in Table 6, environmental conservation sector mostly believed

Table 4
Involvement of participants' organizations in the planning process and use of plan during recovery.

Sector	Involvement in the Planning Process (%)				Use of Plan during Recovery (%)			
	Yes	No	Not Sure	No Response	Yes	No	Not Sure	No Response
Transportation	30.77	15.38	53.85	0	46.15	23.08	30.77	0
Flood Control	73.68	15.79	10.53	0	57.89	15.79	26.32	0
Emergency Response	70.59	22.06	7.35	0	58.82	23.53	17.65	0
Environmental Conservation	38.89	33.33	27.78	0	27.78	38.89	33.33	0
Community Development	55.00	37.50	7.50	0	43.75	38.75	17.50	0

Table 5
Percentage of uses of the plan by participants' organizations in different sectors.

Sector	Use of the Hazard Mitigation Plan (%)											
	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
Transportation	10.00	10.00	16.67	13.33	6.67	6.67	6.67	10.00	13.33	0.00	3.33	3.33
Flood Control	14.49	13.04	11.59	8.70	11.59	8.70	10.14	8.70	8.70	0.00	1.45	2.90
Emergency Response	11.06	15.38	12.98	7.69	7.69	8.65	9.62	10.58	10.10	1.92	1.44	2.88
Environmental conservation	8.57	11.43	11.43	11.43	11.43	8.57	8.57	11.43	8.57	0.00	0.00	8.57
Community Development	9.52	13.23	13.23	8.99	6.88	7.41	11.11	14.29	9.52	1.59	1.06	3.17

U1: To compare damage reports from the hurricane to vulnerabilities and risks anticipated in the hazard mitigation plan, U2: To align recovery goals and objectives with mitigation goals and objectives in the hazard mitigation plan, U3: To implement previously prioritized hazard mitigation policies, programs, projects and other actions during recovery, U4: To remind elected officials of goals, objectives or priorities previously agreed upon for the hazard mitigation plan, U5: To inform short-term non-structural decisions, such as land use planning, U6: To inform long-term non-structural decisions, such as land use planning, U7: To inform short-term structural decisions, such as infrastructure, U8: To inform long-term structural decisions, such as infrastructure, U9: To remember implementation details such as responsible agencies, timelines and expected costs, U10: Other, U11: Not sure about my organization's use of the plan, U12: The Regional Hazard Mitigation Plan is not used by my organization.

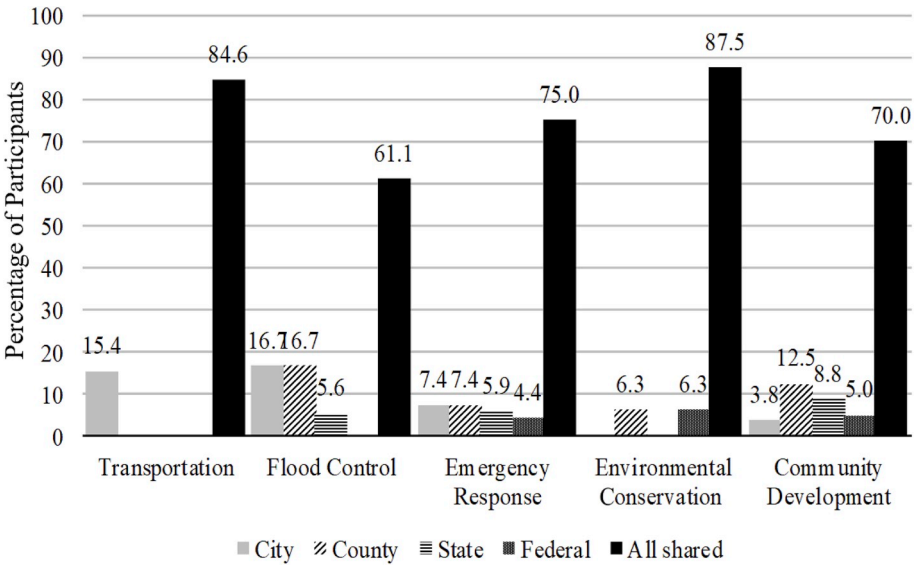
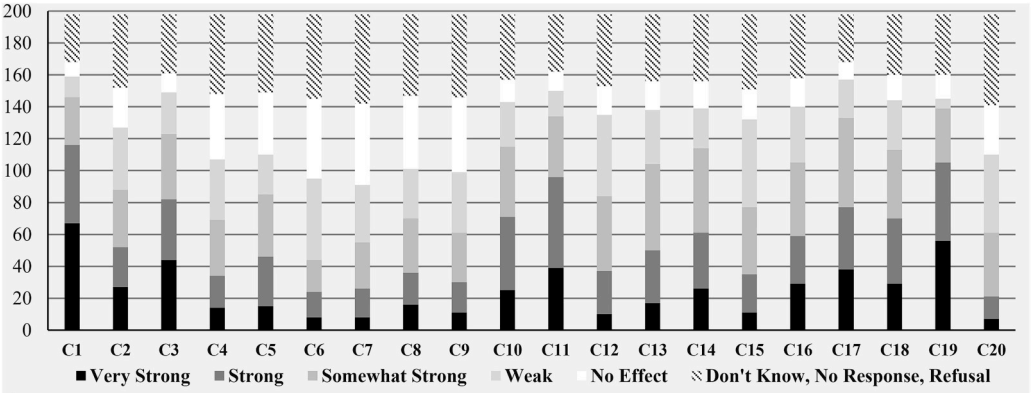


