Master Thesis Report

The Impact of Frugal Innovation Paradoxes on Flood Resilience in Changing Environments

Francisco Franco Bulhões Mendes
5220629
MSc Construction Management and Engineering

TU Delft

The Impact of Frugal Innovation Paradoxes on Flood Resilience in Changing Environments

By

Francisco Franco Bulhões Mendes
Student Number: 5220629

in fulfilment of the requirements for the degree of

Master of Science
in Construction Management and Engineering

at Delft University of Technology,
to be defended publicly on May, 6th, 2025 at 12:45.

Graduation Committee

Prof. dr. P.W Chan,	TU Delft, Chairperson
Dr. M. (Martijn) Leijten,	TU Delft, 1st Supervisor
Dr. A. (Angela) Greco,	TU Delft, 2nd Supervisor

Acknowledgements

This research process has been a deep journey of personal growth, and I would like to express my deepest gratitude to all those who supported and guided me throughout the completion of this thesis.

I will start by thanking me graduation Committee, Martijn Leijten, Paul Chan and Angela Greco whose insightful discussions lead the thesis process along with my own personal development through every step along the way. Our meetings were interesting and kept the development of the topic dynamic. Their commitment to the thesis was particularly special for me given my emotional investment on the topic, its relevance to my community in Brazil and finally how it potentially relates to very present discussions regarding climate adaptation and its ramifications to society. Secondly I'd like to thank my family for unwavering support throughout my life, along with their commitment to education and its relevance. This is the biggest contributor to the completion of this thesis, as the echoes of their actions and nuances certainly have boded their weight on my actions and decisions leading to this divisor of water. Thirdly, I'd like to thank my colleagues and friends whom have also displayed unswerving support through this process through immense kinship and camaraderie along with valuable lessons and feedback. Finally I'd also like to thank the immense community and interviewees whom provided insightful discussions and ideas during the research process; their insights have constructed the intricacies presented in this report, addressing and adding flavor to the discussions and ponderations. Ultimately this thesis stands as a statement of all the encouragement received throughout this process.

Thank you truly, for everything.

Francisco F. B. Mendes

Delft, April 2024

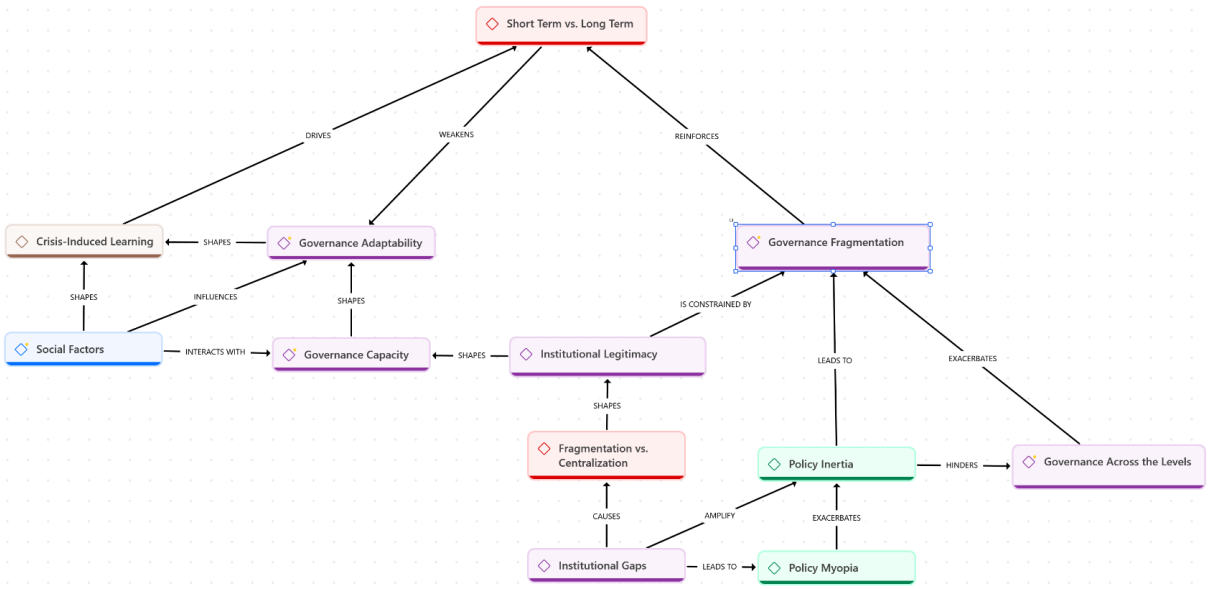
Executive Summary

Flood resilience remains a critical challenge in the Global South, where climatic volatility intersects with persistent institutional, social and financial vulnerabilities. Despite the availability of sophisticated resilience frameworks from the Global North, their direct transfer often leads to a resilience deadlock, where implemented strategies fail to yield durable or inclusive outcomes. This thesis investigates the root causes of this deadlock by applying a paradox lens, uncovering how contradictory logics contribute to fragmented and short-lived resilience outcomes. The study employs the Dynamic Equilibrium Model (Smith & Lewis, 2011) to examine how flood resilience in the Global South can embrace paradoxes. To assess the research problem, this study explores the following overarching research question:

"In what ways do and can the paradoxes of frugal innovation influence flood resilience in the Global South?"

At the heart of this research lies the proposition that paradoxes of frugal innovation influence flood resilience by demanding coordination between competing stakeholders in changing environments. Therefore, To deepen the exploration of how paradoxes of frugal innovation influence flood resilience in the Global South, the research question was developed through three sub-questions, each aimed at uncovering the nature of these paradoxes, their implications for resilience outcomes and their entanglement within governance fragmentation. This approach enabled a nuanced understanding of how tensions arise between frugal innovation and capital-intensive models typically favored in conventional planning. Moreover, these paradoxes are not merely abstract; they emerge tangibly in the field as misalignments between actors, priorities and systems, particularly within informal or under-resourced settings of the Global South. The research shows that such tensions can either obstruct or catalyze resilience-building depending on how they are addressed, with neglect often resulting in delayed or poorly adapted solutions, while constructive engagement can foster learning, compromise and innovation. Furthermore, it reveals that governance fragmentation, expressed through overlapping mandates, poor coordination and unclear roles, exacerbates these paradoxes by impeding institutional alignment and coherent responses.

Figure 34 : Short vs. Long Term Planning Relations

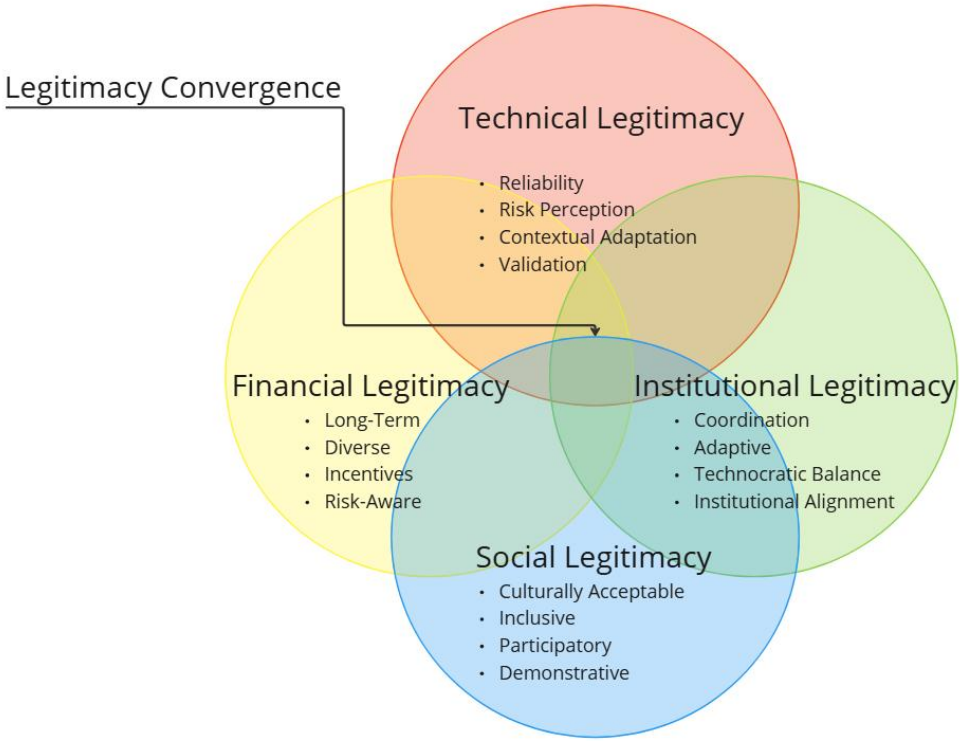


From Author (2024)

This thesis then employs an exploratory qualitative research design to investigate the research topic. Exploratory qualitative research seeks to delve into complex, underexplored phenomena where limited existing knowledge demands a more open-ended and interpretive approach. Accordingly, a multifaceted methodology was adopted to unpack the intricacies of the research question, beginning with a detailed problem definition, the establishment of clear objectives, and a determination of the study's scope. The research was initiated with an extensive literature review that provided the theoretical basis for examining flood resilience, frugal innovation, and paradox theory, especially in the context of the Global South. This review helped surface the existing gaps in resilience governance, particularly in the transfer of technocratic frameworks and the under-theorized role of paradoxes. Building on this foundation, the study conducted twenty exploratory semi-structured interviews with stakeholders across academic institutions, governmental bodies, private consultancies, and international missions. These participants were selected for their expertise and geographical diversity, with contributors from Brazil, India, Tanzania, Indonesia, China, the Netherlands, the United States, and beyond, offering a rich cross-continental view of flood resilience dynamics. Many of these interviewees were directly involved in or familiar with the 2024 floods in Rio Grande do Sul, Brazil, providing grounded insights into the implementation challenges and institutional responses. The interviewees were classified into five thematic categories to systematize the diversity of expertise and perspectives. The qualitative data gathered from these interviews were then meticulously analyzed through a grounded theory-inspired approach using Atlas.ti software. The analysis followed an abductive coding sequence: open coding to distill raw insights, axial coding to identify relationships among emerging themes, and selective coding to distill broader conceptual patterns.

This process culminated in the development of a governance-sensitive model upholding flood resilience. Through iterative interplay between data and theory, the study constructed a legitimacy-centered framework explaining how frugal innovation efforts are influenced by governance structures, institutional fragmentation and the interplay of paradoxes. Central to this framework is the concept of Legitimacy Convergence, a construct developed inductively through this study’s grounded theory approach and expert interviews, which posits that for frugal innovations to move beyond isolated, small-scale interventions and become sustainable components of long-term flood resilience planning, they must simultaneously attain four interconnected forms of legitimacy: technical, institutional, financial and social. The research finds that legitimacy in one dimension cannot compensate for the absence of others; instead, it is the convergence of all four that creates the institutional conditions necessary for transformative adaptation. When any one domain is weak, such as when technical models are robust but lack community support, or when financial resources exist without institutional coordination, frugal innovations risk remaining marginalized or short-lived. By identifying the interdependencies between these legitimacies and illustrating how they can be fostered even within fragmented governance contexts, this framework provides a practical and theoretically grounded roadmap for integrating frugal innovation into holistic flood resilience planning across the Global South.

Figure 34 : 4 Legitimacies



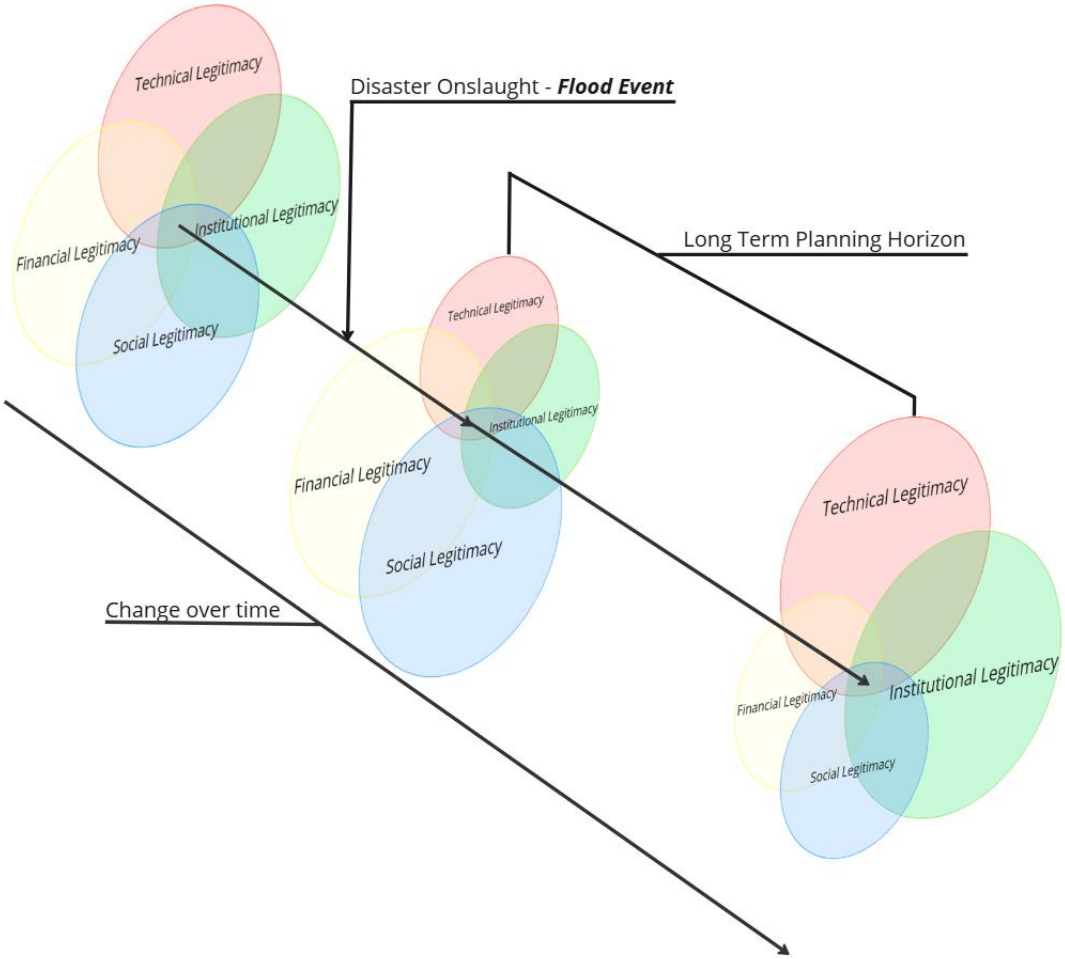
From Author (2024)

The discussion then moves on to explores how governance structure fundamentally shapes the long-term viability of flood resilience. The analysis of Brazil's 2024 flood in Rio Grande do Sul illustrates how the dissolution of national coordinating bodies and the absence of a dedicated institutional framework have led to fragmented governance, reactive decision-making along with lesser asset maintenance. This institutional void has weakened the ability to plan and implement resilience strategies across municipal boundaries, thus resulting in short-term fixes rather than sustained adaptation. Without a mechanism to foster legitimacy over time the resilience landscape remains vulnerable to political cycles and misalignment. In contrast, this study also highlights the Odisha Model as a clear example of legitimacy convergence, where frugal innovation has been successfully integrated into formal governance structures through the alignment of the 4 Legitimacies. Odisha's approach, rooted in decentralized infrastructure and community engagement, demonstrates how resilience efforts gain long-term traction when legitimacy is secured across these interdependent domains. This convergence can thus enable frugal, scalable solutions to evolve beyond isolated pilot initiatives and become embedded within broader, durable flood adaptation strategies.

The thesis also introduces a conceptual shift from understanding flood resilience as the cyclical Deadlock of Flood Resilience to viewing it as a system of mutually dependent legitimacy dimensions. Whereas this first modelling attempt characterized flood governance in the Global South as a sequence of failures, where short-term responses, institutional fragmentation and socio-geographic constraints reinforce one another, the 4 Legitimacies Framework reconceptualizes resilience as an emergent outcome of dynamic interdependencies. The 4 Legitimate must be achieved concurrently, as resilience efforts falter when any single dimension is underdeveloped. This redefinition becomes particularly salient in post-disaster contexts, where legitimacy dimensions fluctuate over time. This dynamic process is illustrated in Figure 45, which depicts how legitimacy domains shift in response to a flood event and evolve across the long-term planning horizon. The diagram demonstrates that while technical legitimacy may be prioritized immediately following a disaster, institutional, financial, and social legitimacy require time and coordination to converge. By adopting a dynamic and

paradox-informed governance perspective, the framework acknowledges that legitimacy must be constantly rebalanced rather than permanently resolved, reflecting the evolving tensions inherent to managing resilience in complex and politically sensitive environments.

Figure 44 : Dynamic Nature of Flood Resilience



From Author (2024)

While this study offers valuable insights into the paradoxes of frugal innovation and the role of legitimacy in flood resilience governance, it is not without own limitations. The deductive framing of interview questions may have shaped interviewee responses, potentially constraining the emergence of unanticipated opinions. Additionally, the reliance on experts risks institutional bias and the absence of a mixed-methods approach limits the generalizability of findings. The study also faced constraints in its scope, given the complexity of the topic and the limitations inherent to a master's thesis; with limited exploration of informal governance dynamics. These limitations point to several avenues for future research, including more granular investigations of bureaucratic structures, more comparative studies across Global North and South contexts and finally critical evaluations of international aid and policy transfer. Further work could also benefit from incorporating mixed methodologies and broader stakeholder perspectives to enhance the analytical depth and applicability of its resilience frameworks.

