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A STAKEHOLDER VALUE-DRIVEN FRAMEWORK FOR EVALUATING RESILIENCE STRATEGIES

Hang, R.[1], Lu, Z.[1*], Andrew, M.[1], Emel, G.[2], Tanyel, B.[1], Ruichuan, Z.[1], and Travis, W.[3]

[1] Myers-Lawson School of Construction, Virginia Tech, Blacksburg, VA, U.S.
[2] Department of Public Policy and Administration, Florida International University, Miami, FL, U.S.
[3] School of Public Policy, Georgia Institute of Technology, Atlanta, GA, U.S.

ABSTRACT: Coastal communities worldwide face increasing threats from disasters. While prior studies have emphasized the importance of integrating stakeholders' values (i.e., the things that are of importance to stakeholders, such as structural robustness, adaptability, and affordability) into resilience planning, they often fail to consider the value systems surrounding these stakeholders and their importance in resilience strategy evaluation. Thus, there is a critical need for a systematic approach that integrates the evaluation of technical performance with these diverse stakeholder values when developing resilience strategies. To address this need, this work proposes a Stakeholder-Centric Resilience Evaluation Framework (SCREF) that integrates stakeholder value systems to assess alternative resilience strategies. By accounting for stakeholder value systems and design technical performance, this framework enables a more holistic evaluation of alternative resilience strategies that might better align with community priorities. A case study that focuses on evaluating residential building roofing retrofits was conducted. The results reveal how the resilience value of alternative retrofit strategies varies across disaster phases and among stakeholders. The findings suggest the importance of integrating stakeholder value systems in resilience strategy evaluation. This research helps promote more effective community resilience planning by providing a systematic approach to develop not only technically robust but also socially acceptable strategies.

1. INTRODUCTION

Coastal communities worldwide face unprecedented challenges from disasters (e.g., hurricanes), with climate change and rapid urbanization amplifying both the frequency and severity of these events (NAS 2012). As these threats escalate, the need for effective community resilience planning becomes increasingly critical. Resilience, defined as a community's capacity to anticipate, withstand, adapt to, and recover from disasters (Aldunce et al. 2016; NAS 2012), has emerged as a cornerstone of urban development and disaster risk reduction. Recent trends, such as the increasing intensity of hurricanes and the growing frequency of urban flooding in coastal regions, emphasize the urgent need for effective resilience planning (Ren et al. 2023; UNISDR 2024).

Resilience planning is a shared responsibility among all stakeholders (Pathak et al. 2020). In this study, stakeholders are defined as individuals, organizations, or groups that are responsible for, have an interest in, or can be affected by resilience planning decisions. This includes representatives from public agencies, private industries, non-governmental organizations (NGOs), academic institutions, and community residents (Ren et al. 2025). However, different stakeholders may prioritize different aspects of resilience planning (Dong et al. 2020; Pathak et al. 2020; Gosain et al. 2022). Such differences are fundamentally driven by their values: the things that are of importance, merit, and utility to them (Zhang and El-Gohary 2016; Gosain et al. 2022; Ren et al. 2024a). Stakeholders from various sectors or communities may have diverse values toward resilience planning, such as increasing structural robustness, improving affordability, providing financial support, or enhancing collaboration and education. Stakeholders may hold numerous values with varying degrees of importance, forming their unique value systems (Zhang and El-Gohary 2016). These value systems are dynamic and can vary across sectors, communities, and disaster phases (e.g., preparedness, response, recovery) (Gosain et al. 2022; Pathak et al. 2020; Ren et al. 2024b). For example, public sector stakeholders may prioritize physical and social resilience, while private sector stakeholders may emphasize return on investment. In addition, stakeholders' value systems may evolve throughout a disaster. For example, research (Pathak et al. 2020) shows that the priorities of safety and resource efficiency gradually decrease from the response to the recovery phase, while the priorities of community growth, community cohesion, social welfare improvement, and infrastructure restoration steadily increase during the recovery phase. Such differences in value systems can lead to changes in stakeholders' perceptions about alternative resilience strategies, potentially shaping policy decisions and investment priorities.