Fig. 1. Participant views of the government with the greatest responsibility for the mitigation of long-term flooding risk.



C1: Building in areas prone to flooding, C2: Insufficient protection of wetlands and open space, C3: too much land cover in concrete or solid materials, C4: Inadequate dam construction, C5: Insufficient dam capacity, C6: Inappropriate dam location, C7: Inappropriate levee location, C8: Insufficient levee capacity, C9: Inadequate levee construction, C10: Inadequate construction of storm water system, C11: Insufficient capacity of storm water system, C12: Inappropriate location of storm water infrastructure, C13: Inadequate retention pond construction, C14: Insufficient retention pond capacity, C15: Inappropriate retention pond location, C16: Ineffective intergovernmental flood planning and cooperation, C17: Citizen ignorance of potential flooding issues, C18: Neglect of potential flooding issues by public agencies, C19: Funding shortage to build appropriate flood protection infrastructures, C20: Failure to comply with the Regional Hazard Mitigation Plan

Fig. 2. Distribution of participant views about the potential contributors with the most and least effect on flooding.

that land use-related issues, such as insufficient protection of wetlands and open space (C2, mean = 4.08), and development that covers too much land in concrete and/or other impervious materials (C3, mean = 4.00), are the main causes of flooding. This urban sector was the only sector that did not put weight on the impact of funding shortage in building protective infrastructures. Contributors that focused on the lack of resistant structures, such as levees and dams (e.g., inappropriate dam location (C6), inappropriate levee construction (C7), and insufficient levee capacity (C8)), had generally low scores in all sectors.

Respondents from the flood control sector selected citizen ignorance on flooding (C17, mean = 3.39) as a chief contributor to flooding damage more than other urban sectors. However, the role of citizen actions was not emphasized by other sectors. Failure to comply with the regional hazard mitigation plan (C20), which concentrated on the involvement in planning and compliance with the plan, had relatively low scores among all urban sectors, specifically among transportation (mean = 2.17) and community development (mean = 2.49).

5.3. *Support of funding policies, insurance pricing, and hazard mitigation policies*

Fig. 3 summarizes the results regarding funding policies for new infrastructure projects. Mean scores were calculated using a numerical scale (most preferred" = 6 to "least preferred" = 1). The survey results show that federal loans and grants are the preferred funding source among participants across all urban sectors. The results also show a congruence regarding the responsibility of the federal government to financially support new infrastructures. Furthermore, except for flood control, all other urban sectors had the same priorities for second and third preferred options. Among different urban sectors, the flood control

Table 6
Participant views about the potential contributors with the most and least effect on flooding.