Table of Figures

Figure 1: Alternative Pathways to Flood Resilience 12
Figure 2 : Floods of 1941 in Porto Alegre, Brazil 24
Figure 3 : May 2024 Floods, Rio Grande do Sul, Brazil 25
Figure 4 : Porto Alegre Airport during May 2024 Floods 26
Figure 5 : Flood Devastation in Brazil 27
Figure 6 : Reactive flood measure in Porto Alegre, Brazil 29
Figure 7 : Vulnerability to flooding in Brazil 30
Figure 8 : How Ancient Terraces Inspired Flood Resilience 36
Figure 9: A Dynamic Equilibrium Model of Organizing 44
Figure 10 : Deadlock of Flood Resilience 50
Figure 11 : Temporary bridge built after flood is swept away in Rio Grande do Sul 51
Figure 12 : defining Flood Resilience 53
Figure 13 : Channeling of Rivers: An Urbanistic Error 59
Figure 14: Inequality & Vulnerability 61
Figure 15 : Room for the River Nijmegen 69
Figure 16 : Stakeholders Network Map 78
Figure 17 : Geographic Distribution of Interviewees 79
Figure 18 : Expertise of Interviewees 80
Figure 19: Abductive Hourglass 83
Figure 20 : Abductive Hourglass - Open Coding 84
Figure 21 : Axial Code Relations 85
Figure 22 : Abductive Hourglass - Axial Coding 86
Figure 23 : Code-document Analysis of Axial Codes 86
Figure 24 : Abductive Hourglass : Selective Coding 87
Figure 25 : Fragmentation of Governance Network 88
Figure 26 : Code-Document Analysis of Governance Fragmentation 89
Figure 27 : Types of Paradoxes 90
Figure 28 : Code-Document Analysis of Types of Paradoxes 90
Figure 29 : Abductive Hourglass - Relational Exploration 92
Figure 30 : Selective Code Co-Occurrence 92
Figure 31 : Selective Coding Relations 93
Figure 32 : Abductive Hourglass - Model Conception 94
Figure 33 : Short vs. Long Term Planning Relations Model 95
Figure 34 : 4 Legitimacies Prototyping 101
Figure 35 : 4 Legitimacies 110
Figure 36 : Sustained Legitimacy Across Time 113
Figure 37 : Emergency Shelters in Odisha, India 115
Figure 38 : Building Community Resilience In Odisha 116
Figure 39 : Tropical cyclone induced damage in Odisha Province in the past Century 117
Figure 40 : Select tropical cyclones in Odisha and its impact during last two decades 118
Figure 41 : From deadlock to Legitimacy 120
Figure 42 : 4 Legitimacies- Aftermath of a Disaster 121
Figure 43 : 4 Legitimacies - Long-Term Resilience 123
Figure 44 : Dynamic Nature of Flood Resilience 125
Figure 45 : 4 Legitimacies 132

Table of Tables

Table 1 : Summary of selected literature..... 18
Table 2 : Paradox Classification and Explanation Table..... 43
Table 3 : Comparative Analysis of Frugal Innovation and Traditional Flood Resilience Methods..... 72
Table 4 : Interviewees List..... 81
Table 5 : Key Determinants of Technical Legitimacy 103
Table 6 : Key Determinants of Institutional Legitimacy 104
Table 7 : Key Determinants of Financial Legitimacy..... 107
Table 8 : Key Determinants of Social Legitimacy 109
Table 9 : Validation Interviewees List..... 126

Table of Contents

Acknowledgements 1
Executive Summary 2
Table of Figures 6
Table of Tables 7
Table of Contents 8
1 Introduction 10
1.1 Background 10
1.2 Problem Definition 11
1.3 Relevance of the Research 12
1.4 Research Question and Sub-Questions 13
2 Methodology 14
2.1 Research Methodology Overview 14
2.2 Scope of the Research 14
2.3 Methodological Framing and Rationale 15
2.4 Literature Review Process 16
2.5 Interview Methodology 19
2.6 Data Analysis Strategy 20
2.7 Validation and Reliability of Data 20
2.8 The Dynamic Equilibrium Model for Flood Resilience 21
2.9 Case Study Analysis 21
2.10 Ethics 22
3 Case Study: 2024 Floods in Rio Grande do Sul, Brazil 22
3.1 Geographical and Historical Context 22
3.2 Case Study: The May 2024 Flood Event 25
4 Literature Review 31
4.1 Flood Resilience: Concepts, Approaches and Evolving Challenges 31
4.2 Paradox Perspective 39
4.3 Frugal Innovation 52
4.4 Contextual Challenges in the Global South 56
4.5 Urban Expansion and River Degradation in the 20th Century 58
4.6 Overcoming Systemic Barriers to Flood Resilience in the Global South 62
4.7 Institutional Frameworks for Flood Resilience 66
4.8 Comparative Analysis: Frugal Solutions vs. Traditional Methods 71
4.9 A Hybrid Institutional Framework for Flood Resilience 76
5 Data Analysis 77
5.1 Interviewee Characterization 79
5.2 Interviewee Profiles and Expertise Overview 81
5.3 Thematic Analysis 83
5.4 Relational Extrapolation for Model Conception 91
5.5 Model Conception 94
5.6 The Role of Legitimacy in Frugal Flood Resilience 100
5.7 Establishing Institutions to Overcome Fragmentation 111
5.8 The Odisha Model: A Case of Legitimacy Convergence 115
6 Discussion 119
6.1 Reframing Flood Resilience: From Deadlock to Legitimacy Convergence 119
6.2 Legitimacies in the Immediate Aftermath of a Disaster Onslaught 120
6.3 Legitimacies in the Transition to Long-Term Resilience Planning 122
6.4 Highlighting the Dynamic Nature of Legitimacy 124
7 Validation 126
7.1 Validation Discussion 126

7.2 The Odisha Model as a Case of Legitimacy Convergence? 128
7.3 Reflection Validation 128
8 Conclusion 129
9 Limitations 133
10 Recommendations 134
References 136
Appendix A : Interview Protocol (Data Analysis) 146
List of interview questions 146
Appendix B : Validation Interview 147
Appendix C : Informed Consent Form 148
Appendix D : Open Codes 150
Appendix E: Axial Code-Document Table 153
Appendix F : HREC Letter of Approval 153

1 Introduction

This chapter aims to set the context of the study by providing background information, identifying the research problem, and defining the research questions. It also introduces the key concepts, outlines the research objectives, and defines the scope and relevance of the study, concluding with an overview of the report's structure.

1.1 Background

Flood resilience has become an increasingly critical aspect of global sustainability, driven by the escalating frequency and inclemency of weather events. The effects of these climate change-exacerbated events disproportionately burden resource-constrained communities, frequently causing severe economic, social, and environmental damage (Takin et al., 2023). This reality is especially pronounced in the Global South, where flood-prone regions frequently lack the infrastructural resilience and governance frameworks required to promote the management of flood risks effectively (Nur & Shrestha, 2017). The Global North has a long history of pioneering flood resilience frameworks, developing approaches that reflect a technocratic perspective on addressing flood contingency. This can be attributed to the Global North's access to robust economic resources, advanced technology, and established governance structures, which in part originated from the legacy of colonial relations that disproportionately benefited the Global North at the expense of the Global South (Lindersson et al., 2023). These frameworks, with their heavy reliance on large-scale infrastructure like levees, dams, and drainage systems engineered to control water flow and protect urban and rural areas, often fail to sufficiently consider the local contexts, sociocultural dynamics, and resource limitations of the less developed regions (Nur & Shrestha, 2017). Consequently, these frameworks struggle to translate effectively, leading to suboptimal outcomes and perpetuating inequitable development.

The Global South, by contrast, faces distinctive challenges when adopting these resilience frameworks developed in the Global North. With socio-economic and geographic complexities that differ significantly from their Northern counterparts, many regions in the Global South encounter barriers to effectively implementing large-scale technocratic solutions imported from the developed world (Chatterjee & Chattopadhyay, 2020). For example, fragmented governance structures, financial limitations, and the general; lack of community involvement in decision-making processes contribute to significant gaps between existing frameworks and local community needs (Yasmin et al., 2019). This gap more often than not results in a paradoxical situation: while frameworks from the Global North provide a template for resilience, they frequently overlook the socio-economic, political, and environmental nuances specific to communities in the Global South (Raub et al., 2024). The resulting misalignment fosters a deadlock in resilience efforts, as solutions that work well in developed contexts may become unsustainable or even counterproductive when transferred directly to developing regions.

In addition to that, the implementation of flood resilience frameworks highlights an inherent tension between technocratic, expert-driven solutions and community-based, locally developed practices and knowledge, at times drawing upon traditional relationships with water, its course, and the natural environment in general (Takin et al., 2023). Moreover, These frameworks are often centralized, relying on expertise and advanced infrastructure that may be inaccessible in low-resource settings. Additionally, this technocratic approach often sidelines essential socio-geographic considerations, such as community participation, cultural practices, and the role of local knowledge in disaster response (Yasmin et al., 2019). Without involving communities, resilience efforts may miss critical insights that could enhance their relevance and adaptability. This disconnect

underscores a need to balance expert-led strategies with locally grounded approaches, aligning flood resilience practices with the complex realities of affected communities.

In light of these challenges, frugal innovation has emerged as a promising alternative to more technocratic flood resilience strategies (Loggia et al., 2020). Represented by nature-based and adaptive, low-cost solutions, frugal innovation emphasizes simplicity, accessibility, and community involvement (Bhatti & Ventresca, 2013). This approach has gained traction as an adaptive strategy that can complement or in some cases even replace traditional infrastructure-heavy frameworks, particularly in contexts where resources are limited and governance is fragmented. Frugal innovation also focuses on core functionality, often leveraging local knowledge and natural systems to create resilient communities without the need for extensive financial or technical investment (Bhatti & Ventresca, 2013). By drawing from local expertise and prioritizing social relevance, frugal solutions present a potential pathway toward overcoming the deadlock of flood resilience in the Global South (Nelson et al., 2020). Given this context, this research explores how a balance between technocratic frameworks and frugal, context-specific solutions might be achieved. To achieve such, this study moves to adopt a paradox perspective based on the work of Smith and Lewis (2011) in order to investigate how the contrasting approaches of technocratic solutions from the Global North and frugal innovations tailored to local realities in the Global South can be reconciled to promote effective and sustainable flood resilience.

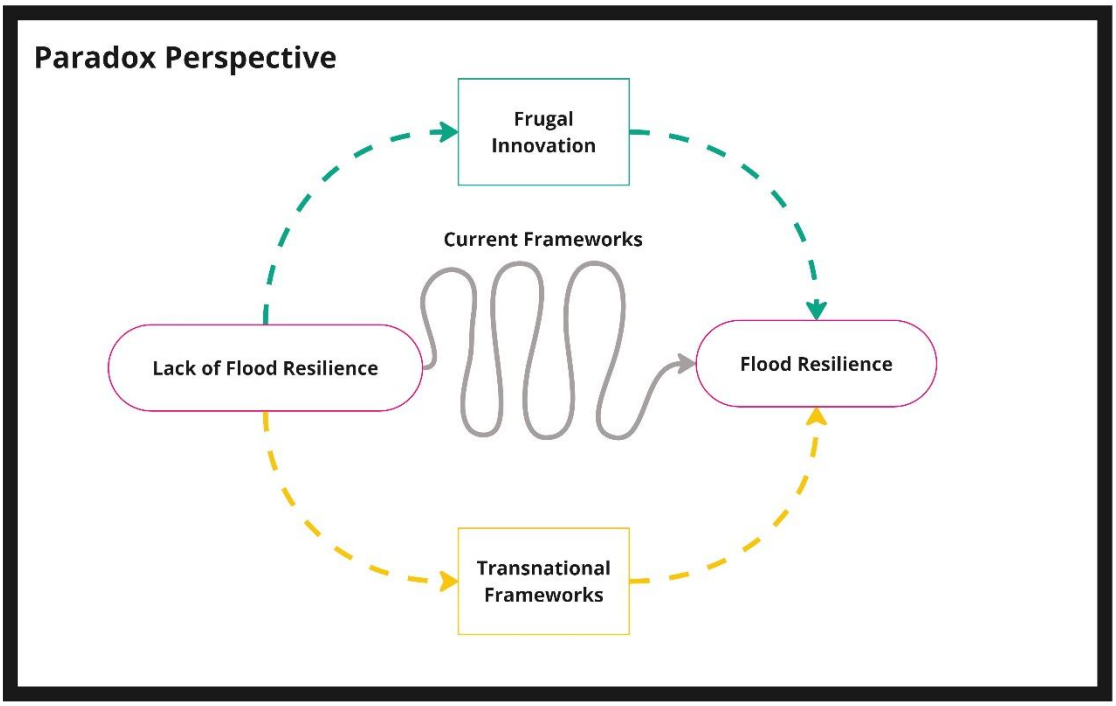
1.2 Problem Definition

Achieving sustainable flood resilience in the Global South has long been a complex challenge due to the inherent limitations of current frameworks, primarily developed in the Global North during the 20th century (Loggia et al., 2020). These frameworks are typically technocratic in nature, relying heavily on engineered infrastructure, standardized procedures, and centralized decision-making processes. While these approaches are effective in high-resource settings, they often fail to align with the socio-geographic realities of the Global South. Here, local communities face unique economic, cultural, and environmental constraints that can render these imported solutions ineffective or unsustainable ((Nur & Shrestha, 2017). This research identifies a significant paradox in flood resilience efforts: technocratic frameworks offer structured, scalable solutions aimed at technical efficiency and large-scale impact, yet these frameworks often lack the adaptability required for diverse, resource-constrained settings, resulting in a 'one-size-fits-all' approach that fails to address specific local needs (Loggia et al., 2020). This can, in turn, lead to a gap between the intended effectiveness of these frameworks and the actual resilience outcomes offered towards vulnerable communities, where root vulnerabilities and socio-economic limitations remain unaddressed and often relegated (O'Brien et al., 2012).

In contrast, **frugal innovation** offers a promising alternative that leverages local knowledge and affordable, adaptive solutions to bridge this gap. This approach emphasizes simplicity, cost-effectiveness, and social relevance, aligning with the unique socio-economic conditions of the Global South. Yet, frugal solutions may face challenges if they remain isolated, lacking the broader support needed to sustain long-term impact (Hossain, 2021). This tension ultimately contributes towards the ongoing **deadlock** in flood resilience efforts within the Global South, where communities are caught between rigid technocratic frameworks and highly localized, frugal innovations—neither of which, on their own, provide a comprehensive solution (Yasmin et al., 2019). This research aims to address the deadlock in flood resilience efforts by examining how the contradictory elements and challenges presented can be tackled using frugal innovation as a standalone solution or in combination with technocratic approaches. To do so, this study will utilize a paradox perspective as the primary framework to identify compromises and synergies between

these contrasting strategies in order to attain long-term, sustainable flood resilience (Smith & Lewis, 2011). The aim here is to explore the potential for a balanced approach that respects the complex socio-economic realities of the Global South, while taking into account the structural robustness often prioritized in technocratic frameworks. By identifying the limitations and barriers inherent in each approach, this study hopes to lay the groundwork for exploring how a compromise might be achieved through a **paradox perspective**, allowing competing demands to coexist and complement each other to help vulnerable communities attain sustainable flood resilience amid increasingly extreme climate condition (O'Brien et al., 2012). In doing so, the research shall contribute to a deeper understanding of how resilience can be shaped to truly meet the needs of these communities, balancing and compromising global standards with locally adaptive solutions. Furthermore, the insights gained from exploring this balanced approach can inform resilience strategies in the Global North, where the mounting climatic challenges of the 21st century and a growing emphasis on integrating nature within flood resilience frameworks call for more adaptive and inclusive solutions (Raub et al., 2024).

Figure 1: Alternative Pathways to Flood Resilience



From Author (2024)

1.3 Relevance of the Research

Flood resilience in the Global South represents one of the most urgent and complex challenges in climate governance today. While international frameworks often promote standardized, technocratic solutions, many communities lack the institutional stability, financial resources and social structures to adopt and further sustain them. At the same time, local responses rooted in frugal innovation, low-cost, resource-conscious and socially grounded, are often dismissed or inadequately supported at every level. This disjuncture reveals a critical gap in how we understand and manage resilience. This research takes on this challenge by examining flood resilience through the lens of paradoxes, persistent tensions that cannot be solved outright but must be navigated and managed over time. Drawing from paradox theory, the study then frames flood resilience not as a matter of choosing between competing approaches, but as a process of coordinating between them. At the heart of this investigation is the idea that paradoxes of frugal innovation influence

flood resilience by demanding coordination between competing stakeholders in changing environments. This framing highlights the constant negotiation between short- and long-term goals, formal institutions and informal actors, centralized expertise and local knowledge. What makes this research particularly relevant is its departure from linear or prescriptive models of resilience. By emphasizing paradox and convergence ; rather than replacement or sequencing them. Through this, the study hopes to offer a new way of thinking about governance under pressure. In a world increasingly affected by climate volatility, rising inequality, and worsening flood exposure, especially in urbanizing and socioeconomically vulnerable regions and the ones found within what has traditionally been defined as the Global South, this research offers timely insight into how governance must evolve to manage competing demands.

Furthermore, the study repositions frugal innovation from a marginal concept to a strategic governance question. It shows that the challenges of flood resilience are not only technical or financial, but fundamentally relational: they require legitimacy, negotiation, and the ability to sustain coordination across levels of governance. In doing so, the research opens space for critical reflection on how knowledge, authority and value are assigned in resilience planning, and most importantly, who gets to decide. By addressing systemic vulnerabilities at the intersection of poverty, institutional fragmentation, and climate-driven disasters and surrounding this discussion within the broader governance dynamics of the Global South, the research contributes to global conversations on resilience, development and adaptation. With that in mind, it invites policymakers, practitioners and scholars to reflect and reconsider how innovation is defined and who is included in that process.

1.4 Research Question and Sub-Questions

In order to assess the research problem, it is necessary to conduct a study. The assessment will be conducted based on the following research question:

Research question:

“In what ways do and can the paradoxes of frugal innovation influence flood resilience in the Global South?”

The research question will be answered through four sub-questions. The sub-questions are as follows:

SQ1: What paradoxes emerge when applying frugal innovation to flood resilience in the Global South?

This sub-question examines the inherent paradoxes that arise when integrating frugal innovation into flood resilience efforts. It explores tensions between low-cost, adaptive solutions and conventional resilience approaches, setting the foundation for understanding how paradoxes shape decision-making in flood management.

SQ2: What is the relationship between the paradoxes and flood resilience outcomes?

This sub-question investigates how the paradoxes identified in SQ1 influence the effectiveness of flood resilience strategies. It examines whether these contradictions hinder or enhance resilience efforts and explores how policymakers and practitioners navigate competing priorities to achieve long-term sustainability.

SQ3: How does governance fragmentation reflect paradoxes in flood resilience?

This sub-question analyzes the role of governance structures in shaping flood resilience policies. It explores how fragmentation contributes to paradoxes in flood management and examines whether integration efforts can reconcile conflicting governance priorities.