Over the years, numerous studies have emphasized the importance of actively engaging stakeholders in resilience planning (Desportes et al. 2016; Pathak et al. 2020; Ren et al. 2025). For example, Tompkins et al. (2008) introduced a scenario-based stakeholder engagement method to bring stakeholders together and incorporate stakeholders' preferences into coastal resilience planning. The authors indicated that stakeholder engagement is critical for the public to understand the trade-offs associated with long-term coastal planning and to gain their support. Bostick et al. (2017) suggested that stakeholders would be frustrated after disasters occurred without earlier involvement in coastal resilience planning for their community. The authors developed a scenario-informed multicriteria methodology to bring stakeholders together and reprioritize future risk management initiatives and identify the most and least disruptive scenarios for prioritization. Yusuf et al. (2018) introduced a region-wide, multi-sectoral, and whole-of-community stakeholder engagement approach for addressing sea level rise (SLR) and flooding through a university-led community engagement event. The authors indicated that the engagement of stakeholders helped participants broaden their perspectives of flooding and SLR and allowed an examination of resilience planning effectiveness as a mechanism for capturing community-wide perceptions. While these studies highlight the necessity of stakeholder engagement, they primarily focus on participatory methods rather than systematically integrating stakeholder values – the underlying principles and priorities that shape decision-making. Despite efforts to engage communities, without explicitly accounting for stakeholder values, resilience planning efforts may fail to align with the priorities of stakeholders, potentially reducing their effectiveness and long-term commitment.

Some recent research has explored the dynamics of stakeholder value systems in disaster resilience (Gosain et al. 2022; Pathak et al. 2020; Ren et al. 2024b). For example, Pathak et al. (2020) explored the dynamics of stakeholder value systems across disaster phases (i.e., preparedness, response, recovery, and mitigation) during Hurricane Michael, and they suggested that stakeholder value systems are dynamically changing across different disaster phases. Gosain et al. (2022) conducted a case study in the City of Miami and identified significant differences in the stakeholder value systems across different sectors (e.g., public sector, non-governmental organizations, private sector) on housing resilience. The authors found that the stakeholder values related to physical and built environment resilience were emphasized more by academic stakeholders, while the ones related to environmental and social resilience were more of a concern to the public sector. Ren et al. (2024) analyzed the social media data (i.e., Twitter) collected in Florida and found that communities with different characteristics (e.g., coastal vs. inland; metropolitan vs. non-metropolitan) showed substantially different value systems regarding community resilience. Previous research has offered valuable contributions to the understanding of stakeholder values in disaster management or resilience planning. However, these studies have not focused on how to effectively incorporate stakeholder value systems into resilience planning.

Recognizing the critical role of stakeholders and their value systems in shaping resilience planning (Tompkins et al. 2008; Bostick et al. 2017; Gosain et al. 2022), there is a pressing need to integrate stakeholder value systems into the evaluation and selection of resilience strategies, including policies, design and retrofit alternatives, and engineering methods. While existing resilience evaluation tools, such as the National Institute of Standards and Technology (NIST) Community Resilience Planning Guide and the United Nations Office for Disaster Risk Reduction's (UNDRR) self-assessment scorecards, provide valuable benchmarks, they often lack systematic guidance to engage stakeholders and assess resilience strategies based on their value systems (Gosain and Zhang 2024). Effective decision-making requires the ability to evaluate resilience strategies and measure the value of resilience in alignment with stakeholder priorities (Bostick et al. 2017; Gosain and Zhang 2024). Without a structured approach to incorporate stakeholder value systems, decision-making processes may fail to reflect community needs, overlook critical trade-offs, and result in ineffective resilience outcomes (Kim et al. 2022; Ren et al. 2024b). Therefore, a stakeholder value-driven evaluation framework is essential to ensure that resilience strategies provide maximum value to those they impact. Such a framework would not only enhance the technical robustness of resilience designs but also improve their social acceptability and long-term success.

To address the research gap, this study proposes a Stakeholder-Centric Resilience Evaluation Framework (SCREF) that evaluates resilience strategies based on how stakeholder value systems dynamically change in the context of a disaster, with a particular focus on hurricanes. Through a case study focusing on residential building roof retrofits, this study demonstrates the framework's practical applicability and its capacity to incorporate stakeholder value systems in roof design evaluation. The findings demonstrate the dynamics of resilience value of alternative designs delivered to stakeholders and the importance of integrating stakeholder value systems in resilience design evaluation.