Sector	Most Supported Contributors				Least Supported Contributors			
	Contributor	Participation (%)	Mean Score	Variance	Contributor	Participation (%)	Mean Score	Variance
Transportation	C1	92.31	4.08	1.54	C20	46.15	2.17	0.57
	C19	53.85	3.71	2.24	C9	53.85	2.29	0.90
	C3	76.92	3.60	1.60	C7	46.15	2.33	0.67
Flood Control	C1	84.21	3.33	1.60	C4	73.68	1.71	0.84
	C19	78.95	3.50	1.38	C9	78.95	1.73	0.92
	C17	94.74	3.39	1.43	C7	78.95	1.80	0.89
					C8	78.95	1.80	1.03
Emergency Response	C1	82.35	3.80	1.40	C6	72.06	2.10	1.55
	C19	80.88	3.64	1.61	C7	75.00	2.12	1.59
	C11	77.94	3.62	1.39	C9	75.00	2.25	1.79
Environmental Conservation	C2	72.22	4.08	1.58	C6	77.78	2.14	0.90
	C1	72.22	4.00	1.50	C7	66.67	2.92	1.54
	C3	83.33	4.00	1.43	C13	72.22	2.92	0.91
Community Development	C1	88.75	4.03	1.26	C6	75.00	2.22	1.36
	C19	86.25	3.97	1.38	C7	72.50	2.38	1.61
	C11	85.00	3.74	1.36	C20	73.75	2.49	1.12

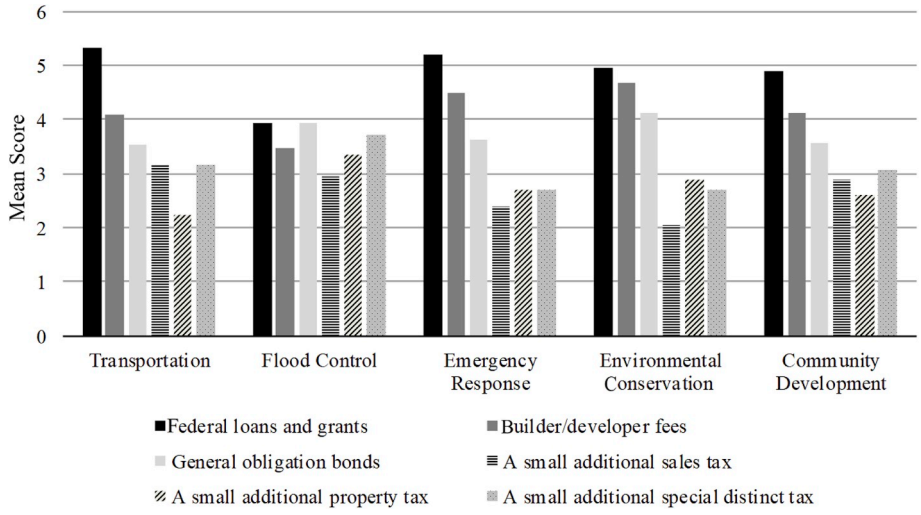


Fig. 3. Mean scores of each funding policy for new infrastructure projects in different sectors.

sector put the highest weight on the funding sources requiring public engagement in setting additional taxes.

Table 7 summarizes results regarding participant views about actuarial pricing for household flood insurance and community-based flood insurance programs. Flood control organizations had the highest level of support for using actuarial pricing to establish the costs of household flood insurance (63.16%). The high frequency of "Not Sure" and "No Response" answers may indicate a lack of knowledge about insurance pricing policies, particularly in transportation and community development sectors. In community-based flood insurance programs, "Not Sure" and "No Response" answers were relatively less frequent.

The list of policies that could reduce the risk of future flooding was included in the survey and is shown in Table 8. This table also shows mean scores and variances regarding the respondents' level of support for each policy. ("Strongly Oppose" = −2 to "Strongly Support" = 2). The percentage of participants that answered this question has also been determined. For each sector, policies with the highest and lowest scores are shown.

There are policies that had been supported by most survey participants, across all urban sectors. For example, flood control, emergency response, and environmental conservation sectors highly support limiting construction in areas frequently affected by floods (P15). Environmental conservation organizations also support establishing and implementing infrastructure resilience programs (P4). In addition, the flood resistance policies that require building more protective infrastructures (e.g., dams and levees) are not supported by participants in all sectors. On the contrary, flood avoidance policies (e.g., building and maintaining stormwater systems and drainage systems) are highly

Table 7
Participants' views about the support of actuarial pricing for household flood insurance and community-based flood insurance programs.