2 Methodology

2.1 Research Methodology Overview

This thesis will employ an exploratory qualitative research design to investigate the research topic. Exploratory qualitative research is a type of research that seeks to explore a phenomenon in depth, often in cases where there is limited existing knowledge or when a deeper understanding of a complex issue is needed. It aims to generate hypotheses and insights rather than test pre-existing ones (Jackson et al., 2007)**.** Therefore the employment of a multifaceted approach to tackle to further investigate the research question and its various faces and intricacies. This process will begin by clearly defining the research problem, establishing the objectives, and determining the scope of the study.

2.2 Scope of the Research

This study shall focus on exploring the challenges and opportunities for flood resilience in the Global South, with a specific emphasis on the paradox that emerges between technocratic frameworks and context-specific, frugal solutions. This research explores how the contrasting approaches of technocratic frameworks from the Global North and frugal, context-specific solutions in the Global South can be reconciled to produce a hybrid model that balances universal standards with the unique socio-geographic conditions of local communities (Nur & Shrestha, 2017). Geographically, this research centers on flood resilience within regions in the Global South, where issues such as resource scarcity, fragmented governance, and diverse socio-economic conditions create significant barriers to implementing standardized resilience frameworks (Matczak & Hegger, 2021). It does not address regions in the Global North, as the primary focus is on understanding how frameworks originating in these developed regions interact with the unique challenges faced by developing areas, potentially providing indirect insights applicable to the Global North as well (Hossain et al., 2016).

Conceptually, the research is grounded in the overarching paradox of **technocratic vs. socio-geographic** approaches to flood resilience. Technocratic frameworks, with their structured and scalable solutions, often fall short when applied in varied local contexts that require flexibility and community-driven strategies (Takin et al., 2023). In contrast, frugal innovations emphasizes affordable, adaptable solutions that prioritize social relevance but may lack the comprehensive structure offered by technocratic approaches. By employing the **Dynamic Equilibrium Model** as a theoretical lens, this study investigates how these seemingly conflicting strategies can be managed and balanced over time, rather than resolved outright (Smith & Lewis, 2011). The model underscores the importance of embracing these tensions to foster a flexible, adaptive approach to resilience that responds to both global and local needs. The 2024 floods in Rio Grande do Sul, Brazil, serve as the case study for this research, illustrating the complex interplay between imported resilience frameworks and local realities (The Water Diplomat, 2024). In the given case study, global standards provided foundational guidelines, yet the scale of the disaster underscored their long-term limitations within a complex and resource-constrained environment (Astrini & Tsavkko Garcia,

2024). The case highlights the challenges faced by communities that rely on both structured frameworks and community-driven adaptations to address the socio-economic and governance obstacles unique to the region. Rio Grande do Sul thus serves as a critical reference for examining how technocratic frameworks and frugal solutions interact in practice, offering insight into how both approaches may coexist or conflict in achieving resilience (Lamoree et al., 2024).

2.3 Methodological Framing and Rationale

Given the exploratory nature of this study and the complexity of its subject matter, a qualitative methodology is particularly well-suited. Methodologically, the research shall adopt an exploratory qualitative approach, relying on semi-structured interviews with key stakeholders, including policymakers, community leaders, and flood management experts from both the Global North and South (Jackson et al., 2007). This approach is thus appropriate because it enables in-depth exploration of subjective experiences, perceptions, and institutional dynamics that are often not captured through mere quantitative means. The focus on paradoxes, such as those between technocratic and frugal solutions, requires an interpretive lens that can handle ambiguity, contradiction and context-specific insights. Furthermore, qualitative methods offer the flexibility to capture emergent themes and complex interactions that are essential to understanding the governance of flood resilience in diverse environments.

The research will be informed by a thorough literature review, which will guide the development of the interview questions (Chigbu et al., 2023). This will ensure that the questions are firmly rooted in existing academic research on flood resilience frameworks, addressing both the technocratic and frugal approaches in a comprehensive manner. Furthermore, these interviews aim to gather nuanced insights into the real-world interactions between technocratic frameworks and frugal innovations, highlighting both the tensions and potential synergies in these approaches (Naz et al., 2022). Temporally, the research shall focus on current frameworks and innovations relevant to contemporary flood resilience challenges, referencing historical influences only insofar as they inform present practices (Fang et al., 2023). Although past policies and frameworks are acknowledged in the background, the study is forward-looking, concentrating on implications for today and the future in terms of developing hybrid resilience strategies that can better serve communities in the Global South (Wantzen et al., 2022). In practical terms, this study is largely theoretical, aiming to contribute to academic discourse and propose a conceptual model for addressing flood resilience. While it offers practical recommendations, it does not involve the implementation or testing of specific resilience measures in the field. Instead, the research provides insights and guidelines that policymakers and practitioners could adapt within their unique contexts to help the achievement of long-term flood resilience. By delineating the scope in this way, this study hopes to provides a focused examination of the paradox in flood resilience frameworks, ultimately offering a pathway to achieving sustainable, adaptable resilience through a balanced approach informed by the Dynamic Equilibrium Model (Smith & Lewis, 2011).

This initial step involves understanding the key concepts and variables relevant to the research topic and iterating on such until the aim of the study is properly and clearly defined (McNabb, 2017). The next step involves undertaking a comprehensive literature review. This literature review will serve to gather relevant insights on the concepts and status quo, while identifying gaps in the existing knowledge, and serving as the basis for the preliminary hypothesis and assumptions pertaining to the subject matter (Bolderston, 2008). This critical phase is essential for positioning the study within the broader academic discourse and establishing a robust framework to guide the subsequent research task and activities (Bolderston, 2008). Following the literature review, the research methodology will be designed to align with the objectives of the study. This will involve selecting the

appropriate data collection methods, hereby represented and chosen to be interviews with key stakeholders (Naz et al., 2022). Given this, the criteria for participant selection will be carefully determined to ensure a diverse pool of perspectives and relevant expertise are represented, including policymakers, community leaders, flood management practitioners, and experts from both local and international contexts. Moreover, the interviews will be conducted using a semi-structured format, allowing for some flexibility to pursue open-ended lines of inquiry while maintaining a clear focus on the core established questions and taking into account the ethicality and management concerns of the process and acquired data (Longhurst, 2009).

Once said data is collected, it will be systematically analyzed using a thematic analysis, after the coding process, thus leading to a response categorization which in turn allows for a nuanced understanding of the insights (Thorne, 2000). This step involves a detailed examination of the interview transcripts and notes to identify key themes, patterns, and relationships that emerge from the data. By carefully analyzing the qualitative data, this study will be able to derive meaningful conclusions and insights, uncovering the underlying patterns and relationships that provide a nuanced understanding of the perspectives and experiences shared by the interview participants (Khokhar et al., 2020). This in-depth qualitative analysis will allow the research to gain a rich, and more contextualized understanding of the perspectives and experiences shared and diverged by the interview participants, which will in turn inform the synthesis of findings from both the literature review and the quintessential step of this data collection process the interviews (Khokhar et al., 2020). Furthermore, the research will employ a case study approach to validate the findings and guide the investigation in a real-world application of its research question. Ultimately, this research design aims to generate a holistic and evidence-based understanding of the phenomenon under investigation, testing the initial hypotheses against the findings from both the literature review and the interviews to challenge assumptions, while producing meaningful and actionable insights to advance the field of study (Niemcryk & Glascoff, 1997). The study will report these findings in a structured format, highlighting the implications for theory, practice, and future research.

2.4 Literature Review Process

In exploring the complexities of the topic, the initial stage of this research involves a comprehensive literature review. The purpose of this literature review is to gather existing knowledge, identify key hypotheses, and delineate assumptions that will guide the subsequent stages of the study (Bolderston, 2008). The rationale for using a literature review as a foundational step lies in its ability to provide a broad perspective on established theories and practices, highlight the existing gaps in research, and establish a conceptual framework that will underpin the empirical investigation (Bolderston, 2008). Also of paramount importance is converging the multiple sub topics and facets of the literature review to in order to successfully recognize their interdependencies and uncover mutually dependent insights (Chigbu et al., 2023). By reviewing the literature, the study aims to uncover underlying insights in potentially breaking the deadlock of non-resilience experienced by the institutional frameworks, or the lack thereof, within the status quo of the Global South. Finally, the literature review will follow a systematic approach, drawing from various relevant and recent works stemming from online repositories and databases to guarantee relevance and applicability (Chigbu et al., 2023).

The literature review will focus on several key areas:

1. **Paradox Perspective**: Exploring how paradoxical factors arise when applying flood resilience frameworks from the Global North to the Global South. This perspective shall examine how

these frameworks, while intended to enhance resilience, can create persistent tensions and vulnerabilities that can inadvertently exacerbate flood risks rather than helping to mitigate them (Smith & Lewis, 2011).

2. **Defining Flood Resilience**: Clarifying what is meant by 'flood resilience,' including its various dimensions (e.g., social, economic, environmental, and infrastructural) (Zevenbergen et al., 2020). This also involves understanding how resilience is conceptualized and measured, particularly in the context of differing vulnerabilities and capacities in the Global North and Global South (Chitadze, 2023).
3. **Frugal Solutions**: Analyzing the potential of frugal solutions, which emphasizes low-cost, socially relevant solutions that maximize core functionality with minimal resources (Weyrauch & Herstatt, 2016). Such approach might prove beneficial in addressing flood resilience challenges and deadlock by providing accessible and affordable defences tailored to underserved communities.
4. **Contextual Challenges in the Global South**: Examining how differing economic, political, and social environments shape the applicability of institutional frameworks for flood resilience in the Global South. Factors such as resource constraints, fragmented governance, and socio-economic inequalities significantly impact the effectiveness of strategies transferred from the Global North. (Dados & Connell, 2012).
5. **Urban Expansion and River Degradation in the 20th Century**: Examining the historical policies that led to urban expansion at the expense of natural river systems. This section shall explore how the prioritization of land reclamation for urban development, both in the Global North and South, has diminished natural flood defenses, increasing vulnerability to flood risks (Fang et al., 2023).
6. **Institutional Frameworks for Flood Resilience**: Assessing how flood resilience frameworks from the Global North, effective in well-resourced settings, often struggle to adapt when transferred to the Global South. The review focuses on how local power dynamics, governance fragmentation, and resource constraints affect the implementation and calls for more context-sensitive and flexible approaches in these diverse environments (Fernandes et al., 2020).
7. **Comparative Analysis Between Frugal Solutions and Traditional Methods**: Comparing frugal solutions like nature-based approaches and adaptive urban planning with traditional methods such as dikes and dams (Cohen-Shacham et al., 2019). The possibility of combing both methods shall also be examined in a mixed approach shall also be discussed.

In order to delineate the scope and inform the conceptual framework of this study, a selection of key literature has been identified. The following table summarizes these selected articles, highlighting their central ideas and relevance to the study’s focus on balancing structured, technocratic frameworks with context-specific, socio-geographic solutions in flood resilience.

Table 1 : Summary of selected literature

Literature	Central Idea	Relevance to Study
Smith & Lewis (2011)	The Dynamic Equilibrium Model highlights the importance of managing paradoxes as "contradictory yet interrelated elements" that must be balanced, not resolved.	Provides a theoretical framework to address tensions between technocratic approaches and community-driven solutions, helping guide the study's exploration of flood resilience paradoxes in the Global South.
Nur & Shrestha (2017)	Examines community vulnerability to flooding in developing countries, emphasizing challenges in applying Global North resilience strategies due to socio-economic and governance limitations.	Highlights the limitations of large-scale, resource-intensive solutions and the need for context-specific approaches in flood resilience, supporting the argument for frugal innovations.
O'Brien et al. (2012)	Discusses the disconnect between global development agendas and local needs in resilience frameworks, emphasizing a sustainable and resilient future.	Relevant to the study's focus on how international frameworks often overlook local socio-cultural and economic factors in flood resilience, underscoring the need for adaptive governance.
Yasmin et al. (2019)	Advocates for adaptive governance as a means to foster sustainable urban transformation in the Global South, acknowledging the importance of local contexts.	Supports the study's examination of governance frameworks that balance global resilience strategies with local adaptability for flood resilience.
Loggia et al. (2020)	Introduces the concept of "floodability," focusing on integrating nature-based solutions in urban planning to enhance resilience.	Provides a practical example of how nature-based, frugal solutions can be more sustainable and context-appropriate, relevant to the study's focus on frugal innovations for flood resilience.
Takin (2023)	Highlights the application of nature-based solutions and community-led interventions for sustainable urban flood resilience.	Reinforces the importance of incorporating local knowledge and nature-based solutions as alternatives to traditional infrastructure-heavy approaches.
Raub et al. (2023)	Explores resilience and nexus approaches in flood risk management, advocating for integrated, adaptable solutions.	Adds to the study's emphasis on achieving long-term resilience by balancing structured frameworks with adaptable, community-oriented strategies.
Weyrauch & Herstatt (2016)	Investigates frugal innovation, highlighting its potential for sustainable, cost-effective solutions that cater to local needs.	Aligns with the study's focus on frugal innovations, especially as viable alternatives to traditional flood resilience frameworks that may be too costly or complex for the Global South.
Matczak & Hegger (2021)	Discusses governance strategies for flood resilience, emphasizing diversified and adaptive approaches.	Supports the study's investigation of governance challenges and opportunities for enhancing flood resilience through diverse strategies.
Chatterjee & Chattopadhyay (2020)	Examines the legacy of urban planning in the Global South, noting the environmental cost of land development at the expense of flood resilience.	Highlights historical planning policies' impacts on flood vulnerability, relevant to the study's examination of urban expansion and resilience.
Lindersson et al. (2023)	Explores political instability and governance challenges affecting long-term planning for flood resilience in the Global South.	Emphasizes the impact of political cycles on sustainable flood management, relevant to the study's exploration of governance barriers.

Bhatti & Ventresca (2013)	Introduces frugal innovation as an approach prioritizing local knowledge and low-cost solutions.	Aligns with the study's focus on frugal innovation for resource-limited flood resilience in the Global South.
Zevenbergen et al. (2020)	Explores integrated flood risk management strategies, emphasizing collaboration and multi-layered safety.	Provides insight into multi-level approaches to flood risk, supporting the study's examination of integrated resilience strategies.
Chitadze (2023)	Analyzes the disconnect between Global North and South frameworks, highlighting challenges in international policy transfer.	Relevant to the study's examination of how Global North solutions often fail in Global South contexts.
Gawel et al. (2016)	Discusses the role of political priorities in short-term flood resilience projects, which often sideline sustainable solutions.	Adds to the study's focus on political motivations that lead to ineffective, reactive flood resilience measures.
Lamoree et al. (2024)	Examines the 2024 Rio Grande do Sul floods, highlighting failures in centralized flood management, socio-economic disparities in response, and fragmented governance.	Illustrates real-world challenges of centralized frameworks, supporting the need for locally adapted, frugal solutions and coordinated governance in flood resilience.

2.5 Interview Methodology

For this study, semi-structured interviews with open-ended questions are the primary method of data collection. An interview can be defined as a research method involving direct interaction between the researcher and participants to gather detailed information and insights (Longhurst, 2009). Moreover, Semi-structured interviews combine a guided approach with open-ended questions, providing a balance between consistency and flexibility (Longhurst, 2009). They revolve around the notion that a set of predetermined questions ensures coverage of key topics, while also allowing interviewees to share their perspectives, experiences, and insights in their own words (Naz et al., 2022). As a result, this approach allows for deeper probing, follow-up questions, and an overarching exploration of complex issues, making it particularly valuable for capturing nuanced understandings of the multifaceted phenomena tackled by this paper.

Moreover, these interviews shall be conducted with a diverse range of key stakeholders, including policymakers, community leaders, flood management practitioners, and local and international experts in flood resilience from both the Global North and South. The semi-structured format allows for flexibility in exploring the participants perspectives while also maintaining a focused line of inquiry, thus enabling the capture of nuanced insights into the paradoxical tensions that often arise when transferring flood resilience frameworks across different global contexts. The interview questions shall then be formulated following the philosophy of the Dynamic Equilibrium Model of Paradox, developed by Smith and Lewis (2011), to uncover the inherent contradictions and challenges in applying flood resilience strategies from the Global North to the Global South. This approach shall ensure a comprehensive exploration of various paradoxes; allowing for an in-depth understanding of how stakeholders navigate the tensions encountered in real-world situations.

By incorporating diverse perspectives, the study aims to identify opportunities for more context-sensitive and sustainable flood resilience practices, potentially highlighting frugal innovation as a viable alternative in attaining flood resilience. This paradoxical lens will serve as a guiding tool in the interview process, allowing this paper to gauge how practitioners and experts navigate the inherent tensions in flood resilience development and implementation. This will in turn help to refine the hypotheses and assumptions developed through the literature review, by enacting and relying on the experience of the experts and field practitioners (Jackson et al., 2007). Finally due to the plurality

of backgrounds of the interviewees, the questions will be produced both in English and Portuguese, potentially also being pursued in Dutch and Spanish if necessary.

2.6 Data Analysis Strategy

The data analysis process in this research aims to transform the empirical data gathered from semi-structured interviews with key stakeholders into meaningful insights about the complexities of transferring flood resilience frameworks. This systematic evaluation helps to identify patterns and paradoxes, develop context-specific theories, validate or challenge existing assumptions, and ultimately address the research questions related to the applicability and effectiveness of these frameworks in diverse settings (Thorne, 2000). Given the qualitative nature of this study, the data analysis will rely on thematic analysis using interview transcripts. Following the six-step approach outlined by Braun and Clarke (2006), the process involves:

1. **Data Preparation**: This initial stage includes transcribing each interview and thoroughly reviewing the content to ensure accuracy and completeness. Interviews conducted via Teams will have their transcriptions accessed through the platform, thoroughly reviewed for integrity, and sent to participants in PDF format (Khokhar et al., 2020). Transcripts in different languages will be translated into English before proceeding with analysis.

2. **Data Familiarization**: After transcription and review, the the data will be read multiple times in order for insights, patterns, and themes to be found and explored. Initial thoughts and observations shall be noted during this process (Khokhar et al., 2020).

3. **Initial Coding**: The next step involves categorizing the data by assigning labels, or "codes," to different segments of the text (Khokhar et al., 2020). This process, facilitated by software ATLAS.ti, will require multiple rounds of refining to accurately capture the data's essence.

4. **Development of Themes**: After coding, the codes are grouped into potential themes that represent recurring patterns across the data samples. These themes are reviewed to ensure their alignment with the research's overarching topic. Definitions and nomenclature are established for each theme to provide clarity and itemization (Khokhar et al., 2020).