2. METHODOLOGY

This study develops a Stakeholder-Centric Resilience Evaluation Framework (SCREF) (Figure 1) to systematically assess alternative resilience strategies by integrating stakeholder value systems into the evaluation process. The framework consists of four key steps: (1) Identifying and quantifying stakeholder value systems to capture the diverse priorities of different stakeholders, (2) evaluating the technical effectiveness of alternative resilience strategies in addressing each stakeholder value, (3) assessing the overall resilience value of each alternative strategy based on its alignment with stakeholder value systems, and (4) constructing "Stakeholder-Centric Resilience Triangles" (SCRTs) to visually represent and compare alternative resilience strategies.

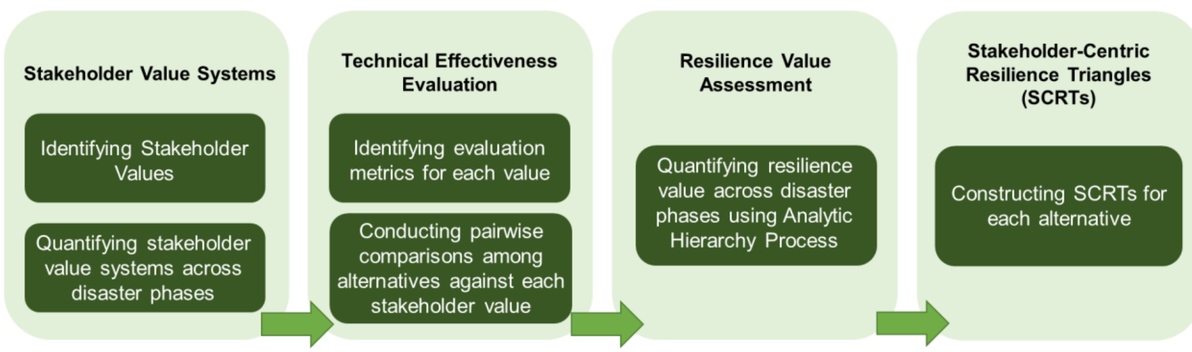

Figure 1: Stakeholder-Centric Resilience Evaluation Framework (SCREF).

The first step of the SCREF focuses on identifying and quantifying stakeholder value systems using interviews and surveys. We first identified the stakeholder values on resilience through multi-sector stakeholder interviews (Pathak et al. 2020; Gosain et al. 2022). Some of the identified values include structural robustness, safety and security, comfort and health, and financial support (Gosain et al. 2022). Following the interviews, we conducted surveys in which stakeholders rated the importance of these values across different phases of disasters, including pre-disaster, during disaster, and post-disaster. The collected responses were then normalized to generate a relative importance score (ranging from 0 to 1) for each value, with higher scores indicating greater importance of the value. These scores allow for prioritization of stakeholder values, forming a structured value system unique to each stakeholder. Thus, the output of this step is a ranked value system for each stakeholder, represented as a set of normalized scores that quantify the relative importance of various resilience-related values.

The second step of the SCREF focuses on evaluating the technical effectiveness of alternative resilience strategies in addressing each stakeholder value. The alternative resilience strategies include both existing common designs and those with different retrofitting options, such as improved roof-to-wall connections and upgraded roof materials. To enable quantitative assessment, based on a comprehensive literature review, we first identified a set of metrics for measuring and comparing the technical effectiveness of resilience strategies in fulfilling each stakeholder value. For example, structural robustness was evaluated through maximum load-bearing capacity or failure resistance (Knoll and Vogel 2009; Chen et al. 2016), comfort and health was evaluated through the air quality index or thermal comfort index (Saad et al. 2017), and safety and security was measured through crime rate (Kmet and Dvorak 2020). Next, we conducted pairwise comparisons among alternative strategies to determine their relative effectiveness in addressing each stakeholder value. For each stakeholder value, we then derived a technical effectiveness vector to represent the relative effectiveness of each alternative based on pairwise comparisons (ranging from 0 to 1) (Aragonés-Beltrán et al. 2014). Thus, the outputs of this step include a set of effectiveness vectors representing how effectively each alternative fulfills the identified stakeholder values.