Sector	Actuarial pricing for Household Flood Insurance (%)				Community-based Flood Insurance Programs (%)			
	Yes	No	Not Sure	No Response	Yes	No	Not Sure	Response
Transportation	38.46	0	61.54	0	46.15	23.08	30.77	0
Flood Control	63.16	5.26	26.32	5.26	47.37	21.05	26.32	5.26
Emergency Response	45.59	11.76	42.65	0	48.53	16.18	35.29	0
Environmental Conservation	38.89	5.56	44.44	11.11	33.33	16.67	38.89	11.11
Community Development	46.25	5	48.75	0	46.25	15	38.75	0

Table 8
Mean score of supporting the policy actions that could be taken to reduce the dangers of future flooding in the Houston area by participants in different sectors.

Sector	Most Supported Policy				Least Supported Policy			
	Policy	Participation (%)	Mean Score	Variance	Policy	Participation (%)	Mean Score	Variance
Transportation	P1	84.62	1.09	0.69	P2	76.92	0.10	0.10
	P10	84.62	1.09	0.49	P12	84.62	0.18	0.56
	P3	84.62	1.00	0.80	P6	76.92	0.40	0.27
Flood Control	P15	89.47	1.59	0.51	P12	89.47	0.12	0.74
	P2	89.47	1.35	0.49	P6	68.42	0.23	0.53
	P16	94.74	1.22	1.12	P7	73.68	0.29	0.68
Emergency Response	P10	88.24	1.28	0.51	P12	83.82	0.19	0.73
	P11	88.24	1.18	0.49	P5	86.76	0.31	0.59
	P15	86.76	1.14	0.81	P6	85.29	0.59	0.70
Environmental Conservation	P4	83.33	1.53	0.41	P12	72.22	0.15	0.47
	P15	83.33	1.53	0.41	P6	72.22	0.27	0.92
	P9	83.33	1.47	0.41	P7	83.33	0.73	0.92
Community Development	P1	85.00	1.24	0.69	P12	77.50	0.47	0.78
	P10	88.75	1.21	0.48	P6	82.50	0.59	0.61
	P11	88.75	1.20	0.47	P13	86.25	0.61	0.86

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: protective wetland and open space, P10: improve stormwater systems, P11: build additional flood water 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.

supported by participants across all sectors. In addition, short-term solutions such as temporarily prohibiting development during the period immediately after a disaster event (P12) have a low score, as well as low variance in all sectors. The variance can reflect the existence or lack of congruence within sectors. For example, stakeholders in flood control sector limit rebuilding in frequently flooding areas (P15); however, the relatively high variance (1.59) indicates mixed support. On the contrary, the improvement of stormwater systems (P10) has relatively low variance in all sectors. This shows that there is a congruence both within and across sectors regarding the importance of stormwater system enhancement. Elevating buildings (P2) is among the highly supported policies by flood control organizations, while organizations in transportation sector highly oppose this policy.

6. Discussion

In this section, findings that are indicated by the results of the empirical study are discussed. The influence of similarities and differences of organizational institutions on collaborative and cooperative management for resilience, the effectiveness of collective actions, and the vulnerability of infrastructures during and after hurricane disasters like the recent Hurricane Harvey are explored.

6.1. Involvement in planning process and use of hazard mitigation plan

In terms of involvement in planning, the finding that organizations from flood control and emergency response sectors have the greatest involvement in the hazard mitigation planning process is in accordance with the fact that these two sectors have the major responsibility for reducing the risk of flooding in infrastructures, as well in planning for response activities. Moreover, a medium level of involvement in community development was observed; however, since community development organizations have an extensive level of public interaction in comparison to other sectors, the higher rate of involvement of this sector in the hazard mitigation planning process can result in greater public engagement in hazard mitigation and recovery activities [70].