5. **Data Interpretation**: The identified themes are then interpreted back to explore their complexities and nuances into the topic. This interpretation connects the themes back to the main research question and its sub-questions, along with the initial post- literature review digression (Khokhar et al., 2020).

6. **Data Presentation**: In the final stage, the findings shall be presented in a coherent and logical manner, ensuring they address the research questions. The results are then discussed within the broader context of the study, helping to identify key topics that will guide further literature review and subsequent research phases (Khokhar et al., 2020).

2.7 Validation and Reliability of Data

In qualitative research, validity refers to the credibility and accuracy of the findings, ensuring they accurately represent the data collected (Leung, 2015). To achieve validity in this study, several strategies have been employed. Triangulation as an approach, involves engaging a diverse range of stakeholders; hereby including policymakers, community leaders, flood management practitioners, and local and international experts, to provide a broad spectrum of perspectives and an array of potential motifs and paradoxes. This approach reduces the risk of bias and enhances the credibility of the findings (Leung, 2015). Additionally, member checking will be used, where participants are

provided with the interview transcripts to verify the accuracy of their statements and offer further clarification if needed. Finally, the findings from the thematic analysis shall also be cross-referenced with existing literature employed in the literature review to align empirical insights with established theoretical concepts and excerpts from academia (Thorne, 2000).

Reliability, on the other hand, ensures that the research methods used are consistent, stable, and dependable over time (Leung, 2015). In this study, reliability shall be maintained through a meticulous process of data management and analysis. All interview transcripts will be thoroughly reviewed and double-checked for accuracy, minimizing potential transcription errors. The coding process, which is a crucial step in ensuring reliability, will be conducted using the ATLAS.ti software. This will enable a consistent and systematic approach to coding the data across all data sets. Additionally, multiple rounds of coding shall be performed to ensure that the meaning of codes remained stable and coherent throughout the analysis (Khokhar et al., 2020). These measures collectively contribute to the reliability and trustworthiness of the study's findings (Thorne, 2000).

2.8 The Dynamic Equilibrium Model for Flood Resilience

This research applies the Dynamic Equilibrium Model (Smith & Lewis, 2011) to explore and manage the paradoxes inherent in adapting technocratic frameworks from the Global North to include the unique socio-geographic status-quo presented in the Global South, with all of its contradictions (Gersonius et al., 2016). This model provides a theoretical basis for addressing contradictory yet interrelated elements within resilience strategies, particularly the tension between technocratic solutions and frugal, context-specific approaches. The development of the model within this research is guided by two main phases. First, a comprehensive literature review identifies key paradoxes breaking down the overarching paradox in a matter of relevance and levels (i.e., Macro, Meso, Local). This foundation shapes the initial framework for applying the Dynamic Equilibrium Model to the context of flood resilience. Second, data gathered from semi-structured interviews with key stakeholders, including policymakers, community leaders, and flood management experts, informs and refines this model (Longhurst, 2009). Through thematic analysis of interview responses, specific themes and patterns emerge that further illuminate how these paradoxes manifest in real-world flood resilience efforts. The model is thereby adapted to reflect these findings, balancing competing demands to develop a holistic approach that integrates both global frameworks and frugal solutions originating from local knowledge (Raub et al., 2024). By integrating insights gleaned from the literature review and interview data, this research endeavors to develop a context-sensitive adaptation of the Dynamic Equilibrium Model, which seeks to offer a balanced, compromise-driven approach to enhancing flood resilience in the Global South.

2.9 Case Study Analysis

Case study research is a strategy that entails a comprehensive examination of a specific issue, event, or phenomenon within its real-world context (Crowe et al., 2011). This method offers a holistic understanding by concentrating on the complexity and distinctiveness of the subject, capturing the nuances that may be missed by more general approaches (Crowe et al., 2011). By investigating a single relevant case, this study aims to gather detailed data from multiple sources on recent events, in order to illustrate the discussions present in the research. This allows for a rich, multi-dimensional exploration of the topic from various perspectives, facilitating a deeper insight into the dynamics and interactions involved (Crowe et al., 2011). The case study approach is, therefore, particularly well-suited for this specific research, given that it enables the examination of the research problem in its natural setting, taking into account the contextual factors that may influence the phenomenon

of interest. This case study has also posited itself as a driving force behind this study, its completion and advancement.

For this research, a case study shall be conducted regarding the May 2024 floods in Rio Grande do Sul, Brazil. This case study was primarily chosen for its unique context of socio-economic, environmental, and governance challenges amid extreme weather (Clarke et al., 2024). This study shall thoroughly examine the effectiveness of adapting flood resilience frameworks originally developed in the Global North, revealing gaps and paradoxes when these are applied in new settings, particularly within the Global South and all that such entails from socio-economic and geographic perspective. By doing so, the case study will serve as an opportunity to try the adapted Dynamic Equilibrium Model in the context of a real-life scenario, exploring the balance between technocratic and frugal approaches within this specific setting. This approach utilizes paradox perspective, rooted in the work of Smith and Lewis (2011) as a lens to explore conflicting outcomes, particularly how strategies from the Global North may inadvertently create vulnerabilities or contradictions in the Global South (Chitadze, 2023).While doing so the research will highlight systemic deficiencies related to the occurrence and exacerbation of catastrophic floods, such as inadequate infrastructure, fragmented governance, and socio-economic disparities (McDermott, 2022). It will also consider whether frugal innovation for flood resilience, might hypothetically bridge these gaps by offering low-cost, simplified, and socio-naturally relevant solutions, potentially more applicable to the local status quo of Rio Grande do Sul, Brazil (Bhatti & Ventresca, 2013). The case study integrates both discussions in the physical (i.e. solutions, consequences, actions, etc.) and governance (i.e. decision making, institutional frameworks, governance levels and interdependencies) places to hoping provide a multifaceted perspective on how the disaster unfolded, the subsequent short and long term adaptation challenges, implications for resilience models in developing nations and finally the need for improved coordination and compromise among governance levels and society to achieve flood resilience.

2.10 Ethics

The research will be conducted in strict accordance with ethical guidelines to ensure the protection of all participants, as this is of the utmost importance. During data collection and analysis, particular attention will be given to maintaining the privacy and confidentiality of the individuals involved (Taquette & Souza, 2022). Participants will be fully informed about the paper’s purpose, procedures, and their rights, including the voluntary nature of their participation and their right to withdraw at any time (Taquette & Souza, 2022). To ensure confidentiality, personal details will not be included in the transcripts or any part of this report. Prior to the interview, each participant will receive an informed consent form outlining the research's purpose, procedures, and confidentiality measures taken. This form must be signed and returned, confirming their informed consent to participate in the study. Before each interview begins, the form's contents will be reviewed again with the participant. Once the interview transcripts are finalized, they will be sent back to the respective participants for review and approval. All collected data will be securely stored on the TU Delft Drive until the conclusion of the research period, after which it will be permanently erased from the files.

3 Case Study: 2024 Floods in Rio Grande do Sul, Brazil

3.1 Geographical and Historical Context

Porto Alegre, the capital of the Brazilian state of Rio Grande do Sul, has a long-standing susceptibility to flooding due to its unique hydrological and geographical features (Guimaraens, 2024). The city's location is pivotal to understanding its flood risk profile. Situated at the confluence of the Guaíba

River and the Jacuí Delta, Porto Alegre lies within a complex and expansive river system that includes the Jacuí, Caí, Sinos, and Gravataí rivers composing the Guaíba River basing which takes approximately 30% of the state's area (Smamus, 2024). These rivers converge to form the Guaíba Lake, creating a network of interconnected waterways that define the region's hydrodynamics. The region encompassing Porto Alegre and the broader hydrological basin is characterized by low-lying floodplains, a complex network of islands within the Jacuí Delta, and narrow valleys with mountain-side riparian settlements more upstream (Guimaraens, 2024). These geographical features contribute to the inherent susceptibility of this area to flooding events.

Therefore, the May 2024 flood event did not only impact Porto Alegre but also affected vast areas across the state of Rio Grande do Sul. The entire state was subjected to a rare combination of meteorological conditions that led to unprecedented rainfall across multiple river basins, including the Jacuí, Taquari, Sinos, and Caí river systems (Buschschlüter, 2024). The state experienced some of the highest recorded rainfall levels, with areas such as Caxias do Sul and Bento Gonçalves in the Taquari River Basin receiving over 1000 mm of rain within a short period (Lamoree et al., 2024). This widespread and intense precipitation caused rivers across the state to swell rapidly, leading to flooding that affected both urban and rural areas. Municipalities throughout the state faced significant challenges as floodwaters inundated homes, infrastructure, and agricultural lands, disrupting the lives of hundreds of thousands of residents (Lamoree et al., 2024). This widespread impact highlighted the interconnectedness of the state's river systems and the collective vulnerability that the 236 municipalities located in the extended riparian basin in Rio Grande do Sul share in the face of extreme weather events (Buschschlüter, 2024).

Historically, the city's approach to flood management has been shaped by significant flood events, notably the catastrophic flood of 1941. This event marked the highest recorded water level in the city, reaching 4.75 meters above the reference level of Guaíba Lake (Guimaraens, 2024). In response to this, a comprehensive flood protection system was developed from the 1950s until the1970s, designed to shield the most vulnerable areas of Porto Alegre, particularly the northern regions, which lie within the extensive floodplains of the river system (Guimaraens, 2024). The flood protection system constructed during this period was extensive, incorporating a network of protective dikes, flood gates, and pumping stations. These infrastructures were intended to manage and control water levels, with the dikes designed to protect against water levels up to 6 meters, including a safety margin of 1.25 meters above the 1941 flood level (Lamoree et al., 2024). The system aimed to safeguard key urban areas, including the city's international airport, which is located in a polder (a low-lying tract of land enclosed by dikes). This project was constructed by the National Department of Sanitation Projects (i.e. DNOS), an autarchy whose responsibility included the integrated and macro-level management of flood risk along major rivers-basins in Brazil, functioning as an institution to act in the governance space between the federal responsibility of the Ministry of Infrastructure, the state governments and finally the municipalities (Soffiati, 2005). However, this infrastructure was developed based on hydrological data and design standards that have since been surpassed by the realities of climate change and urban expansion (Rocha, 2024). The protective system was adequate for the loads experienced by the 1941 floods, but proved itself insufficient in the face of the may 2024 floods (Villela, 2024). Furthermore, the effectiveness of these defenses has been compromised by a lack of consistent maintenance.

Figure 2 : Floods of 1941 in Porto Alegre, Brazil

From “Porto Alegre: enchente de 1941 durou 22 dias e deixou 70 mil desabrigados” by UOL Noticias, 2024, (https://noticias.uol.com.br/cotidiano/ultimas-noticias/2024/05/09/como-foi-enchente-historica-porto-alegre-1941.htm)

3.1.1 Institutional Gaps and Infrastructure Decay

The DNOS, responsible for flood control infrastructure, was dissolved in 1990, leading to an institutional vacuum that has hampered upkeep and modernization efforts (Soffiati, 2005). Over the past 34 years, this lack of dedicated oversight has contributed to the deterioration of flood defenses, rendering them ineffective in the fac e of a extreme high water event (Lamoree et al., 2024). It is also important to note that even during the DNOS's tenure, a truly integrated system of flood barriers encompassing the entire state was never attempted. This lack of comprehensive planning left other areas of the river basin, beyond Porto Alegre, with minimal or nonexistent flood defenses, leaving them acutely vulnerable to extreme events like the May floods (Lamoree et al., 2024). Furthermore, while the northern regions of the city are provided with the aging and inadequately maintained flood protection infrastructure, the southern areas along the Guaíba Lake remain relatively unprotected. This disparity can be attributed to the original conceptualization and design of the flood defense system, which did not anticipate the city's subsequent southward expansion and development in that direction (Zylberkan, 2024). This area, although not as low-lying as the north, is particularly vulnerable to storm surges driven by strong southerly winds, especially when combined with high water levels in the lake which tend to surve as a natural barrier to the southwards flow of the water (Villela, 2024). The lack of similar flood protection measures in the south has left this region more exposed to the elements, with frequent flooding during periods of high rainfall and storm activity, also being the area of the city with the most precarious infrastructure and inequality (Rocha, 2024). The dissolution of the DNOS and consequential institutional vacuum highlight the broader limitations of rigid, centralized frameworks when applied in contexts like Brazil. Rather than blaming local governance for these gaps, the issue highlights the challenges posed by top-down, technocratic solutions, which often struggle to adapt to evolving local socio-geographic realities. Centralized, technocratic approaches, frequently adopted in the Global North, tend to falter in the long-term in developing world contexts marred by discretionary and fragmented governance (Pritchett & Woolcock, 2003). This mismatch leads to gaps in coordination, inadequate infrastructure upkeep, and a failure to adapt to local needs, leaving vulnerable regions without adequate protection (Voß et al., 2009). The disconnect between the institutional design and the evolving realities of urban expansion in Porto Alegre further illustrates the shortcomings of these top-down approaches (O’Brien et al., 2012).

Figure 3 : May 2024 Floods, Rio Grande do Sul, Brazil

From “Southern Brazil Floods Made Twice as Likely Due to Climate Change: Report” by Earth.org, 2024, (https://earth.org/southern-brazil-floods-made-twice-as-likely-due-to-climate-change-report/)

The May 2024 flood event, which devastated large swathes of Rio Grande do Sul, including the capital, Porto Alegre, starkly illustrated the vulnerabilities discussed above. The region's existing flood management systems, originally designed decades ago and subsequently weakened by inconsistent maintenance and institutional gaps, were unable to cope with the unprecedented volume and intensity of the rainfall (Villela, 2024). This catastrophic event exposed critical flaws in the capital’s aging and inadequately maintained flood protection infrastructure, such as outdated dikes, insufficient storm surge defenses, and non-functional pumping station, but also in the lack of a broader regional preparedness and coordination among the 236 municipalities within the extended riparian basin (Rocha, 2024). The widespread inundation across multiple river basins highlighted the fragmented approach to flood management and the lack of comprehensive, far-fetching strategies to address escalating risks from climate change and unchecked urban expansion (Lamoree et al., 2024). Moreover, the failure to protect both urban and rural areas underscored the interconnectedness of the state's river systems and the collective vulnerability that municipalities share when faced with extreme weather events. It further highlights the need to reassess global frameworks that struggle to align with the socio-geographic complexity of these regions, advocating for a comprehensive reassessment and modernization of flood management policies across the entire state (Lamoree et al., 2024).

3.2 Case Study: The May 2024 Flood Event

The flood event that occurred in May 2024 in Porto Alegre and the wider Rio Grande do Sul state was an unprecedented hydrological disaster, marked by its sheer intensity and widespread impact. This flood is now regarded as the most severe in living memory, both in terms of the meteorological conditions that triggered it and the scale of the destruction it caused.

3.2.1 Socioeconomic and Infrastructural Devastation

The May 2024 flood had far-reaching impacts across the state of Rio Grande do Sul, devastating communities and infrastructure in both urban and rural areas. The flood event resulted in the displacement of hundreds of thousands of residents, with close to half a million individuals unable to return to their homes for an extended period due to the significant damage and the gradual receding of floodwaters (The Water Diplomat, 2024). The disaster had a severe impact across more than 236 municipalities throughout the state, profoundly disrupting the daily lives and economic activities of the affected populations (The Water Diplomat, 2024). In the state’s rural areas, the

flooding wreaked havoc on agricultural lands, leading to significant losses in crop yields and livestock. The agricultural devastation ravaged the livelihoods of farmers while also having broader economic consequences for the whole country, given Rio Grande do Sul's status as a major agricultural hub in Brazil (Lamoree et al., 2024). The loss of crops and the destruction of farmland disrupted supply chains, leading to food shortages and price increases across the region (Astrini & Tsavkko Garcia, 2024). The state's agricultural sector, a key contributor to the local and national economy, faces a long and uncertain recovery (Lamoree et al., 2024).

In the metropolitan area of Porto Alegre (i.e. around 6 million inhabitants), the floodwaters inundated critical infrastructure, including roads, bridges, and public utilities, making large parts of the state inaccessible (Sousa, 2024). The transportation network, which is vital for both intra-state commerce and connectivity with the rest of Brazil, was severely disrupted (Sousa, 2024). Many major roads were submerged for weeks, isolating entire communities and hampering the delivery of essential goods and services. The extended closure of key transport routes delayed recovery efforts and exacerbated the economic downturn caused by the disaster (Buschschlüter, 2024). Arguably the heaviest infrastructural casualty revolved around the total incapacitation of Salgado Filho International Airport, a vital transportation hub for southern Brazil. The floodwaters engulfed over 80% of the runway, forcing the airport to suspend all operations (Mazó, 2024). The closure of Porto Alegre's main international gateway had profound economic repercussions, disrupting trade, tourism, and daily commuting patterns across the region (Mazó, 2024). The inability to operate flights resulted in massive logistical challenges, with the nearby Canoas Air Base being hastily adapted to handle a fraction of the regular traffic. However, this temporary solution could only accommodate a small percentage of the usual flights, significantly hampering air connectivity for both passengers and cargo (Mazó, 2024).

Figure 4 : Porto Alegre Airport during May 2024 Floods

From "Aeroporto de Porto Alegre reabrirá em outubro; vendas começam nesta sexta" by InfoMoney, 2024, (https://www.infomoney.com.br/consumo/aeroporto-de-porto-alegre-reabrira-em-outubro-vendas-comecam-nesta-sexta/)

The flooding episode exposed the stark disparities in socioeconomic status within the state, mirroring the broader inequities found across Brazil and other developing nations, referred to as the Global South (Astrini & Tsavkko Garcia, 2024). Specifically, In poorer, informal areas, the residents were hit hardest by the flooding, with many homes completely destroyed and swept by the water loads with little to no immediate assistance provided (Rocha, 2024). These communities, often located in low-lying and flood-prone areas, were particularly vulnerable due to their inadequate infrastructure, which offered little protection against the rising waters. Thereafter, the lack of adequate emergency response from public authorities was especially evident in these areas (Rocha,

2024). Despite common knowledge of the risks involved with settlements in these areas in the case of severe flooding, public initiatives for re-location or strengthening of defenses often fall short or are poorly coordinated, also commonly facing opprobrium from parts of society and from the inhabitants themselves whom wish to remain in the areas they live (Lamoree et al., 2024). Thousands of residents in these informal settlements were therefore left without support during the critical early days of the disaster, relying on informal networks and community efforts for their survival (Clarke et al., 2024).

