An Analysis of the Axiological Antecedents of Inter-Organizational Collaboration in Resilience Planning Using Exponential Random Graph Models

Hang Ren, S.M.ASCE[1]; Travis A. Whetsell, Ph.D.[2]; Lu Zhang, Ph.D., A.M.ASCE[3]; and N. Emel Ganapati, Ph.D.[4]

[1]Ph.D. Candidate, Myers-Lawson School of Construction, Virginia Tech, Blacksburg, VA. Email: hangr@vt.edu
[2]Assistant Professor, School of Public Policy, Georgia Institute of Technology, Atlanta, GA. Email: travis.whetsell@gatech.edu
[3]Associate Professor, Myers-Lawson School of Construction, Virginia Tech, Blacksburg, VA (corresponding author). Email: luzhang@vt.edu
[4]Professor, Dept. of Public Policy and Administration, Florida International Univ., Miami, FL. Email: ganapat@fiu.edu

ABSTRACT

Building resilient communities requires effective collaboration among multisector stakeholders. However, stakeholders may hold different value priorities in implementing resilience strategies. Heterogeneous collections of value priorities form distinct value systems. Differences rooted in value systems may cause conflicts that impede stakeholder collaboration. Despite extensive studies on stakeholder collaboration, there is a lack of systematic understanding on how the value systems of various stakeholders influence their collaboration. To bridge this gap, this study focused on examining the impact of stakeholders' value systems on their collaboration patterns through network and exponential random graph model (ERGM) analyses using data collected from a survey. Our results show that stakeholders' value systems have significant impacts on their collaboration patterns (i.e., presence or absence of collaboration, frequency of communication) in resilience planning. The findings of this study offer insight to enhance stakeholder collaboration in community resilience planning by considering stakeholder value systems.

INTRODUCTION

There has been a growing consensus that achieving community resilience requires collaborative engagement and efforts among diverse stakeholders (Kapucu and Garayev 2011; Smith 2014; Nop et al. 2023), which refer to the groups or organizations (e.g., public agencies, non-governmental organizations (NGOs), private companies, academic institutions) with an interest in addressing common problems (Jiang and Ritchie 2017). Collaboration among stakeholders is critical for tackling complex tasks, such as community resilience planning, which cannot be addressed by any single stakeholder or organization alone. The importance of collaboration in resilience planning has been recognized in various literature (Smith 2014; Desportes et al. 2016; Pyke et al. 2018; Ren et al. 2023). Multi-stakeholder collaboration provides an opportunity to leverage resources and technologies from various sources to enhance complex problem-solving (Nop et al. 2023). It has the potential to improve situational awareness, facilitate social learning, build trust among community stakeholders, and support better decision-making (Taeby and Zhang 2019; Resetar et al. 2020; Ren et al. 2023). Through the collaboration

process, resilience planning may become more transparent and could receive greater support from a range of stakeholders (Singletary et al. 2022).

However, multiple factors may impact or impede stakeholder collaboration, such as ineffective leadership and communication, mistrust among stakeholders, insufficient resources, and bureaucratic constraints (Moser and Ekstrom 2010; Desportes et al. 2016). One of the factors that receive less attention in the existing literature is stakeholder value systems, which refer to ranked systems of things that are of importance, merit, and utility to stakeholders (Zhang and El-Gohary 2016). Stakeholders hold various values with varying priorities, forming their distinct value systems (Pathak et al. 2020; Zhang and El-Gohary 2016). While different stakeholders may share the common goal of building a resilient community, they may have various value systems that cause conflicts and impede their collaboration. For example, public agencies may focus more on the community's long-term development, while private industries may prioritize short-term profitability over long-term resilience. Existing research has focused on either identifying the barriers or factors that impede stakeholder collaboration (Desportes et al. 2016) or exploring stakeholder value systems in the context of resilience planning (e.g., Pathak et al. 2020; Gosain et al. 2022). However, the understanding of how stakeholders' value systems influence their collaboration patterns remains elusive.