Low involvement of stakeholders in the process of planning potentially reduces the effectiveness and quality of plans [45]. Relatively low involvement of transportation organizations in the process of hazard mitigation planning may lead to the development of plans that do not take into consideration transportation-related aspects of hazard risk mitigation. This potentially can lead to transportation developments that increase infrastructure vulnerability. As demonstrated in the case of Hurricane Harvey, the release of water to the downstream neighborhoods as a result of the rising water level in control reservoirs caused flooding in more than 9000 households for more than a week. In this case, developments surrounding the newly constructed State Highway 99 eliminated the vegetated land that retains water in the reservoir's watershed, which further exacerbated the situation. Although the highway was constructed primarily to improve the traffic and mobility in Houston, the lack of consideration for community development and non-communication with flood control organizations in transportation planning clearly contributed to the flooding of the downstream neighborhoods. This tragic situation could have been prevented by increasing the level of involvement of the transportation sector in the hazard mitigation planning process, which would not only have improved the intra-sector coordination, but would have also increased the exposure of stakeholders to the knowledge gained by organizations forms other than urban sectors (community development and flood control in this case).

Our results have shown that one of the most frequent uses of the hazard mitigation plan across urban sectors is to guide implementing previously prioritized hazard mitigation policies, programs, projects, and other actions during recovery. This finding suggests that the existing hazard mitigation plans can help organizations to prioritize and implement hazard mitigation policies, programs, and projects. Additionally. findings of this study show that hazard mitigation plans are not frequently used by the respondents in informing long-term, non-structural decisions, such as land use planning. This finding is significant since a primary purpose of plans would be helping officials make informed decisions and choices [71] such as non-structural ones. Besides, results regarding policy support show that non-structural solutions are generally among highly supported policies across all sectors. In fact, the existing plans cannot facilitate decision-making regarding solutions that are supported by a majority of organizations. This anomaly may indicate a need for investigating potential barriers that limit the use of plans for organizations across different urban sectors in making informed decisions. These barriers may include poor quality of plans or institutional barriers that limit the use of plans. Results also indicate that organizations in the transportation sector use hazard mitigation to implement previously prioritized hazard policies, programs, projects, and other actions during recovery and to remember more frequently implementation details, such as responsible agencies, timelines, and

expected costs. This findings further show that respondents in the transportation sector used the hazard mitigation plan more frequently for implementation purposes.

6.2. The responsibility of mitigation and contributors to hazard

Regarding respondents' view of the government entity responsible for hazard mitigation, results show the establishment of an institutional congruence across urban sectors indicating the suitability of responsibility sharing at different government levels for mitigating the risk of hazards. The existence of such a congruence can potentially support a decentralized and multilayer management scheme, which has been argued to be the best disaster risk management strategy [72]. However, in order to increase the effectiveness of resilience practices and reach a collaborative management scheme, the responsibility of different government agencies should be clearly defined and well distributed. Such a management scheme enables the system to take advantage of both local and national governments' unique capabilities. These capabilities may include the ability of local governments to act as the imperative interface that links people and national government entities [73–75] and the ability of the federal government to financially support hazard risk mitigation policies and programs [76].

In terms of respondents' perception of the causes that contributed to flooding, findings show that the environmental conservation sector is the only urban sector that does not put significant weight on the impact of funding shortage for building protective infrastructures as the main cause of flooding. This finding implies the perception that available funding is sufficient, but the policies that are implemented are not convincing, and therefore the approach to the hazard mitigation may need to be shifted. Moreover, as was observed, there is congruence among responders from different urban sectors and within sectors about the insufficiency of structural tools. In fact, the influence of contributors that focus on the lack of resistant structures such as levees and dam was not generally highlighted by organizations in different urban sectors. This finding indicates a congruence among all sectors regarding the insignificance of resistant structures in flood protection. Such an institutional congruence can be viewed as an opportunity to develop policies that focus on avoidance (such as building and maintaining stormwater systems) or acceptance (such as developing wetlands and detention basins) of flooding [19].

More than other urban sectors, respondents from the flood control sector selected citizen ignorance of flooding as a contributor to flooding damage. However, the role of citizen actions has not been emphasized by other sectors, although recent studies have emphasized the role of public awareness, as well as social capital, in the ability of the community to respond to disasters such as flooding. In addition, failure to comply with a regional hazard mitigation plan, which concentrates on involvement in planning and compliance with the plan, has relatively low scores among all sectors, particularly the transportation and community development sectors, which points out the presence of established shared understanding that inter-governmental cooperation and failure to comply with regional hazard mitigation plan were not an issue.