This delayed response prolonged the suffering of those affected while also underscoring the broader socioeconomic divide in society. Wealthier areas, equipped with better infrastructure and resources, received quicker and more comprehensive aid, including timely evacuation assistance and faster restoration of utilities (The Water Diplomat, 2024). In contrast, the residents of poorer areas, were left to endure the worst of the disaster with minimal support, also in the months following the disaster (Lamoree et al., 2024). This disparity in the distribution of aid and the speed of response further exacerbated existing inequalities, leaving the most vulnerable populations to face the full force and burden of the disaster without adequate institutional assistance (Lamoree et al., 2024). The disaster, and how it was managed, has sparked significant public outcry and demands for accountability, with civil society organizations calling for comprehensive reforms in disaster preparedness and response policies that address these underlying inequalities and their consequences in the dire face of increasingly inclement climate and extreme events (Rocha, 2024).

Figure 5 : Flood Devastation in Brazil

From “Rains in southern Brazil kill at least 39, some 70 still missing” by Reuters, 2024, (https://www.reuters.com/world/americas/rains-southern-brazil-kill-least-31-more-than-70-still-missing-2024-05-03/)

3.2.2 Meteorological Phenomena and Climatic Anomalies

The May 2024 flood was primarily driven by a rare and highly anomalous convergence of multiple meteorological systems. Overlapping climatic phenomena created an environment ideal for extreme rainfall, which was exacerbated by the influence of climate change and the El Niño phenomenon. The confluence of these factors resulted in an extraordinary hydrological load that surpassed even the historic floods of 1941, previously the strongest on record in the area (Clarke et al., 2024).

- **Impact of Climate Change:** The intensity and persistence of these meteorological phenomena were further amplified by climate change. Rising global temperatures have led to an increase in the frequency and severity of extreme weather events, including heavy rainfall and storms. Climate change likely intensified the atmospheric instability and moisture

content, making the conditions more conducive to such an extreme and sustained precipitation event. The warming trends also contributed to the severity of the El Niño, further aggravating the situation (Clarke et al., 2024).

- **El Niño Influence:** The presence of the El Niño phenomenon during this period played a crucial role in exacerbating the flood conditions. El Niño contributed to elevated sea surface temperatures in the Atlantic and Pacific Oceans, leading to increased evaporation and, consequently, higher atmospheric moisture levels. This moisture, when combined with other atmospheric conditions, resulted in unprecedented rainfall across Rio Grande do Sul, further intensifying the flooding (Clarke et al., 2024)).
- **High Instability Areas:** Extensive regions of atmospheric instability developed over Rio Grande do Sul, creating conditions conducive to sustained and intense rainfall. These instability zones were unusual in their persistence and breadth, covering large swathes of the state, with some areas receiving as much as 1000mm of rain (Clarke et al., 2024).
- **Humid Air Mass from the Amazon:** Simultaneously, a mass of humid air originating from the Amazon Basin moved southward. This moisture-laden air mass contributed significantly to the volume of precipitation, as it collided with other weather systems in the region (Clarke et al., 2024).
- **Cold, Wet Air Front from the Atlantic Ocean:** Adding to the complexity was the arrival of a cold and wet air front from the Atlantic Ocean. This front interacted with the Amazonian air mass, creating a potent mix of atmospheric conditions that further intensified the rainfall (Clarke et al., 2024).

These meteorological forces combined in a manner that has rarely been observed in the region. The inability of these systems to dissipate due to the presence of a hot, dry high-pressure zone in central Brazil exacerbated the situation (Clarke et al., 2024). This high-pressure zone effectively trapped the moisture and instability over Rio Grande do Sul, leading to continuous and intense precipitation over several days, culminating in a flood event of unparalleled scale (Astrini & Tsavkko Garcia, 2024). Prospectively, the convergence of these factors is expected to become more common in the years to come, as climate change continues to alter weather patterns. This implies a growing frequency of extreme hydrological events like the May 2024 flood, necessitating significant adaptations in flood management strategies across the region (Clarke et al., 2024).

3.2.3 Evolution of Flood Risk and Challenges in Modern Times

The expansion of Porto Alegre and the wider economic and demographic growth of the state have correspondingly increased the risks and potential impacts of flooding, including threats to human life and economic assets. The expansion of urban areas into flood-prone regions, particularly in informal settlements across the state, has exacerbated the risk of flooding (Lamoree et al., 2024). In Porto Alegre, urban sprawl has led to increased surface runoff, reduced natural infiltration, and greater strain on existing drainage and on the flood protection infrastructure (Smamus, 2024). Similarly, other municipalities within the Guaíba River basin have experienced similar if not worst pressures, hampering the state's economic capacity and severely impacting the life of the inhabitants (Buschschlüter, 2024).

Figure 6 : Reactive flood measure in Porto Alegre, Brazil

From “O muro da Mauá sabe o que destruiu Porto Alegre” by Mendes, 2024,
(https://www.pragmatismopolitico.com.br/2024/05/muro-maua-sabe-que-destruiu-porto-alegre.html)

Additionally, the poor maintenance of critical flood defenses, an issue amplified by the dissolution and subsequent institutional void left by the National Department of Sanitation Projects in 1990, has resulted in much of the infrastructure across the state falling into disrepair, a widespread phenomenon encountered throughout Brazil's infrastructure landscape (Soffiati, 2005). The sedimentation in river and lake systems, due to pollution, illegal dredging and intensive water usage for agriculture, has further reduced the capacity of these water bodies to manage floodwaters, a problem exacerbated by economic inequality and the absence of consistent oversight, particularly in underfunded rural areas (Lamoree et al., 2024). Furthermore, the unchecked and unregulated development in high-risk flood zones, including the unauthorized construction of houses directly on top of flood defense structures, coupled with the lack of consistent enforcement of urban planning regulations by the relevant authorities, has further compromised the effectiveness of the existing flood protection infrastructure, thereby creating additional vulnerabilities within the systems (Zylberkan, 2024). In recent decades, the effects of climate change have become increasingly apparent in the flood patterns across Rio Grande do Sul. The region has experienced a rise in the frequency and intensity of extreme precipitation events, often interspersed with severe drought periods, which have overwhelmed the aging and inadequately maintained flood control infrastructure throughout the state (Astrini & Tsavkko Garcia, 2024). Porto Alegre, in particular, has relied heavily on a flood management strategy that no longer aligns with the realities of climate change and its urban sprawl (Zylberkan, 2024). This reliance on outdated systems, which were originally designed for less severe climate scenarios, has left both the city and the surrounding municipalities vulnerable to increasingly frequent and severe flood events such as the May 2024 events ((Zylberkan, 2024). The absence of an integrated early-warning system and comprehensive disaster response plan left the inhabitants of several neighborhoods ill-prepared to cope with the catastrophic flood event and the subsequent long-term recovery efforts (Rocha, 2024).

Figure 7 : Vulnerability to flooding in Brazil

From “RS: Cheia histórica em Porto Alegre escancara descaso na região das ilhas” by A Nova Democracia, 2024, (https://anovademocracia.com.br/rs-cheia-historica-em-porto-alegre-escancara-descaso-na-regiao-das-ilhas/)

The flood event in May 2024 starkly highlighted these vulnerabilities. The combination of extreme weather conditions, including the convergence of unstable atmospheric systems and the influence of the El Niño phenomenon, resulted in unprecedented rainfall and flooding (Astrini & Tsavkko Garcia, 2024). This event exposed critical flaws not only in Porto Alegre’s flood protection system but also in the broader regional preparedness. Failures included key pumping stations, overtopping of dikes, the inefficacy of flood gates, and the critical issue of unchecked and illegal construction on top of essential flood infrastructure, leading to widespread flooding across both the northern and southern parts of Porto Alegre and across multiple municipalities in Rio Grande do Sul (Lamoree et al., 2024). The events of May 2024 underscore the urgent need for a comprehensive reassessment and modernization of flood management strategies across the entire state, incorporating both structural and non-structural measures that are resilient to the challenges posed by climate change, urban growth, and socio-economic disparities faced by a city with challenges that affect all of Brazil and most cities with similar climate and socio-geographic conditions within the developing Global South (Lamoree et al., 2024). Furthermore such solutions need to also account for the intricate and fragmented institutional governance that exists within Brazil (Almeida & Engel, 2020).

3.2.4 Fragmentation of Governance Between Levels of Government

The Brazilian system of governance is characterized by a division of responsibilities across federal, state, and municipal levels, with each level possessing its own areas of jurisdiction (Fernandes et al., 2020). In theory, this multilayered approach should allow for specialized management of disaster response, with each level of government contributing according to its capabilities and resources (Fernandes et al., 2020). However, in practice, the response to the 2024 floods demonstrated the challenges inherent in such a fragmented system (Lamoree et al., 2024). At the federal level, agencies like the National Water Agency (ANA) and the Ministry of Regional Development have overarching mandates for water management and disaster preparedness (ANA, 1997). However, their ability to effectively manage and coordinate disaster response is often limited by bureaucratic hurdles, overlapping mandates, and the need for collaboration with state and municipal governments, often pursuing contradictory or conflicting agendas motivated by political one-upmanship (Fernandes et al., 2020). This became particularly evident during the 2024 floods when the federal response was delayed and often disconnected from the immediate needs on the ground, exacerbating the situation .

The state government of Rio Grande do Sul, through agencies such as SEMA (State Secretariat for the Environment and Infrastructure), holds significant responsibility for managing large-scale environmental and infrastructural challenges (SEMA, 1999). However, the state's ability to implement effective flood management strategies was severely constrained by inadequate communication and coordination with both federal authorities and the numerous municipalities affected by the flooding (Lamoree et al., 2024). Additionally, the state government failed to effectively communicate with the various municipalities and did not provide an integrated plan that considers the cities and their interdependencies (Lamoree et al., 2024). This shortfall was particularly critical because the state of Rio Grande do Sul lacks sufficient funds to develop a comprehensive flood prevention plan, relying solely on federal funds (Rocha, 2024). These federal resources, however, are often allocated without a full understanding of local conditions and the specific management needs required to create a plan that encompasses the entire state. The lack of a unified approach between the state and federal levels led to delays in decision-making and the deployment of resources, further complicating the response efforts (Zylberkan, 2024).

At the municipal level, particularly in Porto Alegre, the responsibility for local flood defense and emergency response fell primarily to the DMAE (Municipal Department of Water and Sewage) (Clarke et al., 2024). However, the municipal government struggled to manage the crisis independently, given the scale of the disaster and the limited resources at its disposal. Furthermore, the municipal government of Porto Alegre is not equipped to manage the flood prevention plans for other municipalities along the Guaíba basin, also lacking a clear understanding of where its responsibilities end and where those of neighboring municipalities begin (Lamoree et al., 2024). This ambiguity has led to a lack of coordination, with municipalities often acting in isolation. Such uncoordinated actions have inadvertently resulted in negative consequences for downstream municipalities (Lamoree et al., 2024). A notable example of this uncoordinated action occurred in the city of Pelotas, where gated neighborhoods installed clandestine pumps and pipelines to drain floodwater inside their premises, in turn worsening the situation in surrounding municipalities and poorer areas (Sul21, 2024). The failure to coordinate these actions with the affected municipalities has sparked significant public outrage in what would later be described as an act of eco-racism (Sul21, 2024).

The dissolution of the DNOS in 1990 left a significant gap in institutional capacity for integrated flood management, a gap that has not been adequately filled since then (Soffiati, 2005). The DNOS once served as a critical link between federal, state, and municipal governments, coordinating large-scale flood and sanitation projects that often spanned multiple municipalities or even states. Without a similar institution to bridge these levels of governance, there is a significant fragmentation in managing flood risks that extend beyond individual municipal boundaries (Soffiati, 2005). This has left Porto Alegre's, but also the state’s authorities ill-prepared to handle and enact long term planning to avoid this unprecedented flooding event, both in the pre and pos phases of its occurrence.

4 Literature Review

4.1 Flood Resilience: Concepts, Approaches and Evolving Challenges

The concept of flood resilience encompasses a range of strategies and measures designed to reduce the vulnerability of communities, infrastructure, and systems to the impacts of flooding. It involves the ability to predict, prepare for, and respond to potential flood events through forecasting, early

warning systems, and risk assessments (Zevenbergen et al., 2020). Flood resilience also includes the capacity to absorb floodwaters and mitigate immediate impacts through structural measures, as well as the capability to adapt to changing conditions and reduce future risks through flexible and adaptive management practices, nature-based and interactive solutions, along with having room for innovative technologies (Fang et al., 2023). Additionally, it entails the effectiveness of post-flood recovery efforts, including the rebuilding of infrastructure, restoration of services, and support for affected communities to return to normalcy or even improve upon pre-flood conditions(Ali et al., 2020). Therefore, flood resilience requires a holistic approach that integrates environmental, social, economic, and technological aspects to create sustainable and adaptable systems capable of withstanding and recovering from high water events, thereby enhancing the overall resilience of communities in facing flooding while ensuring their safety and stability in the face of more frequent and extreme weather (Zevenbergen et al., 2020).

4.1.1 Traditional Flood Resilience Measures

Traditional flood resilience measures primarily focus on infrastructure-based approaches designed to control and manage water flow, thereby protecting urban and rural areas from inundation per advise of technocratic stakeholders (i.e. experts, engineers, technical boards and councils) (Zevenbergen et al., 2020) . These methods include the construction of levees, dams, and barriers. Levees and floodwalls are typically used to prevent rivers from overflowing and flooding adjacent lands, while dams regulate river flow and store excess water during peak rainfall periods. Barrier systems, such as the Maeslantkering in the Netherlands, provide critical protection for coastal and estuarine regions against storm surges (Jonkman et al., 2018). One of the fundamental characteristics of traditional flood resilience measures is their need for integration over large areas and systems. Such large scale infrastructure projects are extensive and complex, often requiring substantial financial investment and long-term commitment to both construction and maintenance (Aerts, 2018). The scale of these projects means that they must be meticulously planned and implemented over many years, sometimes decades, to ensure their effectiveness. This also means that any failures in these systems can have widespread and catastrophic consequences, making regular maintenance and upgrades imperative (Horning & Neumann, 2008).

Moreover, traditional flood resilience infrastructure is generally designed to withstand a maximum predicted and projected water level, following technocratic principles of load and bearing. These designs are based on historical data and models that predict the likelihood of specific flood events (Yen, 2000). However, as climate change continues to alter weather patterns, the intensity and frequency of extreme weather events are increasing, often exceeding the designed capacity of these systems. As a result, traditional flood defenses may become less and less effective over time, necessitating costly and ever-more complex adaptations or expansions to meet future conditions (Galloway et al., 2018). Although traditional flood resilience measures have inherent limitations, they have historically proven to be the most effective means of safeguarding against flood risks up until the present day. Countries like the Netherlands have demonstrated the success of these measures, showcasing their ability to safeguard vast and densely populated areas (Jonkman et al., 2018). However, it is important to note that these infrastructure-based solutions are primarily applied in the developed world or the "Global North," where financial resources and technical expertise are more readily available. This leaves many regions in the developing world or the "Global South" without the same level of protection, highlighting a significant disparity in global flood resilience capabilities (McDermott, 2022).

Another critical limitation of traditional flood resilience measures is that they do not necessarily promote fast responses to flooding. These systems are typically reactive rather than proactive, focusing on controlling water after it has already started to rise (Loggia et al., 2020). While they can prevent immediate flooding in certain areas, they do not contribute to the broader resilience of communities by enhancing their ability to anticipate and prepare for floods. This lack of rapid response capability can lead to significant delays in emergency response and recovery efforts, exacerbating the impact of floods on affected populations (Loggia et al., 2020). Furthermore, traditional flood resilience measures often fail to address the underlying vulnerabilities of communities to flooding. By focusing predominantly on large-scale infrastructure, these approaches may overlook the need for community engagement, education, and local-level adaptations that can enhance overall resilience (Zevenbergen et al., 2020). Without incorporating these elements, traditional measures may not fully address the diverse and dynamic nature of flood risks, leaving communities susceptible to severe impacts. While traditional flood resilience measures provide essential protection against flooding, they are not without limitations. The need for integration over large areas, substantial financial investment, and long-term maintenance, coupled with their design for specific projected water levels, renders them less adaptable to future climatic changes (Yen, 2000). Additionally, their reactive nature does not support fast responses to flooding, nor do they inherently enhance the broader resilience of communities. As climate change continues to challenge existing flood defense systems, it is increasingly clear that a more integrated and adaptive approach to flood resilience is necessary to protect communities effectively (Loggia et al., 2020).

4.1.2 Innovative Approaches to Flood Resilience

To address the limitations of traditional flood resilience measures, innovative approaches have emerged that aim to enhance the overall resilience of communities and areas in the face of flooding events. These innovative approaches can be broadly categorized into four main areas: nature-based solutions, community-based adaptation, the integration of technology and data analytics (Takin et al., 2023). All of these categories have the potential to fall within the scope of what is considered frugal innovation. As such, they should emphasize the development of cost-effective, functionally-core, and socially-relevant solutions, which can play a crucial role in enhancing flood resilience, particularly in resource-constrained communities (Weyrauch & Herstatt, 2016). Such innovative approaches can provide a more integrated and adaptive approach to flood resilience, which in turn can better protect communities in the face of climate change and extreme weather events. These can be done in complement to existing traditional methods or as a standalone solution, depending on the location and situation (Pearson et al., 2018). A comprehensive and multi-faceted approach is essential to address the dynamic challenges posed by flood events effectively. This involves integrating nature-based solutions, community-based adaptation, the integration of technology and data analytics, and frugal innovation to enhance overall flood resilience.

Nature-based solutions for flood resilience focus on utilizing and restoring natural ecosystems to manage water flow and mitigate the impact of flooding . These solutions may include the restoration of wetlands, the creation of floodplains, and the implementation of sustainable urban drainage systems (Cohen-Shacham et al., 2019). Complementing these nature-based solutions are adjustments to the built environment itself. Increasing the permeability of surfaces in urban areas, for example, can allow water to infiltrate the ground, reducing surface runoff and the strain on drainage systems (Cohen-Shacham et al., 2019). This can involve incorporating permeable pavements, green roofs, and infiltration trenches into urban design. Furthermore, changes to urban planning can create "room for the river" by strategically designating areas for floodwater storage

and conveyance, working with natural water flow patterns rather than trying to constrain them (Sörensen et al., 2016).

