Community-informed Decisions for Efficient, Cost-effective, and Integrative Disaster Resilience planning (Co-DECIDR): Implementation with Natural Language Processing and Large Language Models

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Research Summary

Evaluating community resilience planning in the face of natural hazards and disasters presents significant challenges, including limited system clarity, diverging community priorities, resource constraints, and inherent uncertainties. Traditional methods—often reliant on economic metrics through benefit-cost analysis—may overlook critical factors. In response, the increasing shift towards transdisciplinary methods underscores the importance of integrating local community priorities into resilience planning. This research leverages the Community-informed Decisions for Efficient, Cost-effective, and Integrative Disaster Resilience planning (Co-DECIDR) modeling framework. By merging Fuzzy Cognitive Mapping (FCM), to account for qualitative considerations, with Benefit-Cost Analysis (BCA) for quantitative rigor, Co-DECIDR enables a comprehensive understanding of complex socioeconomic systems that support built and natural infrastructure. The framework can be operationalized via accessible online tools—Mental Modeler for FCM and Economic Decision Guide Software (EDGe$) for BCA—to enhance user engagement and model efficacy. There is increasing use of Natural Language Processing (NLP) and Large Language Models (LLMs) to more efficiently populate a baseline dataset for inclusion in modeling frameworks, such as Co-DECIDR. This approach is especially promising leveraging human-in-the-loop techniques and considering data from the widespread use of multimodal communication technologies.

Research Advancement Details

Local communities face significant risks associated with increased natural and/or human-caused disasters. These disasters impact communities either through acute shocks (e.g., earthquakes, hurricanes, disease outbreaks, market shocks) or chronic stressors (e.g., drought, poverty, food insecurity, social marginalization). Furthermore, complex events can result from multiple traumatic events, often through a complex combination of both natural and human-made causes that exacerbate communities' social and physical

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systems. Thus, community resilience planning, requires actions and strategies undertaken to prepare for such hazards, and to adapt to, withstand, and quickly recover from disruptions. However, adopting community-level investment strategies with the greatest net benefit requires the understanding of benefits, costs, and trade-offs involved in making capital improvements to the social institutions, built environment and other systems associated with the local community for increased resilience. Yet, there are other factors that communities prioritize, for which monetary values are challenging or even impossible to calculate. In such cases, a community may want to establish what additional factors are important in its consideration of alternative investment strategies and take those factors into account when deciding on strategies for local implementation. Thus, community resilience planning takes place in the context of achieving multiple objectives.

The Community-informed Decisions for Efficient, Cost-effective, and Integrative Disaster Resilience planning (Co-DECIDR) is a hybrid framework to help community planners navigate through complex multi-criteria decision analysis (MCDA). Co-DECIDR enables collaborative planning teams (who do not necessarily possess the expertise/resources for conducting MCDA) to perform trade-off analysis and decide amongst alternatives, which will reduce their social and physical vulnerabilities, with their limited economic resources, while taking into account the interdependences between physical infrastructure, social institutions, and natural ecosystems. To address these complexities, Co-DECIDR combines a participatory fuzzy cognitive mapping (FCM) approach with a standard economic methodology for benefit-cost analysis (BCA). To facilitate the implementation of Co-DECIDR framework, implementation may make hybrid use of two publicly available, easy-to-use online tools: (1) Mental Modeler; and (2) Economic Decision Guide Software (EDGe$).

EDGe$ is produced by the National Institute of Standards and Technology (NIST) and provides communities with a standard economic methodology for evaluating investment decisions required to improve community resilience by helping the users identify and compare the relevant present and future resilience costs and benefits associated with new capital investment and perform BCA.

Mental Modeler is based in FCM and allows community representatives and stakeholders to engage with collaborative system modeling and cognitive mapping process through which they can identify their priorities in response to disasters while accounting for other critical community priorities such as social, environmental, equity and economic determinants, and capture their collective knowledge in a standardized format that can be used for scenario analysis.

Planners can use BCA and FCM in tandem to determine the possible outcomes of their planning strategies and decisions and thus administer trade-off analysis between their multiple objectives through the implementation of the Co-DECIDR framework (Fig. 1).

The use of the Co-DECIDR framework can be facilitated through a human-in-the-loop approach leveraging Natural Language Processing (NLP) and Large Language Models (LLMs) approaches. Such methods can strategically integrate information about: 1. relevant aspects of community resilience in the local context (e.g., who and what), 2. identified resilience options, 3. community-level tradeoff assessments among specific options, and 4. community-level values that define the viability of options, even those that are cost-effective. Such an approach can create a bottom-up portrait of the relevant economic and resiliency landscapes.