6.3. Support of funding policies, insurance pricing, and hazard mitigation policies

Analyzing respondents' views regarding proper funding sources for new infrastructure projects shows that increasing tax is not commonly favored by organizations from different urban sectors, which indicates that reliance on public taxes for funding flood resilience projects is not perceived as a proper policy from the organizations' point of view. This finding specifies that there is a consistent institutional congruence among all sectors and that the government should not ask residents to pay for protection against flooding [17,77–79]. Devising such a policy increases the reliance on projects financed by federal funding or by fees paid by builders and developers. However, other sources of funding can be used if the people are informed about the benefits and future revenues of such infrastructures. Survey results indicate that the flood control sector has put the highest weight on the funding sources that require additional taxes. This finding points out the possibility of using such funding sources in the flood control sector, which may be due to a belief in this sector regarding the efficiency of such infrastructures, which is in accordance with the higher familiarity of flood control organizations with such projects.

Results also show that the flood control sector has the highest level of support for actuarial pricing in setting household flood insurance. This sector is highly involved in the practices aimed at minimizing damages to citizen property and life through designing and building infrastructures that decrease the vulnerability of households to flooding. On the other hand, one of the controversial issues related to flood insurance following Hurricane Harvey has been the role of floodplain mapping accuracy [80]. The information regarding floodplains impacts the success of risk-based insurance programs. As this issue is a concern for stakeholders from the flood control sector, risk-based insurance programs are expected to be supported by the organizations in this sector.

Environmental conservation organizations strongly support establishing and implementing infrastructure resilience programs. The support of such policies by those organizations suggests that they may believe that the existing policies for infrastructure resilience management are not comprehensive. On the other hand, the fact that for the other sectors this choice is not among the highly supported options shows that the existing program has sufficiently addressed transportation and flood control sectors requirements, which is desirable. However, considering the fact that operationalizing such programs needs cooperative actions by different organizations [81], the optimal use of the program would be constrained since the program does not include considerations of all sectors, and consequently, all stakeholders are not involved or willing to cooperate in implementing the program's policies.

When comparing policy preference of transportation and flood control sectors, the result shows that transportation organizations highly oppose building elevation as an appropriate policy for reducing the danger of future flooding in an area, while this policy is among those that are highly supported by the flood control sector. This finding shows that stakeholders who focus on flood protection (i.e., flood control sector) tend to accept flooding as an inevitable consequence of events, such as Hurricane Harvey. They believe that the propagation of water cannot be perfectly limited, and therefore there might be a need to save buildings and assets once flooding approaches them. On the contrary, the transportation sector supports the idea that there is a need for limiting inundation of assets instead of accepting flooding and putting efforts on minimizing the consequences of inundation. The existence of such an institutional incongruence negatively affects the overall process of resilience management. For example, multiple road closure experiences during and after Hurricane Harvey can be prevented in future events if the practices between transportation and flood control sectors are coordinated. They can both focus on actions that limit stormwater propagation or protect roads from inundation by implementing policies such as elevating roads. These incongruences can also impact the actions of other sectors. For example, inaccessibility of roads is one of the barriers that prevented acute response by emergency response organizations during and following Hurricane Harvey. The lack of institutional congruence between transportation and flood control sectors organizations can lead to great difficulty in implementation emergency response activities that could have minimized physical and human loss.

7. Summary, significance, limitations, and future works

7.1. Research summary

Resilience in IISs is managed by a set of organizations from different

levels and sectors. Organizations across urban sectors and within a sector may have different objectives, socially constructed values, rules, and norms that shape their decision-making logic and behaviors. This study investigates the congruence of organizational institutions in resilience management of IISs. Three significant aspects of resilience management were selected. Specific research questions regarding congruence of organizational institutions were developed and the level of congruence among various stakeholders (i.e., organizations) forming different urban sectors was evaluated. A case study in the Harris County region was conducted to evaluate institutional congruence in hazard mitigation activities prior to Hurricane Harvey. Considering specific research questions, the study used data from a stakeholder survey to explore and analyze the congruence of organizational institutions regarding three important aspects of resilience management in ISSs.