These nature-based approaches provide flood protection while also providing for additional environmental and social co-benefits, such as improved biodiversity, recreational opportunities, and urban heat island mitigation (Fang et al., 2023). An interesting example of a nature-based solution currently being developed is the Emerald Tutu project in Boston. This innovative project, involves deploying floating mats of marsh grass and seaweed around the city's harbor (Hopkins, 2022). These mats, which resemble a "tutu" encircling the waterfront, are designed to absorb wave energy and reduce the impact of storm surges, thereby mitigating coastal flooding (Hopkins, 2022). Therefore, The Emerald Tutu is an example of flood protection which also enhances water quality and offers recreational spaces for the community. The modular nature of these mats allows for flexibility and scalability, making it a promising solution that also promotes adaptability towards inclement weather for other coastal cities facing similar challenges (Cohen-Shacham et al., 2019).

Community-based adaptation, on the other hand, emphasizes the active involvement of local communities in the development and implementation of flood resilience strategies (Loggia et al., 2020). This approach recognizes that communities have a deep understanding of their local contexts and vulnerabilities, and can therefore play a vital role in identifying appropriate solutions. Community-based adaptation may include initiatives such as flood risk mapping, early warning systems, and the development of emergency response plans tailored to the specific needs of a community (Cooper & Pile, 2014). An interesting case is found in the community of Kampung Melayu in Jakarta, Indonesia, where local residents collaborated with non-governmental organizations to create community flood maps and establish a neighborhood flood early warning system (Karyono et al., 2017). This initiative empowered the local community to elevate their preparedness and response to upcoming and potentially more severe flooding events.

The integration of technology and data analytics offers new opportunities for enhancing flood resilience. The rapid advancements in remote sensing, geographic information systems, and predictive modeling can provide valuable insights into flood risk and enable more informed decision-making. These technologies can support the development of early warning systems, real-time monitoring of flood conditions, and the optimization of emergency response strategies (Yuan et al., 2022). Additionally, the use of big data and analytics can help identify patterns, trends, and vulnerabilities, allowing for more proactive and targeted interventions (Yuan et al., 2022). One promising application of data analytics in flood resilience is the use of machine learning algorithms to improve flood prediction and response. In this case, data from multiple sources such as river flow gauges, weather stations, and satellite imagery are integrated and analyzed using machine learning models to predict flood events with greater accuracy (Mosavi et al., 2018). These models can identify emerging flood risks by analyzing real-time data and historical patterns, enabling authorities to issue timely warnings and deploy resources more effectively. Furthermore, data analytics can facilitate the optimization of evacuation routes and emergency response plans by simulating various flood scenarios and assessing their potential impacts (Yuan et al., 2022). This proactive approach enhances the ability of communities to respond swiftly and efficiently to flood threats, thereby reducing the overall damage and ensuring a quicker recovery.

When considering the role of frugal innovation within flood resilience, it becomes evident that there is significant potential for cost-effective and accessible solutions to emerge. Frugal innovation, which emphasizes the development of products and services that are affordable, accessible, and sustainable, can play a crucial role in enhancing flood resilience, particularly in resource-constrained

communities (Brem et al., 2020). One example of frugal innovation in flood resilience is the use of low-cost sensors and IoT devices to establish community-based early warning systems (Yuan et al., 2022). These systems can provide affordable and localized flood monitoring and alert mechanisms, empowering communities to take proactive measures to safeguard themselves. Additionally, rather than relying solely on large-scale, capital-intensive infrastructure, frugal innovations may involve the use of locally available materials to create temporary barriers or flood-resilient housing (Perricone et al., 2023).

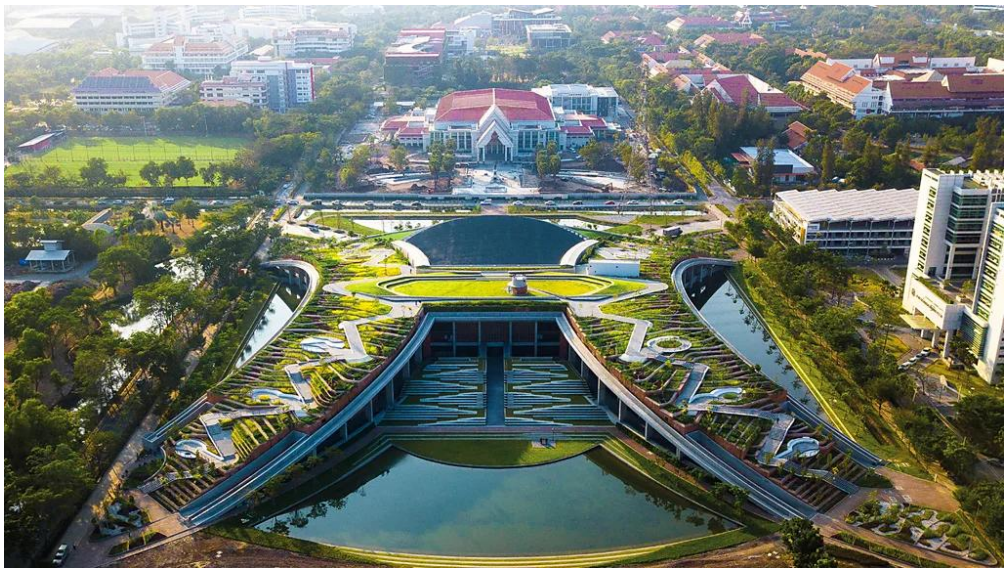
4.1.3 Integrating Flood Resilience with Society

The successful integration of flood resilience with society requires a comprehensive and integrated approach that acknowledges the complex interplay between the built environment, natural systems, and the needs and mobilization of local communities (Loggia et al., 2020). Several alternatives demonstrate promising potential to facilitate the integration of flood resilience with society. These include the implementation of early warning systems, the adoption of participatory approaches to flood resilience, the prioritization of long-term planning, and the establishment of non-partisan mechanisms to ensure sustained commitment to flood resilience initiatives (Zevenbergen et al., 2020). In this context, early alarm systems, which leverage advancements in technology and data analytics, play a crucial role by providing communities with timely and accurate information about impending flood events, thus enhancing the integration of flood resilience measures within society (Yuan et al., 2022). These systems can be developed to integrate data from various sources, such as weather forecasts, river level sensors, and satellite imagery, to generate real-time flood predictions and warnings (Yuan et al., 2022) with a relatively low cost involved in building heavy infrastructure. By disseminating this information through multiple channels and community outreach, they can empower residents to take appropriate actions, such as evacuation or the implementation of temporary flood protection measures (Raub et al., 2024).

Participatory flood resilience, on the other hand, emphasizes the active involvement of local communities in the planning, implementation, and maintenance of flood resilience strategies (Zevenbergen et al., 2020). This approach recognizes that communities have a deep understanding of their local contexts, vulnerabilities, and needs, and can therefore play a vital role in the co-creation of effective and sustainable solutions. Participatory approaches may involve the establishment of community-based flood risk mapping, the development of emergency response plans, and the implementation of nature-based solutions that integrate local knowledge and resources (Hughes et al., 2021). Traditional methods and local knowledge offer valuable insights into decentralized, community ownership for flood defenses. For example, ancient rice terraces in Asia, such as those found in Thailand and Vietnam, have been maintained for centuries as natural flood control systems (Xiaoying, 2019). These terraces effectively manage water flow by slowing it down and utilizing the landscape itself, fostering a participatory approach to flood resilience. Such methods inspire modern cities to develop community-led, nature-based solutions that encourage local ownership and involvement in flood defense systems, ensuring sustainability and societal engagement and have been steadily valued for both by society and the governance for their added value in fostering flood defenses (Xiaoying, 2019). However, it is crucial to highlight that local communities are not the root of the problem. The misalignment of external frameworks and their lack of adaptability to the local context is often what renders these initiatives ineffective. Rather than blaming local conditions, it is essential to emphasize that the incorporation of frugal innovation and, thus tr community knowledge can lead to more resilient and socially integrated flood defense systems. The key lies in adaptation, not replacement (Yasmin et al., 2019). One illustrative example is found in the city of Surat, India, where the municipal government collaborated with local communities to develop a

comprehensive flood resilience plan (Bhat et al., 2013). Through this collaborative process, the plan incorporated locally relevant solutions, such as the construction of elevated pathways and the restoration of natural drainage channels, while also strengthening community preparedness and emergency response capabilities while also engaging and providing ownership of the defensive systems to the community (Bhat et al., 2013).

Figure 8 : How Ancient Terraces Inspired Flood Resilience



From "https://www.bbc.com/future/article/20240805-how-ancient-rice-terraces-inspire-flood-resilience-in-asian-cities, 2024, (https://www.bbc.com/future/article/20240805-how-ancient-rice-terraces-inspire-flood-resilience-in-asian-cities/)

To ensure the effectiveness and sustainability of flood resilience initiatives, decision-making processes must include mechanisms to prioritize flood resilience and long-term planning (Pearson et al., 2018). This prioritization should be embedded within urban and regional planning frameworks, ensuring that flood resilience is considered in all relevant policies and projects . Additionally, it is crucial that these mechanisms operate in a non-partisan and non-politically dependent manner to avoid short-termism and ensure continuity and consistency in flood resilience efforts (Takin et al., 2023). By establishing independent bodies or councils with the mandate to oversee flood resilience planning and implementation, communities can safeguard against political fluctuations and ensure that flood resilience remains a consistent priority (Stokkom & Smits, 2005). The water boards in the Netherlands, with their long-standing tradition of water management, provide a compelling example of such independent mechanisms for overseeing flood resilience planning and implementation (Stokkom & Smits, 2005). These decentralized, democratically-elected bodies have been responsible for managing the country's complex network of dikes, canals, and water infrastructure for centuries, ensuring a consistent and non-partisan approach to flood prevention and mitigation. The water boards' autonomous status, coupled with their technical expertise and community-based decision-making processes, have enabled them to navigate political changes and maintain a steadfast focus on long-term flood resilience strategies (Stokkom & Smits, 2005). This model of institutionalized, community-driven water governance offers valuable insights for other countries seeking to establish similarly robust and enduring flood resilience frameworks tailored to their local contexts (Matczak & Hegger, 2021). However, merely replicating such models in other countries without adapting to local governance structures would potentially prove to be insufficient. There must be adaptation to create these mechanisms within the local context (Yasmin et al., 2019).

4.1.4 Flood Resilience Maintenance: Challenges and Opportunities

The maintenance of flood resilience infrastructure and systems is a critical yet often overlooked aspect of ensuring long-term effectiveness. Neglecting maintenance can lead to the gradual deterioration of flood protection measures, ultimately compromising their ability to withstand and respond to flood events (Pearson et al., 2018).

One of the key challenges in flood resilience maintenance is the need for sustained financial resources and political commitment. Maintaining flood infrastructure, necessitates a consistent and reliable flow of funding for regular inspections, repairs, and upgrades. However, in many cases, the fluctuations in political priorities and election cycles can disrupt the continuity of funding for flood resilience, leading to deferred maintenance and increased vulnerability (Yen, 2000). Ensuring political stability and the clear delineation of institutional responsibilities at the municipal, provincial, and federal levels are crucial in managing flood resilience (Matczak & Hegger, 2021). The overlapping jurisdictions and ambiguous accountability across these levels can prove challenging, as multiple institutions may share responsibility for certain aspects, while other crucial areas may be left unattended. Establishing clear lines of jurisdiction and accountability across different levels of government is, thus, essential for maintaining a coherent and effective flood resilience strategy.

Another challenge lies in the complexity of coordinating and integrating the maintenance of diverse flood resilience components, which may be managed by multiple and fragmented stakeholders in a globally dependent supply chain (Matczak & Hegger, 2021). This diversity of stakeholders involved often means that they have divergent motives and objectives, potentially leading to gridlock and in turn requiring cautious negotiation to achieve compromise. This paradoxical dynamic (i.e. all parties potentially prioritizing personal gain over the all ensuing goal of long term flood resilience) becomes further complicated when a solution is transplanted from a different geographical context with distinct prevailing conditions and operational norms, necessitating substantial adaptation to align with the local context and institutional frameworks (Smith & Lewis, 2011).

4.1.5 Community Vulnerability to Flooding

Vulnerability is a crucial concept in flood resilience, particularly within the context of developing countries, where the combination of biophysical risks and social inequalities exacerbates the impact of flood events. Vulnerability is commonly understood as the susceptibility of a community to harm due to exposure to hazards and the limitations of its adaptive capacity. Community vulnerability, in this context, extends beyond physical exposure to flood hazards; it is deeply tied to social inequality, poverty, and social exclusion (Nur & Shrestha, 2017). Communities that are socially and economically marginalized often face compounded risks due to their precarious living conditions, limited access to resources, and weak political representation. These factors render them less able to prepare for, cope with, and recover from flooding events, leading to disproportionate impacts on these groups (Nur & Shrestha, 2017).

Rampant social inequality and poverty further entrench vulnerability, as poorer communities are often forced to reside in flood-prone areas with inadequate infrastructure (Rentschler et al., 2022). Their exclusion from decision-making processes exacerbates their vulnerability, as their voices are seldom considered in flood management planning. Social exclusion also plays a significant role, as marginalized groups are frequently overlooked in policy-making, leaving them without the support structures needed for resilience (Choudhury & Haque, 2016) . These marginalized populations end up experiencing the direct threats of flooding, while also sustaining the prolonged socioeconomic ramifications that further entrench their vulnerable status (Rentschler et al., 2022).

In the context of flood resilience, community vulnerability encompasses various dimensions, including social, economic, and institutional factors. Marginalized groups, often residing in flood-prone areas, are more vulnerable due to limited access to resources, weak governance structures, and inadequate infrastructure. The barriers to sustainable flood management in Brazil, for example, highlight how socio-economic inequalities and poor institutional coordination exacerbate community vulnerability (Vasconcelos et al., 2021). Key barriers include the lack of long-term planning, insufficient design standards, and the reluctance to change existing strategies. Such barriers in turn prevent vulnerable populations from accessing effective flood protection measures. Vulnerability is also compounded by the lack of dissemination and knowledge, particularly in communities with limited technical expertise in sustainable urban drainage systems (Nur & Shrestha, 2017). For instance, In Brazil, stakeholders identified "lack of dissemination" as one of the most pressing barriers to implementing effective stormwater management practices. Engaging and empowering vulnerable communities to address barriers is crucial for reducing vulnerability and enhancing long-term flood resilience (Vasconcelos et al., 2021).

A significant paradox emerges when technocratic models, often used in flood management, fail to address the social and institutional challenges specific to vulnerable communities (Smith & Lewis, 2011). These top-down approaches, while offering modern solutions, can inadvertently increase vulnerability by overlooking local knowledge and adaptation practices. This creates tension between external expertise, which seeks universal solutions, and local realities that require context-specific strategies. The global push for standardized flood resilience measures often clashes with the unique needs of communities, limiting their ability to actively participate in shaping their own resilience frameworks (Smith & Lewis, 2011). Addressing community vulnerability, thus, requires solutions that go beyond technocratic fixes and prioritize inclusive, locally-driven strategies. Therefore, Flood resilience must be approached from a social perspective, with an emphasis on inclusive measures that prioritize the needs of vulnerable populations (Nur & Shrestha, 2017). Frugal innovations, such as nature-based solutions, offer promising pathways to reduce vulnerability by integrating local knowledge and low-cost strategies into flood management frameworks.

4.1.6 Future Challenges in Flood Resilience

The future of flood resilience faces a multitude of formidable challenges, including the accelerating impacts of climate change, rapid urbanization, and the increasing frequency of extreme weather events. Climate change is a primary driver of the escalating flood risk, as it manifests through rising sea levels, intensified precipitation patterns, and the increased likelihood of extreme weather occurrences (McDermott, 2022). The impacts of climate change are not limited to coastal regions, as inland areas also face aggravated risks of riverine and pluvial flooding due to the changes in precipitation regimes (McDermott, 2022). Responding to these climate-driven challenges requires a fundamental shift in flood resilience strategies, moving beyond traditional infrastructure-centric approaches to more holistic and adaptive solutions, Particularly with regard to the prevailing conditions in the Global South, which tend to have aggravated hazards and risks associated with flooding events (Takin et al., 2023). The rapid pace of urbanization, particularly in the developing world, poses another significant challenge to flood resilience. As more people migrate to urban centers, the concentration of assets, infrastructure, and population in flood-prone areas increases, amplifying the potential for catastrophic consequences during flood events (McDermott, 2022). Innovative approaches to urban planning and design, such as weaving more nature-based integration within the city grounds, will be crucial in building resilience within these densely populated and complex urban systems (Sörensen et al., 2016). Furthermore, the increasing frequency of extreme weather events, including intense rainfall, hurricanes, and monsoons, poses a

formidable challenge to already existing flood resilience efforts. These events can overwhelm even the most robust flood protection measures, underscoring the need for a multifaceted approach that combines structural and non-structural interventions, early warning systems, and community-based adaptation strategies (Loggia et al., 2020).

Ultimately, the future of flood resilience will require a paradigm shift that embraces a more comprehensive, integrated, and adaptive approach in contrast to the existing more reactive approach (Raub et al., 2024). This will necessitate a combination the factors included in this discussion, including technological advancements, nature-based solutions, community engagement, and robust institutional frameworks to address the complex and evolving challenges posed by climate change, urbanization, and extreme weather events (Loggia et al., 2020).

4.2 Paradox Perspective

Contemporary social and organizational realities are inherently complex, marked by the coexistence of contradictions and conflicting angles, often weaved in a mutually dependent manner (Smith & Lewis, 2011). The Paradox Perspective has emerged as a prominent theoretical framework for understanding and navigating these contradictions, especially in contexts where multiple stakeholders often have conflicting motives and viewpoints. **I**n the domain of flood resilience, a central paradox arises from the over-reliance on technocratic, expert-driven solutions that neglect the critical role of societal involvement. Technocratic solutions may be technically sound but often fail to engage local communities, resulting in ineffective or unsustainable outcomes**.** Unlike traditional approaches that seek a singular, optimal solution to complex problems, the paradox perspective posits that tensions and contradictions are intrinsic to both organizational and social realities. For flood resilience, this means that technocratic solutions must be balanced with community-driven, context-specific needs**.** Success, therefore, lies in the ability to recognize, embrace, and skillfully manage these paradoxes over time (Smith & Lewis, 2011). The origins of the paradox perspective can be traced back to earlier explorations in organizational theory and strategic management, where scholars recognized the persistence of tensions and dualities within organizational life and grappled with the complexities and dilemmas faced by leaders and organizations, initially framing these as dilemmas or challenges to be resolved (Lewis, 2000).