The third step of the SCREF focuses on quantifying the resilience value of each resilience strategy at a specific disaster phase. Here, resilience value is defined as a stakeholder's perceived value of a strategy that integrates (1) the stakeholder's value systems, which capture the relative importance of different resilience-related values; and (2) technical effectiveness of the strategy in addressing these values. To achieve this and ensure simple implementation, we adopted the Analytic Hierarchy Process (AHP), a structured multi-criteria decision-making method that helps decision-makers compare alternatives and make decisions for complex problems (Aragonés-Beltrán et al. 2014). Traditionally, AHP involves pairwise comparisons to derive the relative importance of both criteria (stakeholder values) and alternatives. In this study, we simplified the AHP process by directly using the normalized stakeholder value systems derived from Step 1 as the relative importance weights. To combine stakeholder value systems with the technical effectiveness of each alternative, we calculated the resilience value for each alternative using Eq. 1. The output of this step is the resilience value of each strategy, represented as a numerical score, which reflects the overall capability of the strategy in both technically fulfilling stakeholder values and aligning with stakeholders' priorities. In this step, the SCREF addresses potentially competing stakeholder values by converting their priorities into quantitative weights based on the normalized value systems. These weights are then integrated with the technical effectiveness of each strategy to calculate a resilience score that reflects how well the strategy meets different, and sometimes conflicting, stakeholder values. This approach enables transparent comparison and prioritization of strategies, even when value conflicts are present.

[1] $RV_{jk} = \sum_{i=1}^{n}(SVS_{ik} \times TES_{ij})$
where RV_{jk} refers to the resilience value of alternative j at disaster phase k; SVS_{ik} is the normalized priority/importance of stakeholder value i; TES_{ij} is the technical effectiveness vector score for alternative j with respect to stakeholder value i; and n represents the total number of identified stakeholder values.

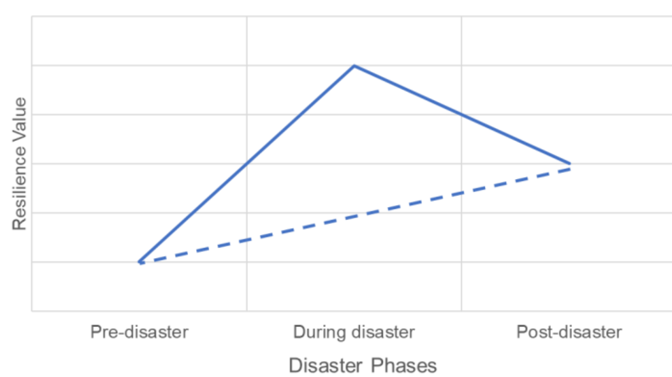

Figure 2: Stakeholder-Centric Resilience Triangle (SCRT) of a Design.

The last step of the SCREF focuses on constructing a Stakeholder-Centric Resilience Triangle (SCRT) for each strategy to represent the dynamics of resilience value over different disaster phases. In previous research (e.g., Bruneau et al.2003), resilience triangles have been used to show functional loss and recovery of a system over time, which focuses on how quickly a system returns to its original state after a disruption. Building on this conceptual foundation, we propose the Stakeholder-Centric Resilience Triangle (SCRT) (Figure 2) to expand the traditional approach by integrating stakeholder-value-driven resilience evaluation. As per Figure 2, the horizontal axis represents the disaster phases (i.e., pre-disaster, during disaster, post-disaster), while the vertical axis represents the resilience value of alternative strategies. Since stakeholder value systems evolve across different disaster phases, resilience value also changes over time. By plotting and connecting the resilience value across these phases, we construct a triangle that visually represents the shifts in stakeholder-perceived resilience value throughout the disaster cycle.

3. CASE STUDY

3.1 Case Study Design

To validate the proposed framework, we applied the SCREF to a case study on assessing roof retrofitting strategies for residential buildings. The case study focused on evaluating three roof retrofitting alternatives (Table 1) with each featuring distinct design characteristics. While all designs share the same roof dimensions (28 ft x 40 ft) and slope (4:12), they differ in terms of roof shape, material, and roof-to-wall connection type. Alternative 1 features a gable roof constructed with wood shingles, using 16d nails for roof-to-wall connections. Alternative 2 adopts a hip roof with wood shingles, secured with H2.5 hurricane clips to enhance wind resistance. Alternative 3 also utilizes a hip roof but is distinguished by its metal roofing material, which offers improved durability and wind resistance. The choice of hurricane clips in Alternatives 2 and 3 reflects an effort to enhance structural resilience against high winds. These three retrofit options were selected to represent different designs typically considered in practice with varying costs and performance. Among them, Alternative 1 refers to a basic, lower-cost design; Alternative 2 offers a moderate upgrade with improved connections and a more resilient roof shape; and Alternative 3 represents an enhanced, higher-cost design with advanced materials and structural features designed to maximize wind resistance.