To address this knowledge gap, this study focuses on examining the impacts of stakeholders' value systems on their collaboration patterns through network and exponential random graph model (ERGM) analyses. We first designed and implemented a survey that collects data regarding stakeholders' value systems and collaboration patterns. The survey was conducted in Greater Miami and the Beaches (GM&B) in Florida. Based on the survey data, we built a one-mode stakeholder collaboration network. We then focused on examining the impacts of value systems on network edge formation through both binary and valued ERGM analyses. Our results show that stakeholder value systems have significant impacts on stakeholder collaboration patterns (i.e., presence or absence of collaboration, frequency of collaboration) in resilience planning. The following sections review the relevant literature, introduce the research methodology, present and discuss the results, and summarize the research with future recommendations.

LITERATURE REVIEW

Over the last few decades, the frequency and intensity of disasters have greatly escalated across the world. Many communities have been striving to advance their capabilities to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover quickly from potential disasters by developing resilience plans (McAllister 2013). However, resilience planning is a complex social problem that requires various stakeholders to share the responsibility in building the capacity to prepare for, respond to, and recover from potential disasters (Ren et al. 2023); it requires the whole community to work collaboratively toward the common goal of achieving resilience (Desportes et al. 2016; Bostick et al. 2017). Stakeholders from different sectors with diverse backgrounds are expected to participate in the decision-making process together (Nop et al. 2023; Ren et al. 2023).

The importance of stakeholder collaboration in resilience planning has been emphasized in many studies. For example, previous research (e.g., Lyles et al. 2014; Li et al. 2021) has demonstrated that the inclusion of diverse stakeholders is fundamental to improving the quality of resilience plans (e.g., hazard mitigation plans, climate change adaptation plans) and obtaining

long-term support from stakeholders. Engaging multiple stakeholders offers the opportunity to define the core values collectively, improve the understanding of complex problems, and reduce conflicts in the planning process (Li et al. 2021). Collaborating during the early phases of resilience planning enhances transparency and garners stakeholder support, thereby playing a vital role in the successful implementation of strategies or securing investment support (Therrien et al. 2020).

Despite the importance of collaborative resilience planning, a significant gap in the existing research lies in comprehensively understanding how stakeholders' value systems influence their collaboration patterns. Existing studies (e.g., Moser and Ekstrom 2010; Desportes et al. 2016), on one hand, have shed light on the obstacles and factors impeding stakeholder collaboration. For example, Desportes et al. (2016) investigated the barriers that impeded stakeholder collaboration in addressing flood risk in Cape Town through a case study. They found that some of the key barriers included insufficient resources, different cultures and behaviors, and inadequate institutions and regulations. Nop et al. (2023) identified the key barriers that undermined effective collaboration in building urban resilience in Phnom Penh, which included the limited understanding of the importance of stakeholders' participation and collaboration, livelihood constraints, insufficient information sharing, and lack of coordination. However, they have not thoroughly examined the role of stakeholders' value systems in shaping collaborative behaviors. On the other hand, some recent research (Pathak et al. 2020; Gosain et al. 2022) has provided valuable insights into stakeholder value systems in the context of resilience planning. For example, Bostick et al. (2017) conducted case studies to investigate stakeholder prioritization of coastal disaster resilience planning initiatives in Mobile Bay, United States. Pathak et. al (2020) conducted semi-structured interviews to identify the stakeholder value dynamics across different disaster phases (i.e., preparedness, response, recovery, and mitigation) in Hurricane Michael. Li et al. (2021) proposed a plan evaluation framework to investigate how different plans captured and incorporated stakeholder policy preferences in the resilience planning of interdependent infrastructure systems. Gosain et al. (2022) investigated the similarities and differences of stakeholder value priorities across multiple stakeholder sectors in the City of Miami. Nevertheless, these studies have not specifically investigated the relationship between stakeholders' value systems and their patterns of collaboration.

METHODOLOGY

The context of this research is the GM&B region, which encompasses Miami-Dade County, the City of Miami, and the City of Miami Beach. This region has been significantly impacted by various disasters (e.g., hurricanes, sea-level rise, floods) and has become increasingly vulnerable (Fields and Renne 2021). The following sections explain the methodology in detail.