Smith and Lewis (2011) defines paradox as "**contradictory yet interrelated elements that exist simultaneously and persist over time**." This definition highlights two core components: the underlying tensions, which are elements that seem logical individually but inconsistent when juxtaposed, and the responses that embrace these tensions simultaneously. For flood resilience, this highlights the need to manage the tension between technocratic, top-down solutions and the local, socio-geographic needs of communities**.** This framework challenges the traditional notion of resolving paradoxes as problems and instead proposes a Dynamic Equilibrium Model of organizing. This model depicts how purposeful and cyclical responses to paradoxical tensions enable organizations to achieve sustainability by achieving peak performance in the present while ensuring long-term success (Smith & Lewis, 2011).

4.2.1 Understanding the Paradoxes

Flood resilience planning is shaped by a set of inherent paradoxes that stem from the fundamental tension between technocratic, expert-driven solutions and the socio-geographic realities of communities affected by flooding. While large-scale, standardized approaches often prioritize efficiency, long-term viability, and structural robustness, they may fail to adequately account for local needs, social dynamics, and environmental variability. On the other hand, adaptive, community-driven solutions offer flexibility and responsiveness but can struggle with scalability, institutional support, and long-term sustainability (Raub et al., 2024). These paradoxes reflect the broader challenges of integrating top-down governance with bottom-up resilience efforts, balancing financial and technical constraints, and aligning short-term recovery with long-term planning. By categorizing and analysing these paradoxes, this section aims to illuminate the complex trade-offs that decision-makers must navigate in flood resilience planning. Understanding these tensions is essential for developing strategies that bridge the gap between technocratic control and community adaptability, ultimately leading to more effective, inclusive, and sustainable flood resilience measures. Finally, this study highlights the relevance of mapping and further managing these tensions through the Dynamic Equilibrium Model by Smith and Lewis (2011).

4.2.1.1 Simplicity vs. Complexity Paradox

Flood resilience planning often faces a paradox between simplicity and complexity, where technocratic solutions tend to favor large-scale, complex infrastructure that can be challenging to adapt to specific local contexts. Frugal innovation, on the other hand, offers more straightforward, flexible solutions that cater to the pressing needs of affected communities (Bhatti & Ventresca, 2013). However, technocratic approaches, engineered for widespread applicability, often reinforce standardized solutions that are not readily adaptable to the diverse and evolving realities of the Global South (Pritchett & Woolcock, 2003). This results in a disconnect between global frameworks that push for technically sophisticated, complex solutions and the need for practical, easily implementable alternatives.

The challenge lies in carefully balancing the preference for large-scale infrastructure projects—often favored due to their perceived robustness, long-term viability, and political showmanship—with the urgent demand for adaptable, community-driven solutions that promote sustainability and inclusivity (Yasmin et al., 2019). Technocratic approaches typically prioritize standardized solutions designed for broad application, often shaped by global directives and expert knowledge from the developed world. However, these solutions may fail to fully account for the unique socio-geographic conditions of different regions, making them difficult to implement effectively (Yasmin et al., 2019). In contrast, frugal innovations that emerge from local knowledge and resource constraints can provide cost-effective, flexible alternatives that are better tailored to specific challenges. These solutions prioritize practical implementation and adaptability, often requiring fewer resources and infrastructure investments. Successfully navigating this paradox requires decision-makers to integrate both technocratic and community-driven perspectives, ensuring that large-scale infrastructure projects incorporate mechanisms for local adaptation while empowering grassroots innovations that enhance flood resilience (Loggia et al., 2020).

4.2.1.2 Short-Term vs. Long-Term Sustainability Paradox

Flood resilience planning involves a fundamental paradox between short-term adaptability and long-term sustainability. Technocratic approaches typically prioritize high-cost, long-term investments aimed at ensuring resilience over extended periods (Restemeyer et al., 2018). However, these long-term plans often remain unimplemented or become obsolete as socio-economic and environmental conditions change, preventing their anticipated benefits from materializing (Voß et al., 2009). The time horizon of such planning frequently clashes with the urgent and evolving nature of flood risks, requiring solutions that can respond dynamically to immediate challenges.

Frugal innovation, in contrast, offers low-cost, flexible solutions that address immediate needs, embodying a "living with water" philosophy that fosters rapid adaptation and recovery. Nature-based solutions, for instance, can be more affordable and easier to rebuild than large-scale infrastructure projects such as dams. However, the paradox deepens as the long-term effectiveness of frugal solutions depends on sustained community involvement, which can fluctuate over time, leading to challenges in ensuring their continuity (Loggia et al., 2020). This paradox highlights the difficulty of balancing short-term adaptability with the perceived durability of large-scale, long-term planning—both of which can falter under shifting conditions. Achieving an effective balance requires integrating flexible, community-responsive innovations with forward-looking, sustainable investments to ensure resilience strategies remain relevant and effective over time.

4.2.1.3 Local Adaptability vs. Scalability Paradox

Flood resilience planning often faces a paradox between the need for scalable, standardized solutions and the necessity for locally adaptable approaches. Technocratic frameworks frequently prioritize uniform solutions that emphasize scalability, standardization, and robustness, aiming for broad applicability (O'Brien et al., 2012). While this approach can enhance efficiency and streamline implementation, it often fails to account for the distinct socio-geographic characteristics and specific needs of individual communities (Yasmin et al., 2019). Conversely, frugal innovation thrives on flexibility and responsiveness, tailoring solutions to the unique challenges of different environments. Locally driven approaches can offer more context-specific, practical alternatives that directly address community needs (Loggia et al., 2020). However, these adaptable solutions can struggle with institutional integration and scalability, making it difficult to implement them at a broader level without losing their core flexibility. The tension emerges as large-scale frameworks often disregard the local nuances that make frugal solutions effective, while decentralized, community-driven efforts may lack the structural support needed for widespread adoption (Yasmin et al., 2019). Navigating this paradox requires finding a balance where scalable solutions incorporate mechanisms for local adaptation. Decision-makers must ensure that flood resilience strategies are not solely dictated by broad institutional priorities but also allow room for flexible, community-driven approaches to coexist and thrive (O'Brien et al., 2012).

4.2.1.4 Flexibility vs. Institutional Control Paradox

Flood resilience planning faces a tension between flexibility and institutional control. Frugal innovations, often emerging from community-driven initiatives, are inherently adaptable and responsive to unique socio-geographic conditions (Loggia et al., 2020). These solutions thrive on

their ability to be customized to specific local challenges, making them highly effective in addressing diverse flood resilience needs. However, for such innovations to be widely adopted and sustained, they must be integrated into formal institutional frameworks that tend to emphasize standardization, consistency, and centralized control. This creates a paradox, as the flexibility and adaptability that make frugal solutions effective often clash with the structured, uniform requirements of institutional systems, which prioritize scalability and regulatory compliance over localized adaptability (Pritchett & Woolcock, 2003). Institutional frameworks typically favour structured, top-down approaches that can be implemented at scale, often overlooking the potential benefits of decentralized, community-led solutions (O'Brien et al., 2012). Technocratic systems frequently resist these flexible solutions due to perceived risks, regulatory constraints, or concerns about their compatibility with existing standards (Voß et al., 2009). This resistance can prevent frugal innovations from being widely adopted or scaled, even when they offer more effective, cost-efficient alternatives tailored to specific community needs (O'Brien et al., 2012). Addressing this paradox requires striking a balance between institutional control and the need for adaptability. Decision-makers must explore ways to integrate flexibility into broader institutional structures while ensuring that standardized approaches do not undermine the effectiveness of locally driven innovations. This shift necessitates a re-evaluation of how institutions perceive and incorporate local knowledge and community-driven solutions, fostering a governance model that accommodates adaptability without compromising scalability (Bhatti & Ventresca, 2013).

4.2.1.5 Local Level: Frugality vs. Perception of Sophistication Paradox

Flood resilience planning often encounters a paradox between cost-effective, practical solutions and the high-tech, complex approaches favored by technocratic systems and transnational frameworks. Frugal innovation, which frequently emerges from local knowledge and resource constraints, provides efficient, low-cost solutions tailored to immediate needs. However, these solutions are often perceived as less sophisticated by higher-level actors, who equate technological advancement with effectiveness and modernity (Pritchett & Woolcock, 2003). This paradox becomes evident when frugal solutions are dismissed as unviable in favor of more complex, globally recognized alternatives that are perceived as superior, cutting-edge, or more aligned with international standards. Such preferences can also be influenced by political one-upmanship and career-building incentives among policymakers, further sidelining practical, locally driven solutions (Voß et al., 2009).

Communities that prioritize cost-efficiency and practicality often find their approaches undervalued, despite their proven effectiveness in specific socio-geographic contexts (Pritchett & Woolcock, 2003). This creates a disconnect between the need for affordable, adaptable solutions and the global preference for standardized, high-tech strategies that may not fully address localized challenges (O'Brien et al., 2012). Navigating this paradox requires decision-makers to recognize the value of frugal innovation while balancing it with the need for solutions that meet broader technical and regulatory benchmarks. By integrating community-driven frugal solutions alongside technocratic approaches, flood resilience strategies can become both effective and sustainable (Yasmin et al., 2019). The key challenge is to shift perceptions so that frugality is not equated with a lack of sophistication but rather acknowledged as a viable, context-specific approach to resilience (Loggia et al., 2020).

As explored in the preceding discussion, the paradoxes that emerge in flood resilience planning highlight the tensions between large-scale, standardized solutions and the need for adaptable, context-specific approaches. These paradoxes influence decision-making processes and the effectiveness of resilience strategies by shaping how different stakeholders, ranging from policymakers to local communities, navigate conflicting priorities (Smith & Lewis, 2011). The following table categorizes these paradoxes and provides a concise explanation of each:

Table 2 : Paradox Classification and Explanation Table

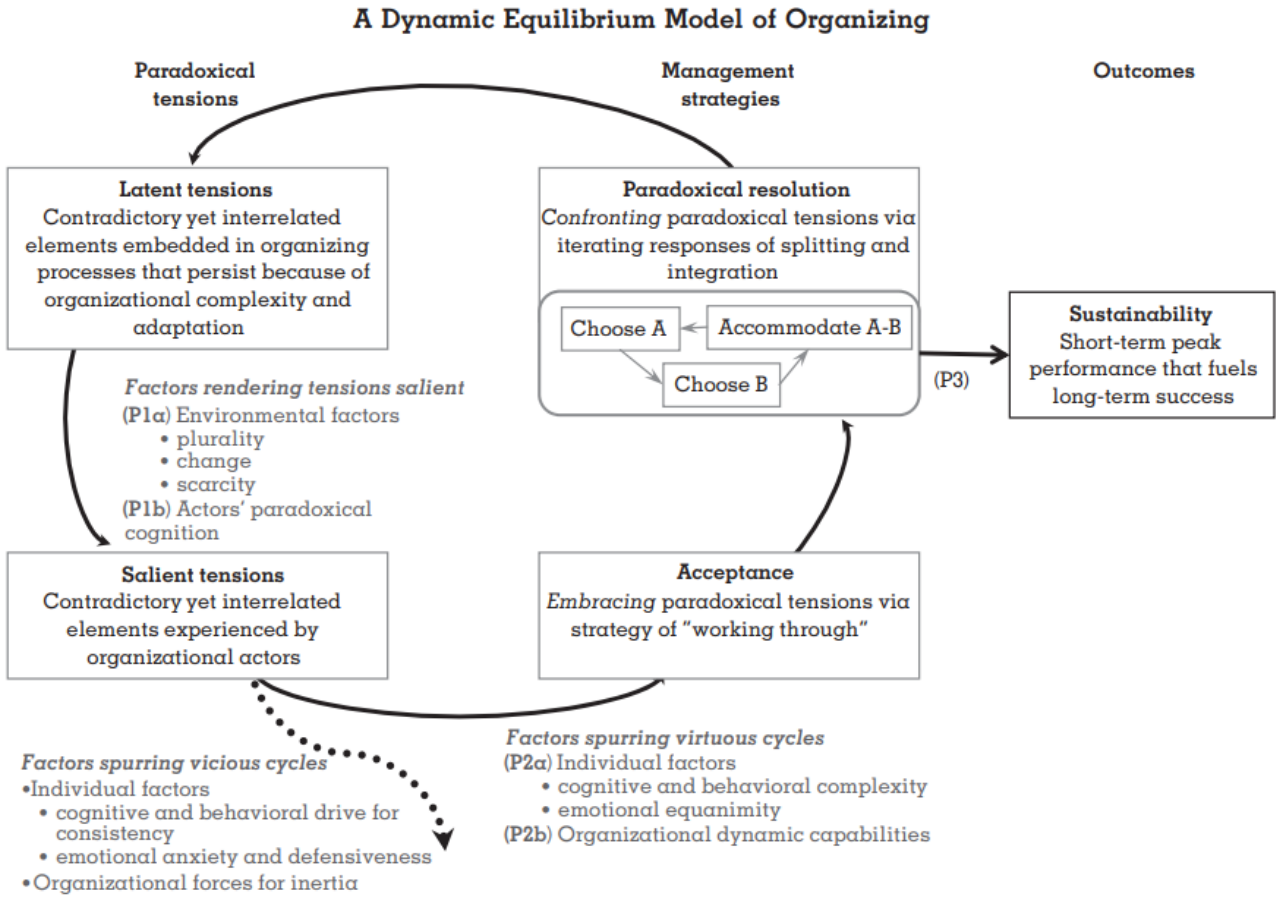
Paradox	Explanation
Simplicity vs. Complexity	Large-scale, complex solutions often dominate resilience planning, while frugal innovations offer simpler, immediate solutions.
Short-Term vs. Long-Term Sustainability	Global frameworks focus on long-term investments, often overlooking immediate, low-cost interventions offered by frugal innovation.
Local Adaptability vs. Scalability	The challenge is balancing the need for localized, adaptable solutions with the need for scalability across different regions.
Flexibility vs. Institutional Control	Grassroots innovations are tailored to local contexts, while institutional frameworks prioritize standardized, scalable approaches, leading to tensions between flexibility and control.
Frugality vs. Perception of Sophistication	Local communities may value frugality and practicality, while higher-level frameworks perceive frugality as lacking sophistication or prestige.

Global frameworks and technocratic solutions often dominate decision-making processes, prioritizing long-term investments along with scalable and complex solutions. However, this top-down approach can overlook the immediate needs of local communities, which may be better served by more adaptable and nature-integrative solutions found within the domain of what is known as frugal innovation (O'Brien et al., 2012). Similarly, tensions emerge within governance structures, where institutions seek to maintain control through standardized approaches, while grassroots innovations introduce flexibility that may challenge institutional norms and customs (Driessen et al., 2018). Additionally, while communities often prioritize practicality and frugality, higher-level actors may undervalue these approaches, perceiving them as lacking sophistication (O'Brien et al., 2012). The table presented above categorizes these paradoxes, offering explanations for their underlying tensions. This categorization is crucial for understanding the interplay between different actors in flood resilience planning and for identifying how solutions like frugal innovation can be best applied to navigate these tensions. By breaking down these paradoxes, this research provides a clearer roadmap for how stakeholders can work together to achieve flood resilience while addressing the overarching technocratic versus socio-geographic paradox (Chapardar, 2016). Ultimately, the deadlock of flood resilience failure in the Global South stems from the misalignment between top-down frameworks and the socio-geographic realities of local communities, rather than inherent local limitations.

This breakdown is particularly relevant in the context of the **Dynamic Equilibrium Model** (Smith & Lewis, 2011), which emphasizes the importance of managing and balancing paradoxes over time rather than attempting to resolve them outright. By recognizing the level at which each paradox operates, decision-makers will better understand how to navigate these competing demands, creating a more long-term and compromise to achieve solutions for flood resilience in the Global South.

4.2.2 Dynamic Equilibrium Model of Paradox

Figure 9: A Dynamic Equilibrium Model of Organizing



From "Toward a Theory of Paradox: A Dynamic Equilibrium Model of Organizing", by Smith & Lewis, 2011, (https://doi.org/10.5465/amr.2011.59330958)

The **Dynamic Equilibrium Model of Paradox** is a conceptual framework developed by Smith and Lewis (2011) that helps organizations understand and manage the inherent contradictions and tensions they face. This model emphasizes the simultaneous existence of contradictory yet interrelated elements, termed paradoxes, that persist over time and must be continuously managed to achieve long-term sustainability. Unlike traditional management theories that advocate for choosing between competing demands, the dynamic equilibrium model focuses on embracing and balancing these tensions to enhance organizational resilience and adaptability (Smith & Lewis, 2011).

In the context of flood resilience, a key paradox arises between technocratic, expert-driven approaches and the need for societal involvement. Technocratic solutions, which are heavily dependent on engineering and infrastructure, may fail to account for local knowledge and the socio-cultural realities of the communities they are designed to protect. The dynamic equilibrium model

provides, thus, a lens to balance technocratic exertise and community-driven needs without negating the importance of either. Furthermore, this model will be used to investigate the paradox of achieving flood resilience in the Global South, This model will be applied in this study to examine the tensions within existing frameworks for achieving flood resilience in the Global South. The study will explore how the paradoxes between transnational frameworks, technocratic solutions, and frugal innovation can be navigated to address the socio-geographic complexities of flood resilience in the Global South, using the dynamic equilibrium model to examine how transnational frameworks and frugal innovation can help to find compromise, thus promoting an equitable balance between tensions in turn leading to long-term flood resilience.

4.2.3 Managing Tensions in Cross-Cultural Collaboration

Navigating the complexities of cross-cultural collaboration involves managing a delicate balance between differing values, communication styles, and expectations, which can often lead to misunderstandings and tensions that hinder progress (Papachroni et al., 2014). This challenge is particularly evident in fields such as international development and disaster risk reduction, where well-intentioned initiatives can fail if they do not adequately consider the cultural contexts in which they are implemented. From the paradox perspective, however, these cultural differences are not merely obstacles to be overcome but opportunities for fostering learning, innovation, and more effective collaboration (Vangen, 2016). Embracing paradoxes inherent in cross-cultural settings allows for a more nuanced and adaptive approach that aligns with the dynamic equilibrium model, which emphasizes balancing competing demands over time (Smith & Lewis, 2011).