Table 1: Alternative Roof Designs.

Feature	Alternative 1	Alternative 2	Alternative 3
Roof Dimension	28 ft x 40 ft	28 ft x 40 ft	28 ft x 40 ft
Roof Slope	4:12	4:12	4:12
Roof Shape	Gable	Hip	Hip
Roof Material	Wood shingles	Wood shingles	Metal Roof
Roof-to-Wall Connections	16d nails (4.11 mm diameter, 88.9 mm long)	H2.5 Hurricane clips	H2.5 Hurricane clips

To evaluate these alternative designs, we identified five stakeholder values that are critical in resilient roofing decisions, including structural robustness, constructability, redundancy, durability, and affordability (Table 2). These values were selected based on our previous work related to stakeholder value identification (Gosain et al., 2022) and expert consultations to ensure that the analysis captures the key factors influencing decision making related to roof designs.

3.2 Case Study Implementation

We then performed the case study following the four steps in the proposed SCREF. First, we collected the data on stakeholder value systems through a structured survey that is divided into two major sections: (1) stakeholder background information, and (2) understanding stakeholder values for roof retrofits. The first section of the survey collects demographic details such as stakeholder sector, age, gender, race, educational background, and income. The second section assesses stakeholder value priorities by asking participants to rate the importance of five stakeholder values (i.e., structural robustness, constructability, durability, redundancy, and affordability) using a five-point Likert scale (1 = Not Important, 5 = Extremely

Important) (Gosain et al. 2022). These ratings are collected for three distinct disaster phases: pre-disaster, during disaster, and post-disaster, allowing for an assessment of how stakeholder priorities evolve throughout the disaster cycle. For the preliminary study, a total of six responses were collected from stakeholders representing the community group.

Table 2. Metrics used for resilience value quantification.

Stakeholder Values	Definition	Metrics
Structural Robustness	The ability of a structure to withstand potential disasters.	Wind speed at failure (Lee and Rosowsky 2005)
Constructability	The ability to be constructed easily.	Time required to complete the roof construction (Trigunarsyah 2004)
Redundancy	The ability to maintain essential services through backup systems/components during a disaster.	Improvement of roof-to-wall connections (Satheeskumar 2016)
Durability	The ability to ensure long-term functionality.	Expected lifespan of roof based on material type (Grant et al. 2014)
Affordability	The ability to have affordable housing.	Average cost of roof installation (Mohamed and Mahmoud 2023)

Table 3. Design features of each alternative regarding each metric.

Stakeholder Values	Metrics	Alternative 1	Alternative 2	Alternative 3
Structural Robustness	Wind speed at failure (Roof Shape)	Gable: 130 mph	Hip: 150 mph	Hip: 150 mph
	Wind speed at failure (Roof Material)	Wood: 100 mph	Wood: 100 mph	Metal: 140 mph
	Wind speed at failure (Roof to Wall Connections)	16d nails: 204 mph	H2.5 Hurricane clips: 304 mph	H2.5 Hurricane clips: 304 mph
Constructability	Time required to complete construction	9-18 days	11 to 22 days	5 to 14 days
Redundancy	Wind speed at failure (Roof to Wall Connections)	16d nails: 204 mph	H2.5 Hurricane clips: 304 mph	H2.5 Hurricane clips: 304 mph
Durability	Lifespan (Material)	Wood shingles: 30 - 50 years	Wood shingles: 30 - 50 years	Metal roof: 40 - 70 years
Affordability	Average Cost	$34,264	$51,675	$51,976