The widespread use of multimodal communication technologies has greatly increased the volume of available data that requires processing, curation, and categorization. In particular, there are opportunities for research on: a. how NLP techniques can extract key information about resource constraints from relevant documents, reports, and social media; b. the use of LLMs in analyzing historical disaster data (qualitative and quantitative) to identify patterns and uncertainties relevant to community resilience; c. how NLP can be applied to improve the clarity and place-based relevance of resilience plans and related documents for community members and interested parties.

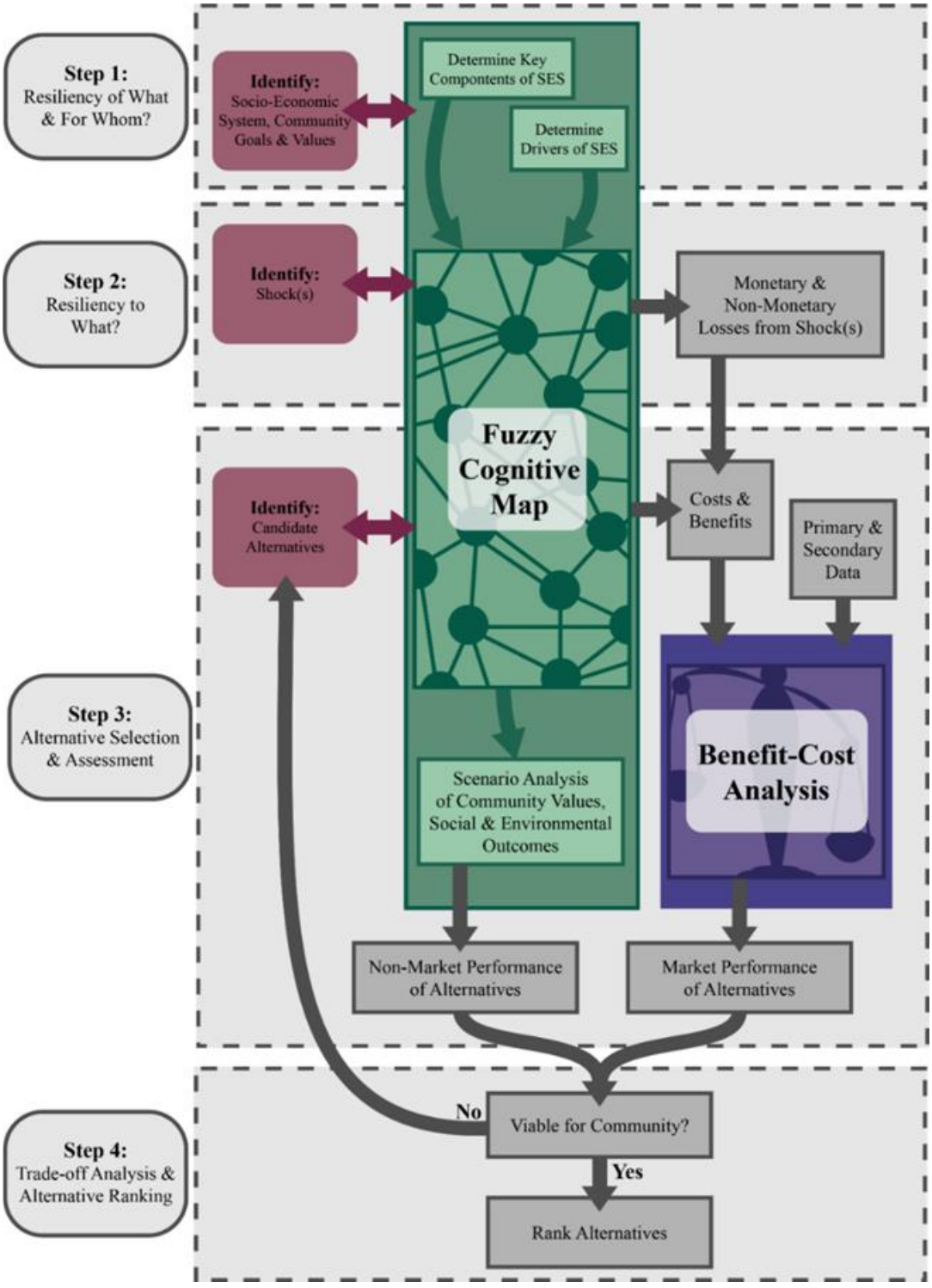

Fig.1. Four steps to implement the Co-DECIDR framework facilitated by a hybrid use of BCA and FCM.

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