Survey design and implementation. To investigate the impact of stakeholders' value systems on their collaboration patterns, we developed a survey consisting of four sections: (1) organization information, (2) importance of resilience values, (3) collaboration relationships, and (4) respondents' background. The first section gathered information on the organizations that the respondents belong to, such as the names, sizes, and sectors of the organizations. The second section solicited the stakeholders' value systems on housing resilience. We included a list of thirty stakeholder values (Figure 1) and asked the respondents to rate the importance of these values using a five-point Likert scale. The stakeholder values were identified and defined in Gosain et al. (2022). The third section collected information on stakeholder collaboration

patterns regarding housing resilience planning. We asked the respondents to provide the names of their collaborators, the nature of contact (e.g., information exchange, joint work on projects), and the contact frequency. The fourth section gathered the personal background information of the respondents. The survey targeted representatives of stakeholders who contributed to the existing resilience planning documents. We identified the target respondents through a review of secondary sources (e.g., resilience plans, reports, and guidelines) that were published on government websites in the GM&B region. The survey was conducted online using Qualtrics and distributed to the target respondents through email from September 2021 to March 2022. This survey received exemption approval from the Institutional Review Board (IRB) of Florida International University.

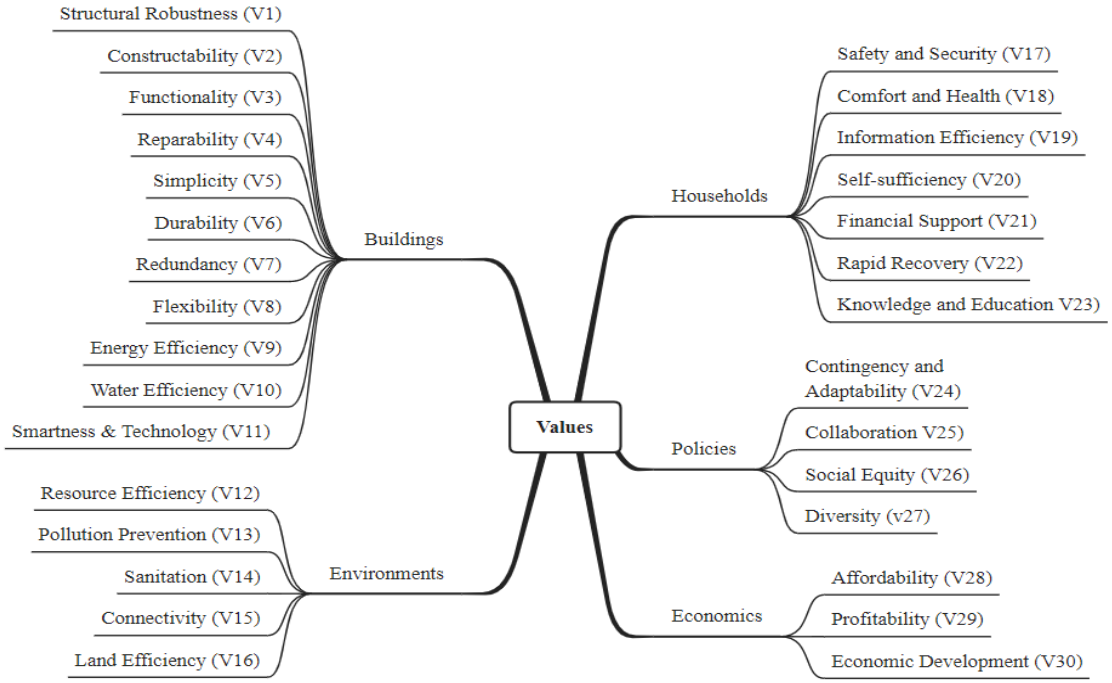

Figure 1. Hierarchy of stakeholder values (Source: Gosain et al. 2022).

