FUZZY COGNITIVE MAPPING: PROPOSED ASSESSMENT FRAMEWORK FOR COASTAL RISK MANAGEMENT PROJECT PROCESSES

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INTRODUCTION

As coastal development, understanding of coastal hazards and engineering capability have increased over the past century, it has become standard practice to implement risk reduction strategies to mitigate impacts of inundation, flooding and erosion on coastal communities. The implementation process of coastal risk management projects can be simplified to three phases: i) conceptualization, ii) engagement, and iii) execution with project termination possible at any stage. Each phase is affected by both actors and actants (non-human influencers). To date, there have been few attempts to robustly analyze and understand the technical, institutional, financial, social and temporal complexities of these risk management processes. Consequently critical factors that underpin implementation or abandonment of these projects are poorly resolved. For the purposes of this research, the ratio of projects that are constructed or policies which are enacted as compared to those that are abandoned prior to implementation is termed the "implementation gap" (Lowry, 1985). The implementation gap in coastal risk management in Germany over the past 30 years is approximately 50% (Becker, Huitema, & Aerts, 2015). Furthermore, the implementation gap for policy-centric retreat or adaptation projects is wider than for conventional defense (Gibbs, 2016; Heffernan, 2012). While singular case study approaches aid in understanding dynamics of a particular project and location, coastal risk management and climate change literature have both called for creation of a robust framework to examine decision making processes across several case studies to better understand the "adaptation deficit" in climate change adaptation or the "implementation gap" in coastal risk management (Eisenack, et al., 2014; Dow, et al., 2013).

Here we summarize the methods undertaken to develop and test a framework reliant on fuzzy cognitive mapping that will allow comparison of the varied social, financial, and institutional influences driving project outcomes in the conceptual design, engagement, and execution phases of coastal risk management implementation. Testing of this framework will be performed with approximately 25 case studies in Hawke's Bay, New Zealand and Terrebonne Parish, United States.

FUZZY COGNITIVE MAPPING

Fuzzy cognitive maps (FCMs) have been used since the late 1980s to visualize weighted influence relationships between actors and actants (non-human influencers) either qualitatively or quantitatively in the form of an enhanced mental model (Kosko, 1986). Fuzzy cognitive mapping of decision making is an emergent tool (Jetter & Kok, 2014) that has great potential to better resolve complex factors influencing coastal risk management decision making. Fuzzy cognitive maps are composed of nodes and sub-nodes representing actors and actants and edges representing influence. This mixed methods approach allows for mathematical representation of visual aids in the form of matrices coupled with qualitative descriptors for the states of nodes and sub-nodes and the internodal levels of influence (Ozesmi & Ozesmi, 2004).

Creation of linked fuzzy cognitive maps depicting the conceptualization, engagement and execution phases of coastal risk management project processes involves three primary steps: (1) building qualitative maps of sub-nodes, nodes and edges with preliminary valuation spectrums and weightings by identifying influencing factors from existing literature; (2) populating qualitative maps with case study data creating individual, mixed-methods map sets for each project; and (3) using the case study specific maps to verify appropriateness of valuation spectrums (quantified nodes and sub-nodes) and to calibrate relative magnitudes of influence (quantified edges).

IDENTIFYING PHASE INFLUENCES FOR QUALITATIVE MAPPING

The conceptualization, engagement, execution process is influenced by a wide range of factors that are both project

