Adaptation and Maladaptation Pathways of Coastal Infrastructure Projects

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Research Problem Statement or Purpose

The confluence of climate change, coastal flooding, and population growth are increasing risk for coastal communities globally (Vousdoukas et al., 2018). There is a growing need for coastal infrastructure that protects communities, reduces disaster risk and supports their adaptation to a changing climate (Steven et al., 2020; OECD 2018; Sutton-Grier et al., 2015). Grey infrastructure, for example, seawalls or dikes, are often preferred as protection solutions because of their long use history and path dependency – a phenomenon that leads planners to implement solutions that are familiar to them (Seddon et al., 2019; Powell et al., 2018). However, grey infrastructure can provide a false sense of security, negatively affect ecosystems, and is costly and difficult to maintain under changing and increasingly uncertain climatic conditions (Van Zelst et al., 2021; Kuwae & Crooks, 2021; Peck et al., 2022; Matsushima & Zhong, 2022).

In recent years, there has been an increasing focus on grey and hybrid infrastructure, often conjointly referred to as nature-based solutions (NbS), for example, mangroves and living shorelines, as an alternative to grey infrastructure projects (Fernandes & Guiomar, 2018). Despite NbS having many social and ecological co-benefits and being less expensive than grey infrastructure, their uptake remains slow (Van Zelst et al., 2021; Apine & Stojanovic, 2024; Narayan et al., 2016). This can be attributed to a lack of standardised frameworks and data to measure, understand, and compare the adaptation outcomes of NbS and grey infrastructure projects. This lack of comparison limits our knowledge of when to employ different infrastructure approaches, hindering the prioritisation of NbS in funding schemes (Apine & Stojavonic, 2024; Narayan et al., 2016; Singhvi et al., 2022). Understanding when and how to select NbS is further complicated by the uncertainty brought about by climate change, leading to increasing challenges when designing, investing, and planning coastal infrastructure projects (Colombo & Byer, 2012).

The few existing comparative studies of grey infrastructure and NbS projects focus on specific performance metrics to reduce natural hazard impacts, for example, wave attenuation (e.g., Morris et al., 2018; Singhvi et al., 2022). Others evaluate the impact of specific project conditions such as stakeholder involvement on outcomes of coastal adaptation projects (e.g., Rasmussen et al., 2020). However, there is a significant gap in understanding how different dimensions of project implementation, such as organisational approaches and delivery mechanisms, interact with the type of infrastructure of a project to produce adaptation (or maladaptation) outcomes.

Therefore, this study aimed to answer the research question:

How do different project conditions (stakeholder engagement, project scale, project leadership, project objectives, project setting, community archetype, and infrastructure type) interact to influence climate change adaptation (and maladaptation) outcomes in coastal infrastructure projects?

Research Methodology and Approach

This research uses fuzzy-set qualitative comparative analysis (fsQCA) to explore how combinations of project conditions in coastal infrastructure projects interact to produce climate change adaptation. The outcome of interest will be climate change adaptation (CCA), which is defined by the United Nations Framework Convention on Climate Change as: "Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change" (UNFCCC, n.d.).

fsQCA is a methodology that can be seen as bridging quantitative and qualitative approaches (Ragin, 2008). The method seeks to establish causal 'recipes' of conditions that lead to an outcome (Korjani & Mendel, 2021). The method is especially suited to capturing interactions between variables or conditions (Jordan et al., 2011) – a gap in our understanding of coastal infrastructure project implementation within a changing climate. The conditions chosen for this study were stakeholder engagement (in terms of breadth and depth of involvement), project scale (defined by project budget, geographic scope and completion time), project leadership (in terms of leadership types), project objectives (with a special lens of disaster risk reduction (DRR)), project setting (urban, rural), community archetype (economic conditions, social conditions such as if livelihoods depend on the sea) and the coastal infrastructure type (on a spectrum of grey to NbS).

For this research, we conceptualised coastal infrastructure along a spectrum of grey to NbS. This departs from established binary categories. This conceptualisation along a spectrum is based on ideas from Singhvi et al. (2022), who show that several characteristics that are usually attributed to NbS, such as being more adaptive and multifunctional, were found not to be unique to NbS but could be found across several different types of coastal infrastructures. The characterisation along a spectrum enables a more holistic understanding of how project conditions interact to achieve CCA outcomes.

We analysed 20 coastal infrastructure projects sourced from project evaluation reports from databases from the World Bank Group and the Asian Development Bank, which have an extensive, publicly available document library. These facilities were chosen because of their work and investments across several countries in the Asia-Pacific, enabling a broader and more holistic analysis by including a variety of geographical and cultural case sites. We theoretically sampled the cases to ensure variation in both observed CCA outcomes and the selected project conditions.

Key Findings

This study shows how combinations of stakeholder involvement, project scale, project leadership, project objectives, project setting, community archetype, and infrastructure type interact to influence CCA outcomes in coastal infrastructure projects. Through understanding infrastructure type across a spectrum from grey to NbS, different pathways to CCA arise for specific coastal infrastructure types (e.g., dike, living shoreline). The equifinality of the identified solutions shows that there is not one single approach but rather combinations of conditions that act together in a set context. Overall, the findings underscore the importance of integrating infrastructure type and project organisation when planning for coastal infrastructure to achieve better outcomes.

Implications

This research has significant practical implications for policymakers and project planners working in the field of coastal infrastructure resilience. The identified pathways for CCA provide a framework for decision-makers and practitioners to support designing coastal infrastructure projects that balance short-term needs, such as immediate flood protection – by for instance building a seawall, with high stakeholder involvement to ensure long-term sustainability that prioritises local needs. The findings can inform funding allocations and policy frameworks, potentially leading to more informed decision-making about how and where to use specific types of coastal infrastructure, especially in regions vulnerable to climate change.

Furthermore, this study advances theory by positioning project outcomes as an interaction and duality between coastal infrastructure type and project conditions. The characterisation of coastal infrastructure along a spectrum challenges the binary conceptualisation often used in research, allowing for more nuanced discourse. The use of fsQCA underscores the complexity of causal pathways, enabling us to theorise on the building blocks to plan projects that effectively improve adaptation for coastal communities. In a changing climate that is imposing increasingly complex and uncertain conditions, this research advances knowledge of coastal infrastructure resilience and climate change adaptation of coastal communities.

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