Second, we evaluated the technical effectiveness of alternative roof designs in addressing each stakeholder value. Table 2 shows the metrics used in evaluating different roofing designs regarding each stakeholder value. These metrics provide a quantitative basis for comparisons, which ensures that resilience evaluations are grounded in objective performance indicators. Table 3 shows the design features of each alternative with respect to each metric. We then conducted pairwise comparisons through a comprehensive evaluation of the features of each design alternative in fulfilling each stakeholder value. For example, based on the design features provided in Table 3 and technical evaluation from Lee and Rosowsky (2005); Ryan (2023); ShakeGuys (2023); and Cloud Roofing (2024), Alternative 2 demonstrates higher technical effectiveness than Alternative 1 in enhancing structural robustness. Similarly, for redundancy, Alternative 2 and 3 outperform Alternative 1 by integrating H2.5 Hurricane clips that offer additional layers of protection and enhance the connections between roofs and walls. The technical effectiveness vector was then derived for each stakeholder value. These vectors quantified the relative effectiveness of each alternative for each stakeholder value and served as inputs for the next step.

Third, we derived the resilience value of each alternative across different disaster phases through Eq.1 to capture how resilience value of various alternatives evolved over time, which enables direct comparison of alternatives based on both technical effectiveness and stakeholder value systems.

Finally, we constructed the SCRT for each strategy to represent the dynamics of resilience value over different disaster phases. This visualization allowed for a comparative assessment of how each alternative performed throughout the disaster cycle.

3.3 Case Study Results and Discussion

Table 4 summarizes the results of stakeholder value systems across different disaster phases for survey respondents. As per Table 4, the value systems of various stakeholders are dynamically changing across different disaster phases. Table 5 shows the results of the resilience value on different roofing designs. As per Table 5, the resilience value of different roofing designs vary significantly across both alternatives and disaster phases.

Table 4. Results of stakeholder value systems for different respondents.

Stakeholder Values	Phases	R1	R2	R3	R4	R5
Structural Robustness	Pre-Disaster	0.190	0.200	0.136	0.200	0.143
	During Disaster	0.227	0.263	0.208	0.188	0.217
	Post-Disaster	0.182	0.174	0.200	0.125	0.182
Constructability	Pre-Disaster	0.190	0.250	0.182	0.200	0.238
	During Disaster	0.182	0.158	0.167	0.250	0.174
	Post-Disaster	0.227	0.217	0.200	0.250	0.227
Redundancy	Pre-Disaster	0.190	0.150	0.227	0.200	0.143
	During Disaster	0.182	0.263	0.208	0.125	0.174
	Post-Disaster	0.182	0.174	0.200	0.250	0.227
Durability	Pre-Disaster	0.190	0.150	0.227	0.200	0.238
	During Disaster	0.182	0.158	0.208	0.188	0.217
	Post-Disaster	0.182	0.217	0.200	0.125	0.136
Affordability	Pre-Disaster	0.238	0.250	0.227	0.200	0.238
	During Disaster	0.227	0.158	0.208	0.250	0.217
	Post-Disaster	0.227	0.217	0.200	0.250	0.227

Figure 3 further illustrates the resilience value dynamics of survey respondent #2 through SCRTs. As per Figure 3, The SCRTs represent how the resilience value of each alternative shift across different disaster phases. The shape of the triangle varies depending on whether resilience value increases, decreases, or remains stable throughout the phases. Among these three alternatives, Alternative 3 exhibits a positive SCRT, with resilience value increasing from the pre-disaster to the during-disaster phase. This trend highlights the robustness of Alternative 3 in withstanding disasters, which reinforces its structural resilience under extreme conditions. However, in the post-disaster phase, its rank drops below Alternative 2, suggesting that stakeholders may prioritize factors such as constructability and cost-effectiveness during recovery rather than solely focusing on structural resilience.

In contrast, Alternatives 1 and 2 both exhibit negative resilience triangles for respondent #2, with resilience value gradually declining from pre-disaster to during-disaster phases. This indicates that their perceived effectiveness decreases once a disaster occurs. However, Alternative 2 emerges as the most prioritized design in the post-disaster phase, suggesting that stakeholders value its balance between resilience and post-disaster recovery considerations, such as affordability and ease of reconstruction. Therefore, Alternative 3 is considered to be the best strategy for survey respondent #2 as it obtains comparable resilience value to Alternative 2 in the pre-disaster and post-disaster phases and significantly outperforms both Alternatives 1 and 2 during the disaster.