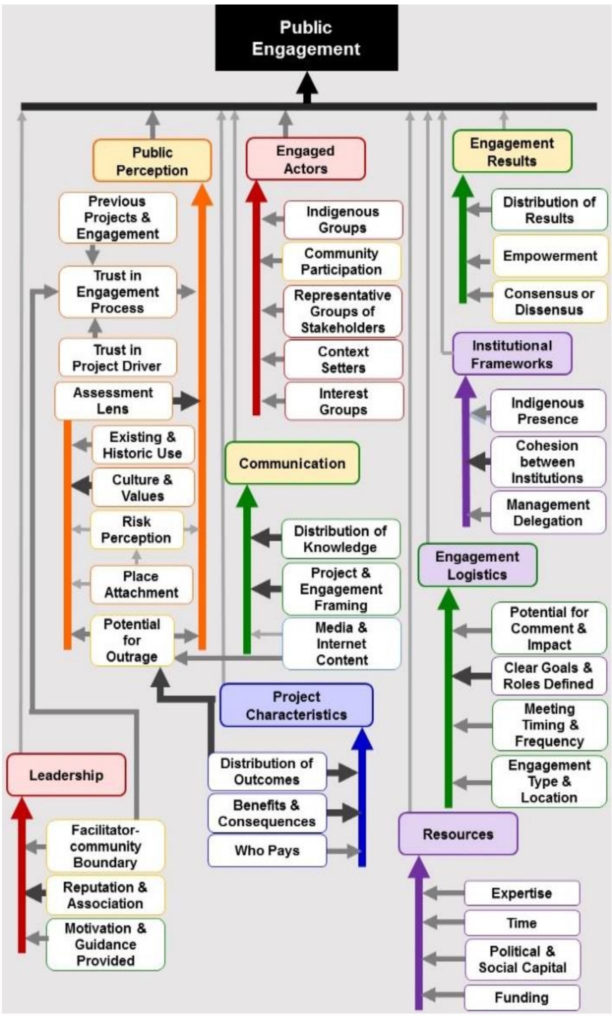

Figure 1. Draft Qualitative Engagement Map

specific and cumulative over time within a region. Social, financial and institutional influences are variously interrogated and documented within existing technical project evaluations and academic literature. It is noted that factors heavily influencing one phase may have less influence on another thus affirming the need for a phase-based procedural evaluation. Influencing factors on each phase of the conceptualization, engagement, execution process are distilled from existing literature and used to build qualitative FCMs for each phase using the prominence of discussion of each influencing factor as an early indicator of magnitude of influence on the phase's outcome.

A sample qualitative fuzzy cognitive map representing the social, institutional, and financial factors influencing the public engagement phase is shown in Figure 1. Sub-nodes (white backgrounds) can influence each other and nodes (shaded backgrounds). Nodes then influence the central phase (engagement - black background) and are summed whereby the model will either progress onto execution, iterate in the engagement phase, or abandon the project.

CASE STUDY SELECTION AND ANALYSIS

To identify and examine key factors critical in the decision making process, we are creating detailed, region-specific historic chronologies of coastal risk management projects and processes. Environmental, economic, regulatory, and social changes and events are documented for selected communities within Hawke's Bay, NZ and Southeast Louisiana, USA. Both regions are exposed to coastal hazards (to varying degrees), have indigenous peoples, and have industrial and agricultural use. Management of erosion, inundation, and flooding utilizing retreat, adapt, or defense strategies has been ongoing in both case study locations for at least 50 years. Selection of projects for further analysis within the two regions allows for inclusion of a variety of regulatory and economic conditions while maintaining a thorough understanding of community and environmental dynamics. Information about project timeline, design, budget, community meetings and other documented changes is collected through review of local government and newspaper archives. Additional nuanced information will be collected through semi-structured interviews with key actors as identified by the archival review.

QUANTIFYING 'INFLUENCE' WITH FCMs

Pilot case study data and existing literature were used to define valuation spectrums (between +/-5 dependent on nodal state) of actors/actants (nodes) previously identified in literature-based maps, and weight their level of influence on each phase of the conceptualization, engagement, execution process. For example, access to financial resources and political capability are identified in the literature as influencing the potential outcome of coastal project processes. Such indicators can be expressed through the quantitative valuation of nodes and their subsequent influence weightings. In this case, sub-nodes representing context setting stakeholders (see Figure 1 under the 'engaged actor' node) who can afford to hire experts to lobby on their behalf are valued more highly (+/-5), than those submitting written statements (+/-3), or those who simply attend a meeting (+/-1) with directionality (+/-) dependent on project support or opposition. Each node is valued (between +/-5) and has influence arrows with relative weightings (between +/-1) as to reflect unequal influence. Preliminary weightings are based on academic literature with further refinement by calibration based on data from the case studies.

FUTURE WORK

The resulting FCMs will provide a deeper understanding of influencing factors on coastal risk management project processes and will allow comparison of how changing regulatory, economic and stakeholder engagement environments affect this process. A better understanding may spur more effective engagement and communication potentially leading to implementation of more equitable, technically sound coastal risk management strategies.

This research is a portion of Laura Robichaux's doctoral thesis (estimated completion mid-2020). She intends to use machine learning to calibrate the influence weightings of the maps. The resulting set of FCMs is not intended to serve as a predictive model but rather as a framework by which a variety of coastal risk management case studies may be compared.

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