Stakeholder collaboration network. We constructed a one-mode stakeholder collaboration network based on the survey responses, where the nodes represent the stakeholders, and the edges represent the collaboration relationships between the stakeholders. The node attribute considered in this network is the priorities of the thirty values to each stakeholder, which were captured through a five-point Likert scale (1=not important, 2=slightly important, 3=moderately important, 4=important, and 5=very important). In addition, the contact frequency among the stakeholders is used as the edge attribute, which is represented through a numerical scale of 1 to 5 (1=very rarely, 2=somewhat rarely, 3=occasionally, 4=somewhat frequently, 5=very frequently). We then generated the stakeholder collaboration network through Gephi 0.10.1, which is a commonly used software for social network visualization (Bastian et al. 2009).

Binary and valued exponential random graph model analysis. We performed both binary and valued ERGM analysis to study the effects of value systems on the collaboration network. ERGM is a statistical modeling technique used to predict the probability of network formation by accounting for the factors that may affect edge formation (Lusher et al. 2013). The binary ERGM

does not consider the edge attribute (i.e., contact frequency) and is only used to predict the presence or absence of edges (Eq. 1), while the valued ERGM takes the edge attributes (i.e., contact frequency) into consideration and is used to predict the edge strength between the nodes (Eq. 2) (Krivitsky 2012; van der Pol 2019). In our analysis, we focused on analyzing (1) the configuration of network structures and (2) the effects of stakeholder value systems on network formation. Among the ERGM terms, we used nodecov, absdiff to investigate the impact of stakeholder value systems on the network formation. More specifically, nodecov evaluates whether stakeholders with higher priorities on a specific stakeholder value have a tendency to form collaborations with others, while absdiff explores whether two stakeholders who have similar value priorities tend to form a collaboration.

$$P(Y = y) = \frac{\exp(\theta' s(y))}{k(\theta)} \quad (1)$$

where Y represents the random variable for the state of the network (with realization y); $s(y)$ is a vector of model statistics for network y; θ is the vector of coefficients for those statistics; $k(\theta)$ is a normalizing constant.

$$P(Y = y) = \frac{\mathrm{h(y)}\exp(\theta' s(y))}{k(\theta)} \quad (2)$$

where most of the parameters are identical as those in the Eq. 1; the valued ERGM includes a reference distribution h(y) to model the distributions of each edge value (i.e., contact frequency).

In this study, we only considered the stakeholder values that had significant impacts on network formation. That is, stakeholder values that facilitate or impede stakeholder collaboration in a statistically significant manner. To do that, we employed stakeholder value priorities as node attributes and performed binary ERGM analysis on each value independently to identify the values that had significant impacts on network formation. Next, in order to address the concern of incorporating highly correlated values into a binary or valued ERGM model, thus mitigating the issue of multicollinearity, we conducted factor analysis with polychronic correlations (Holgado–Tello et al. 2010), which allowed us to group the values into clusters or factors. Based on the results of the factor analysis, we were able to derive the aggregated value priorities by consolidating the priorities of values that were grouped within the same factor. Subsequently, we utilized the derived aggregated value priorities as updated node attributes for conducting both the binary and valued ERGM analysis. This approach allowed us to examine the influence of a cluster of stakeholder values on the formation of networks, enabling a comprehensive exploration of their impact. We conducted the ERGM analysis through the "statnet" package in R programming (Krivitsky et al. 2023).

PRELIMINARY RESULTS

Stakeholder network visualization. In our analysis, a stakeholder represents an organization (e.g., a government agency, an NGO, a university, a private company) that is involved in or interested in resilience planning. Based on the survey responses, we identified 40 distinct stakeholders from multiple sectors. Of the 40 stakeholders, 12 are from public agencies, 9 are from private industries, 15 are from NGOs, and 3 are from academia. Figure 2 shows the visualization results of the stakeholder collaboration network. As per Figure 2, there are a total of

40 nodes and 62 edges. The nodes are color-coded with green, orange, purple, and light blue representing public, private, NGO, and academic stakeholders, respectively. The thickness of the edges is proportional to its strength with thicker edges indicating higher contact frequencies.