This demonstrates that Alternative 3 not only maintains stable resilience during the pre- and post-disaster phases but also provides superior protection during a disaster. These findings highlight that the priorities of resilience strategies are phase-dependent, and that resilience planning should account for the dynamics of value systems of stakeholders across disaster phases to identify the optimal and most effective strategy.

Table 5. Results of resilience value on alternative roofing designs.

Respondents	Pre-Disaster			During Disaster			Post-Disaster		
	A1	A2	A3	A1	A2	A3	A1	A2	A3
R1	0.267	0.352	0.380	0.294	0.348	0.358	0.304	0.352	0.344
R2	0.273	0.361	0.366	0.270	0.351	0.378	0.304	0.350	0.346
R3	0.273	0.347	0.379	0.291	0.346	0.363	0.295	0.350	0.355
R4	0.266	0.355	0.380	0.312	0.354	0.334	0.314	0.352	0.334
R5	0.283	0.354	0.363	0.294	0.346	0.359	0.301	0.353	0.346
R6	0.270	0.343	0.387	0.286	0.354	0.360	0.290	0.353	0.357

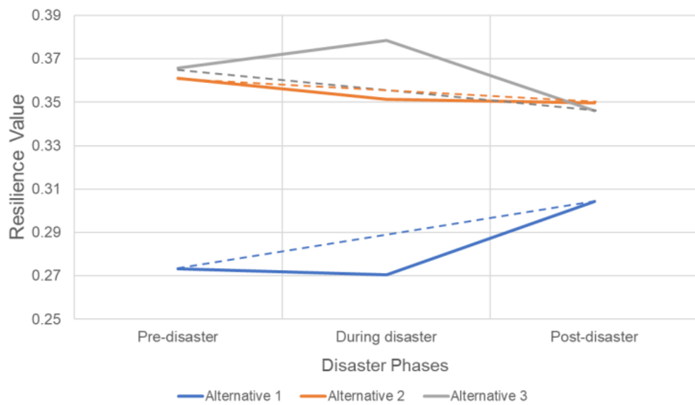

Figure 3: Resilience triangle of three alternatives based on Respondent #2's value systems.

4. CONCLUSIONS

This study presents a Stakeholder-Centric Resilience Evaluation Framework (SCREF) to systematically assess resilience strategies by integrating stakeholder value systems into decision-making. By incorporating stakeholder value systems, the SCREF enables a structured evaluation that captures how these priorities shift across different stakeholders and different disaster phases. The case study on residential building roof retrofits demonstrates the framework's practical application and illustrates how resilience value varies among different designs and across different disaster phases. The findings emphasize the importance of integrating stakeholder value systems into resilience planning. The variation in resilience value across designs and disaster phases demonstrates the need for a decision-making approach that considers not only technical effectiveness but also the value systems of various stakeholders.

This research makes three primary contributions to the field of resilience planning and engineering. First, it introduces a new framework that bridges the gap between technical assessment and stakeholder perceptions in resilience strategy evaluation. Second, it provides a systematic method for quantifying and integrating qualitative stakeholder values into resilience decision-making processes. Third, it demonstrates through empirical evidence how consideration of stakeholder values can lead to different choices across different disaster phases, which reinforces the need to integrate these values into resilience decision making. By combining technical evaluations with stakeholder value systems, this study advances resilience planning methodologies and promotes stakeholder-centric decision-making; it has the potential to provide valuable insights to policymakers, engineers, and urban planners to develop effective resilience strategies that integrate stakeholder perspectives.

Despite the contributions of this study, future research can further enhance the SCREF's robustness and applicability. First, there is a need to increase the sample size of respondents who participate in the case study. A larger and more representative sample would provide a more comprehensive understanding of stakeholder values and strengthen the framework's applicability to real-world decision making. Second, there is a need to incorporate uncertainty analysis of the stakeholder value systems to investigate how risk perception influences resilience strategy evaluations. Third, the SCREF can be applied to other resilience strategy selections, such as foundation retrofits, relocation decisions, and building code upgrades. Fourth, future research could conduct longitudinal case studies to assess the long-term effectiveness of resilience strategies developed using the SCREF. By examining the long-term performance of implemented strategies across multiple disasters, future research could further validate the effectiveness of the framework over time.

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