The results of the case study show the extent of congruence in organizational institutions among actors that were involved in resilience management in the Harris County region, during and after Hurricane Harvey. Results also show how the existence of institutional incongruency could cause vulnerabilities and create barriers in the process of hazard risk mitigation. In terms of involvement in planning and use of the plan, results show that the lower levels of involvement in the planning process can lead to negative outcomes because the plans often do not account for risk and potential hazards. The analysis also shows that existing plans help organizations to prioritize and implement hazard mitigation policies, programs, and projects. However, there is a need for reconsidering the role of plans in supporting short-term and long-term decisions made by organizations.

In terms of government responsibility for the mitigation of long-term flooding risks, there is a relative congruence in stakeholders' view regarding the necessity of responsibility sharing. Regarding the potential contributors to flooding, there is an institutional congruence about the idea that funding limitations and developments in flood-prone areas lead to flooding, whereas issues related to resistance structures such as dams and levees are generally accepted as not being significant in mitigating flood risk. This shared understanding can be viewed as an opportunity to shift policy focus on nonstructural tools. The lack of citizens' awareness about flooding issues is not generally supported by stakeholders.

Assessment of organizations' preferred policies for mitigation of risk of hazard reveals that reliance on federal funding is consistently accepted as the preferred source of finance for new infrastructure projects. Organizations are not willing to ask citizens to invest in such projects, which can limit flexibility in using various funding means such as different types of taxes. Findings related to policy support by organizations show that there is no congruence about the suitability of the existing infrastructure resilience program. The existence of congruence about the need for reliance on flood avoidance policies and limitation of construction in flood-prone areas, as well as congruence about the ineffectiveness of reliance on protective infrastructures, can facilitate shifting policy making from building more flood protection infrastructures to focusing on avoidance policies such as improvement of stormwater and drainage systems. The flood control sector supports elevating buildings, which means it accepts flood propagation and supports protecting assets by means of increasing their elevation, while the transportation sector opposes this approach. This institutional incongruence might have contributed to the road closures during and after Hurricane Harvey, and can also negatively affect actions by other sectors whose activities are dependent upon the infrastructures managed/affected by transportation and flood control sectors.

7.2. Research significance and contribution

Although the specific findings cannot be generalized, the case study shows examples of how organizational institutions can be congruent and incongruent across different urban sectors. Furthermore, findings show that such congruencies can provide rooms for improvement of the effectiveness of resilience management in IISs. Additionally, we observed how inadequate institutional congruence may contribute to uncoordinated actions and increased vulnerability of IISs. The significance of this study is to illuminate the impact of a missing social factor (institutional congruence) on the management of resilience in IISs. Certainly, these findings will help researchers and practitioners from different fields (e.g., engineering, urban planning, emergency management, etc.) to revise the challenging issues in their fields through the new lens of an organizational perspective to resilience management in IISs.

This study contributes to the body of knowledge by setting a theoretical foundation for resilience management in IISs through the integration of assessment of organizational institutions. The study also introduces a new concept of "institutional congruence" as an important phenomenon influencing resilience management in IISs. From a practical perspective, the study findings provide new insights to decision makers and government agencies regarding challenges in the path to the effective management of disaster risks. The findings of this study will also benefit decision-makers in resilience management by investigating the underlying managerial challenges in disaster risk mitigation and post-disaster recovery efforts from an organizational perspective. The findings also help to identify the institutional barriers that can potentially impact hazard mitigation actions by involved organizations.

7.3. Limitations and future works

This study aimed to address the gap in the existing literature regarding the assessment of institutional congruence in the field of risk and resilience management in IISs. The study has some limitations. For example, due to the nature of the survey, it was relatively long. The length of the survey, to some extent, affected the response rate. Nevertheless, the number of responses were sufficient to obtain variation across different sectors and organizations to conduct a meaningful analysis. Moreover, the current study does not distinguish different elements that form organizational institutions (i.e., normative, regulative, and cultural-cognitive elements) [82,83]. Future studies can focus on how organizational institutions are developed and established and how inherently different institutional pressures are interacting together and contribute to the establishment of institutional congruence across different urban sectors. The role of actors' communications and network of organizations that work together for planning and implementing resilience management plans and programs can also be investigated [84].

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2020.101515.

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