Results of factor analysis. Table 1 presents the stakeholder values that had significant impacts on network formation and the results of factor analysis. As per Table 1, out of the 30 values, 12 values had significant impacts on network formation. We then identified and extracted the factors based on Kaiser's criteria, which only consider the factors with an eigenvalue above 1.0 (Williams et al. 2010). As shown in Table 1, nine values can be grouped into three major factors based on factor loading results, using a threshold of 0.5. Factor 1 is related to environmental resilience and health, including energy efficiency (V9), water efficiency (V10), pollution prevention (V13), land efficiency (V16), and comfort and health (V18). Factor 2 is related to resilient recovery, and it includes financial support (V21) and rapid recovery (V22). Factor 3 is related to economic resilience, including profitability (V29) and economic development (V30).

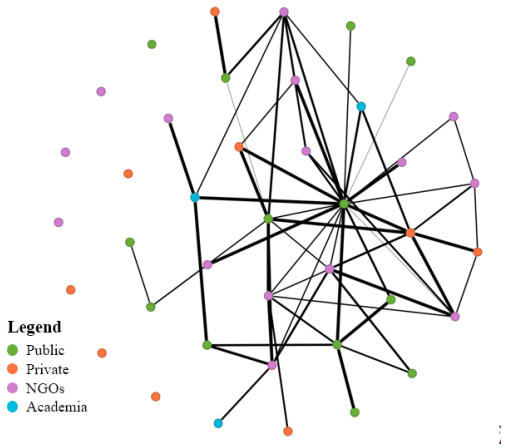

Figure 2. Stakeholder collaboration network.

Table 1. Results of Factor Loadings.

Stakeholder Values	Factor 1	Factor 2	Factor 3	Theme
Energy efficiency (V9)	0.891			
Water efficiency (V10)	0.830			Environmental
Pollution prevention (V13)	0.870			resilience and
Land efficiency (V16)	0.578			health
Comfort and health (V18)	0.674			
Financial support (V21)		0.701		Resilient
Rapid recovery (V22)		0.987		recovery
Profitability (V29)			0.541	Economic
Economic development (V30)			0.651	resilience
Durability (V6)				
Sanitation (V14)				
Connectivity (V15)				

Note: Factor loadings are not shown if they are less than 0.5.

Results of binary and valued ERGM analyses. Table 2 presents the estimated coefficients and p-value results of the binary and valued ERGM analyses on the three factors. The edges/sums serve as a constant term to control the network density and contact frequency without considering other factors respectively.

For the binary ERGM analysis, the nodecov result of the resilient recovery factor (Factor 2) is positive and significant (0.38878), indicating that stakeholders with higher priorities on financial support (V21) and rapid recovery (V22) are more likely to form connections with other stakeholders. In contrast, the nodecov result of the economic resilience factor (Factor 3) is negative and significant (-0.28324), suggesting that stakeholders with higher value priorities on profitability (V29) and economic development (V30) are less likely to form connections with others. Additionally, the significantly negative result (-0.48236) of absdiff on environmental resilience and health factor (Factor 1) implies that two stakeholders with greater differences in their priorities of energy efficiency (V9), water efficiency (V10), pollution prevention (V13), land efficiency (V16), and comfort and health (V18), are less likely to form connections.

Similar to the results of binary ERGM, for the valued ERGM analysis, the nodecov result of the resilient recovery factor (Factor 2) is positive and significant (0.59623), implying that stakeholders with higher priorities on financial support (V21) and rapid recovery (V22) are more likely to form connections with higher contact frequencies. On the contrary, the nodecov result of the economic resilience factor (Factor 3) shows a significantly negative result (-0.42014), which means stakeholders with higher priorities on profitability (V29) and economic development (V30) tend to have less frequent contact with others. The absdiff results of environmental resilience and health factor (Factor 1) and economic resilience factor (Factor 3) both have significantly negative coefficients (-0.60978 and -0.15909, respectively), which suggests that two stakeholders with greater differences toward energy efficiency (V9), water efficiency (V10), pollution prevention (V13), land efficiency (V16), comfort and health (V18), profitability (V29), and economic development (V30) tend to have less frequent contact with each other. The absdiff result of the resilient recovery factor (Factor 2) has a significantly positive coefficient (0.33921), suggesting that two stakeholders with smaller priority differences on financial support (V21) and rapid recovery (V22) tend to have less frequent contact with each other.

Table 2. Results of Binary and Valued ERGM Analyses.

ERGM Terms	Binary ERGM	Valued ERGM
Network structural configuration		
Edges/Sums	-2.06160*	-0.61891
Transitivity	0.56949*	-0.78514*
Effect of stakeholder value systems		
nodecov. Factor 1	-0.02696	0.03129
nodecov. Factor 2	0.38878*	0.59623*
nodecov. Factor 3	-0.28324*	-0.42014*
absdiff. Factor 1	-0.48236*	-0.60978*
absdiff. Factor 2	0.28426	0.33921*
absdiff. Factor 3	-0.16059	-0.15909*

Note: * $p < 0.1$.

DISCUSSIONS

Overall, we identified three main findings based on the results summarized in the above section. First, stakeholders who prioritize resilient recovery (i.e., financial support, rapid recovery) exhibit a higher likelihood of establishing collaborative relationships, and they also tend to engage in more frequent communication with one another. These findings align with prior studies (Mannakkara and Wilkinson 2013; Pathak et al. 2020) that indicate stakeholders are inclined to collaborate during the post-disaster recovery phase. Following a disaster, stakeholders typically display increased friendliness and generosity towards others, driven by heightened empathy and a sense of responsibility. Consequently, this enhanced disposition often fosters collaborative efforts with other stakeholders (Mannakkara and Wilkinson 2013). Second, stakeholders with higher priorities on economic resilience (i.e., profitability, economic development) are not likely to form collaboration relationships, nor would they communicate with each other frequently. This could be attributed to the perceptions among some organizations that collaboration may potentially distract from or pose a threat to their primary goal of maximizing short-term gains (Frazier et al. 2010). For example, private industries may perceive collaboration with stakeholders who prioritize long-term development as detrimental to their profitability and would negatively impact their own business operations and growth, and they may resist sharing information to maintain their competitive advantage (Boyer 2019). As a result, these stakeholders may not be willing to engage in the collaboration process. This finding highlights the presence of a collaboration gap among stakeholders who prioritize economic resilience. To enhance the efficacy of resilience planning, it is crucial to address and improve collaboration among stakeholders who place significant emphasis on economic resilience. Third, stakeholders who exhibit large disparities in their priorities regarding environmental resilience and health (e.g., energy efficiency, pollution prevention, land efficiency) tend to have lower levels of collaboration and infrequent communication with each other. This finding aligns with previous research (Gray and Purdy 2018) which suggested that conflicts arising from divergent values can hinder stakeholders' collaborative efforts. Different priorities over environmental resilience may specifically impede effective collaboration. These findings underscore the importance of recognizing discrepancies in value priorities during the early stages of resilience planning, as such variations can potentially lead to conflicts and ineffectiveness in the collaborative process. Consequently, addressing and managing these differences becomes critical for promoting successful collaboration in resilience planning.

CONCLUSIONS

This study focused on examining the impacts of stakeholders' value systems on their collaboration in planning for resilient communities. We first built a stakeholder collaboration network through data collected from a survey that was conducted in GM&B in Florida. We then performed binary and valued ERGM analyses to study the effects of stakeholder values systems on their tendency and frequency of forming collaboration relationships. We found that stakeholder value systems have significant impacts on their collaboration patterns (i.e., presence or absence of collaboration, frequency of communication) in resilience planning. The findings of this research provide insight into the role of stakeholder value systems in shaping stakeholder collaboration regarding resilience planning. By recognizing the impacts of stakeholder value systems, policymakers could better understand the factors that may facilitate or hinder

collaboration among stakeholders. Especially, it is essential to improve the cooperation among stakeholders whose value systems would seriously impede their collaboration relationship.

One limitation of this study is the relatively small sample size. The survey collected responses from a limited number of stakeholders, which may not fully represent the diverse relevant stakeholders and may thereby restrict the generalizability of the findings. In their ongoing or future research, the authors will continue to collect data from a larger group of diverse stakeholders and further examine other network attributes (e.g., stakeholder sector, nature of contact, resilience goal achievement) that may have an impact on stakeholder collaboration in resilience planning.

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