A prominent paradox in cross-cultural collaboration, particularly within development contexts, is the tension between top-down and bottom-up approaches. Global frameworks and best practices, often developed with universal applicability in mind, can clash with the specific needs and priorities of local communities (Brooks et al., 2020). This tension is mirrored in the technocratic vs. societal paradox, where global standards prioritize technical efficiency, and local communities favor solutions that align with their cultural values along with their socio-economic realities (O'Brien et al., 2012). For example, a flood resilience strategy designed by international experts might emphasize large-scale infrastructure projects, while local communities could prioritize nature-based solutions or early warning systems more congruent with their cultural values and local knowledge. This clash of priorities represents a performing paradox where global goals must be reconciled with local realities. Ignoring local perspectives can lead to ineffective interventions that lack community buy-in and fail to achieve their intended outcomes (Calton & Payne, 2003). Frugal innovation, by contrast, hopes to provide an approach that emphasizes low-cost, adaptable solutions, often built on local knowledge and social relevance. (Sheikh et al., 2023).

Furthermore, rather than placing the blame on local communities or governance structures, the challenge here is rooted in the misalignment of global frameworks that lack the flexibility to incorporate local knowledge effectively (Yasmin et al., 2019). This misalignment frequently leads to solutions that fail to fully capitalize on the strengths of local expertise or adequately address the sociocultural complexities of the local context. The paradox lies in the assumption that technocratic, top-down approaches are inherently superior, neglecting the critical need to empower local actors as valuable contributors to the overarching strategy (Pritchett & Woolcock, 2003). The challenge of knowledge transfer further amplifies this tension. While the exchange of expertise and best

practices across cultures is crucial, it must be carried out with sensitivity and a deep appreciation for the value of local knowledge. Local communities often possess an intimate understanding of their environment, vulnerabilities, and coping mechanisms developed over generations. In the context of flood resilience, for example, local knowledge might include traditional building techniques adapted to flood-prone areas, indigenous knowledge of flood forecasting, or community-based early warning systems (Munawar et al., 2021). A paradox-sensitive approach, therefore, requires managing the tension between global knowledge dissemination and the preservation and integration of local expertise, recognizing that neither approach is inherently flawed but rather incomplete without the other (Raub et al., 2024).

Moreover, cultural differences and existing power dynamics can significantly impact resource allocation in disaster response and recovery efforts. Aid distribution may sometimes favor communities with greater political influence or those more aligned with the cultural values of the donors, exacerbating existing inequalities and undermining the effectiveness of interventions (Clarke & Parris, 2019). This highlights another dimension of a paradox: balancing the need for equitable resource allocation with the realities of power dynamics and cultural affinities. In this instance, the emphasis should not be on perceived deficiencies within local communities and their organization, but rather on the challenge of adapting global frameworks to navigate the local power dynamics in a manner that promotes inclusivity and fairness (Yasmin et al., 2019). Therefore, a paradox perspective here will then encourage a blended approach that acknowledges these dynamics while striving for fairness and effectiveness.

4.2.4 Navigating Paradoxes in Governance and Institutional Frameworks

Institutional frameworks for governance often embody a paradox between the need for structured governance and the desire for effective local actions. On one hand, centralized control and standardized rules are crucial for maintaining order, ensuring consistent policy implementation, and providing stability across diverse contexts (Lewis, 2000). These uniform guidelines and centralized decision-making processes help establish coherence within large-scale systems, especially in managing complex issues like flood resilience (Driessen et al., 2018). The challenge here lies in integrating the strengths of centralized systems without overlooking the adaptability and flexibility brought to the table by local communities to assist in navigating their specific socio-economic and environmental contexts (Raub et al., 2024). However, the rigidity of centralized governance can also limit the ability of local actors to respond nimbly and creatively to rapidly changing circumstances and unique community needs. Local communities frequently possess invaluable, context-specific knowledge that could lead to more effective, tailored solutions better aligned with local realities (Ensor et al., 2016). This paradoxical tension between the benefits of centralized control and the need for decentralized, flexible approaches presents a significant challenge for public agencies (Smith & Lewis, 2011).

Decentralized governance structures, which allocate decision-making authority closer to local stakeholders, hold the potential to cultivate more inclusive and innovative approaches to public administration (Kim & Jurey, 2013). This approach allows diverse stakeholders to participate more actively and influence policy through the modification, adaptation, or reinterpretation of existing institutional rules, potentially spurring social change. However, the push-and-pull of this dynamic frequently leads to 'incomplete decentralization,' where local governments are granted some

autonomy but face ongoing resistance and pushback from higher-level authorities over issues of resource allocation, decision-making, and accountability (Marks & Lebel, 2016).

This resistance suggests that the very act of decentralization can trigger a scalar politics of control, with competing claims over the 'right' level for various governance functions. Such tensions exemplify the paradoxical interdependence between central authority and local autonomy, where attempts to balance these forces may inadvertently undermine both, aligning with the notion of persistent contradictions that need to be managed (Smith & Lewis, 2011). Higher-level authorities may contend that local stakeholders, driven by their own narrow interests, could undermine overarching policy goals if granted too much autonomy. However, it is crucial to emphasize that local stakeholders are not directly the root of the problem, but rather the rigid frameworks that fail to adjust to the socio-political intricacies of decentralized governance. Furthermore, this may not break the vicious cycle of non-implementation of proposed solutions and could lead to further fragmentation of governance (Kim & Jurey, 2013).

The challenge becomes even more pronounced when global frameworks and foreign solutions, often developed for the contexts of the Global North, are introduced into developing countries with different governance structures and socio-political realities (Raub et al., 2024). In such settings, the paradox of governance is not merely about choosing between centralized and decentralized approaches but about continuously navigating the dynamic tension between these competing demands (Smith & Lewis, 2011). Rather than blaming local governance inefficiencies, it is the misalignment between global frameworks and local capacities that creates barriers to their effective and large-scale implementation (Voß et al., 2009). For developing countries, where governance systems may be less mature or more fragmented, the imposition of standardized global frameworks can inadvertently undermine local effectiveness, reducing the impact of resilience-building initiatives. Therefore, a paradox-sensitive approach to governance must recognize and manage these inherent contradictions by allowing space for both structured control and local adaptability, fostering an environment where global strategies are blended with local knowledge to achieve more sustainable outcomes (Smith & Lewis, 2011).

4.2.5 Balancing Transnational and Localized Approaches in Flood Resilience Governance

As previously mentioned, this study examines the paradox of the persistent lack of flood resilience in the Global South and evaluates whether global frameworks, frugal innovation, or a combination of both can effectively transform current frameworks to achieve enduring flood resilience. A central tension exists between technocratic, top-down approaches often developed in the Global North and the need for locally-driven, context-specific solutions (Matczak & Hegger, 2021). The literature suggests that implementing collaborative global work projects requires managerial actions beyond formal solutions (Brooks et al., 2020). While transnational policies offer broad guidelines, local contexts may demand more tailored action and adaptive governance strategies (Matczak & Hegger, 2021). This paradox underscores the need to balance top-down and bottom-up approaches while effectively managing the transmission and flow of information from decision-makers to the practical execution of proposed interventions. Aligning the interests and needs of multiple stakeholders across different scales and governmental levels is crucial (Kim & Jurey, 2013). However, achieving this balance remains a challenging accomplishment. While top-down transnational policies may provide overarching guidelines, the diversity of local contexts requires more localized, adaptive governance strategies that can respond to specific needs (Raub et al., 2024). Moreover, the flow of information from decision makers to the practical execution of proposed interventions can be

hindered by misaligned interests and needs of stakeholders at different scales. Striking the right balance between centralized and decentralized governance remains a critical challenge in navigating the effective application of solutions and processes, a challenge that requires compromises and collaboration to achieve its aims, even if such deviate from the original proposed solution, thus proposing something taking a different stance (Smith & Lewis, 2011).

4.2.6 Persistent Challenges in Implementing Sustainable Flood Resilience

The implementation of sustainable flood resilience measures faces a range of persistent challenges that hinder their widespread adoption and effectiveness. One such challenge is the inherent inflexibility of existing flood risk reduction methodologies, which often fail to adequately account for the unique contexts and data availability in less-developed regions (Nkwunonwo, 2020). This rigidity can undermine the practicability of these approaches, particularly in settings where access to relevant datasets and technical requirements is limited (Nkwunonwo, 2020). Furthermore, the complexity of flood-prone environments is frequently exacerbated by demographic and climate pressures, creating a "post-normal" situation where standard scientific recommendations rarely achieve the intended outcomes (Bwambale et al., 2020).

The socio-economic conditions that shape the context of flood risk governance are another critical factor in the paradox of balancing local and transnational strategies (Driessen et al., 2016). Existing research highlights how socio-economic inequality can exacerbate the vulnerability of certain populations to flood risks, with marginalized communities often facing the greatest threats (Nkwunonwo, 2020). This is further complicated by the reality that regions most susceptible to flood risks often contend with weaker and more fragmented institutions. These institutions may lack the capacity, resources, and coordination to effectively address flood risks, often also falling prey to a lack of transparency (Alexander et al., 2017). This confluence of socio-economic disadvantage and institutional weakness creates a perfect storm of vulnerability for marginalized communities (Nur & Shrestha, 2017).

Additionally, the effectiveness of technological solutions in flood resilience is often contingent upon the availability of relevant datasets and technical infrastructure (Nkwunonwo, 2020). In less developed contexts, data scarcity and weaker technological capacities can undermine the applicability of advanced methodologies, emphasizing the need for more flexible, context-specific technological solutions that prioritize locally available resources and traditional knowledge (Lam et al., 2020). This calls for a balanced approach that leverages the latest scientific and technological advancements while ensuring they are relevant and accessible to the communities they aim to serve (Shah et al., 2015).

Another persistent issue is the gaps and shortcomings in current flood risk assessment processes, which have led to improper planning and design of flood risk reduction measures, ultimately resulting in their ineffective performance during major flood events (Shah et al., 2015). Developing countries often face persistent challenges in implementing sustainable flood resilience measures. Limited resources, weak governance, and power imbalances between stakeholders hinder the effective implementation of flood resilience strategies (Johannessen & Mostert, 2020). The disconnect between local needs and global priorities further exacerbates this paradox, making it difficult to address the recurring issues that undermine flood resilience in the developing world. The persistence of these challenges is central to understanding the paradox perspective in the context of flood resilience.

4.2.7 Weak Governance and Paradox Persistency

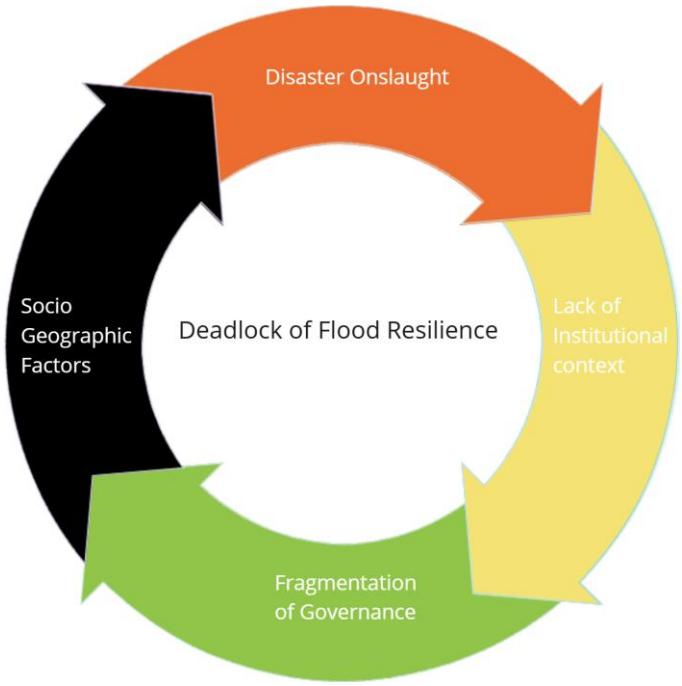
The persistence of challenges in implementing sustainable flood resilience is also closely linked to issues of weak governance and power imbalances among stakeholders (Matczak & Hegger, 2020). Historically, flood risk management has been predominantly a top-down, technocratic endeavor led by government agencies, with limited participation from local communities and other stakeholders (Matczak & Hegger, 2020). This technocratic approach has often failed to address the complex social, economic, and environmental factors that contribute to flood vulnerability, leading to the recurrence of flood-related disasters (Matczak & Hegger, 2020). However, this technocratic approach has also faced criticism for its inability to address the complex power dynamics and local realities that shape the implementation of flood resilience measures (Raub et al., 2024). Local communities, who often bear the brunt of flood impacts, have largely been marginalized from decision-making processes, leading to a disconnect between global priorities and local needs. Addressing this power imbalance and fostering meaningful participation of diverse stakeholders, including community members, is crucial for overcoming this developmental deadlock and, thus, developing sustainable and equitable flood resilience strategies (Laeni et al., 2021).

Moreover, when different agencies and levels of government operate compartmentalized approaches, with unclear mandates and poor coordination, it hinders the development of comprehensive flood resilience strategies (Driessen et al., 2016). Thus, fragmented governance further exacerbates these challenges. This fragmentation can lead to contradictory policies where, for example, development plans might clash with flood zone regulations, undermining resilience efforts. Additionally, limited resources might be wasted due to a lack of coordination and shared priorities. This lack of clarity regarding responsibilities makes it difficult to hold actors accountable for failures in flood resilience planning or implementation (Driessen et al., 2016).

4.2.8 Deadlock of Flood Resilience

Another factor contributing to the persistence of flood resilience challenges is the ever increasing frequency and intensity of flood events, which disrupt the recovery cycle and overwhelm the capacity of communities and institutions to adapt. As disaster events become more frequent and severe, the ability of communities to effectively recover, learn, and implement long-term resilience measures is severely constrained (Herath & Wijesekera, 2020). This "disaster onslaught" hinders the development of a robust, iterative learning process that is crucial for building sustainable flood resilience. The lack of time and resources for recovery and reflection often results in a reactive, short-term approach to disaster management, rather than proactive, long-term resilience building. This leads the region to remain in a deadlock where the interventions on the built environment only seem to be partially effective and resilience efforts are continuously undermined by the next flood disaster (Raub et al., 2024). The persistent challenges that hinder the implementation of sustainable flood resilience measures are central to understanding the persistency of the paradox within this context, as the system is unable to break free from the cycle of repeated failures, thus always demanding for immediatism in its propositions in contrast to a more proactive and long-term approach in building sustainable flood resilience (Raub et al., 2024).

Figure 10 : Deadlock of Flood Resilience



From Author (2024)

The recent collapse of a temporary bridge in Rio Grande do Sul rebuilt after the flood events, further illustrates the Deadlock of Flood Resilience described above (Trindade & Alt, 2025). Constructed as a provisional solution after devastating floods in May 2024 destroyed the original structure, this bridge was swept away in January 2025, less than three months after its delayed inauguration. The incident highlights several dimensions of the described resilience deadlock. First, the disaster onslaught is evident in the recurring extreme weather events that outpace the capacity of local infrastructure to withstand them (Hossain & Kalyanapu, 2012). The temporary bridge, built with reinforced containers, was unable to endure the elevated water levels of the river, which rose significantly above normal parameters during a recent storm, albeit at lower level then in the historic May 2024 floods (Trindade & Alt, 2025). This demonstrates the urgent need for infrastructure designed to account for more extreme hydrological conditions.

Second, the reliance on short-term solutions like provisional bridges reflects the lack of a cohesive institutional context to guide resilience efforts. While the bridge served as a critical connection for heavy vehicles and regional logistics, its failure highlights the lack of institutional planning and coordination needed to anticipate and withstand future disasters (Trindade & Alt, 2025). Without a structured, long-term vision, recovery efforts remain fragmented, perpetuating a cycle of reactive responses and undermining sustainable flood resilience, which also potentially means a negative delta regarding resilience where after every disaster onslaught the infrastructure is rebuilt in a weaker and even more temporary manner (Driessen et al., 2018). Finally, this case illustrates the fragmentation of governance and socio-geographic challenges in managing flood resilience. The construction of the temporary bridge involved collaboration between residents, the private sector, and the local government, yet the outcome reveals the limitations of such efforts in addressing systemic issues, as there was no higher or integrated plan to guide efforts towards resilience. The disruption to mobility and economic activity caused by the bridge's collapse extends beyond the area, affecting neighbouring municipalities and emphasizing the broader regional impact of inadequate resilience planning (Trindade & Alt, 2025).

Figure 11 : Temporary bridge built after flood is swept away in Rio Grande do Sul

From “Ponte construída após enchente em Feliz é levada pelo Rio Caí, 2025, (https://gauchazh.clicrbs.com.br/geral/noticia/2025/01/ponte-construida-apos-enchente-em-feliz-e-levada-pelo-rio-cai-cm5g8bjh4016m015wbgewktwa.html)

The collapse of the temporary bridge also underscores the short-term vs. long-term sustainability paradox at the macro level. Following the destruction of the original structure, the urgency to restore connectivity drove a disorganized push for immediate reconstruction, resulting in a provisional solution that lacked durability (Driessen et al., 2018). While this approach addressed immediate needs, it failed to integrate long-term sustainability into its design. The absence of a cohesive strategy to transition from temporary infrastructure to permanent, resilient solutions demonstrates how the urgency of disaster response can undermine long-term resilience (O’Brien et al., 2012). The reliance on short-term measures perpetuates reactive cycles and weakens the overall system, as temporary solutions often degrade with each subsequent disaster. This highlights the inherent tension between addressing immediate recovery needs and investing in durable, adaptive infrastructure aligned with evolving environmental conditions (O’Brien et al., 2012). By prioritizing short-term fixes without addressing systemic vulnerabilities, the region remains trapped in a cycle where provisional efforts delay, and sometimes preclude, the implementation of sustainable, long-term solutions.

4.2.9 Power Dynamics and the Local-Global Disconnect in Flood Resilience

The persistence of these challenges is also closely tied to the complex power dynamics that shape the discourse and implementation of flood resilience measures (Laeni et al., 2021). Global development agendas and transnational institutions have often set the priorities for flood resilience, with local communities having limited voice in these decision-making processes (Laeni et al., 2021). This disconnect between local needs and global priorities has led to the development of "one-size-fits-all" solutions that fail to address the unique social, economic, and cultural contexts of flood-prone communities (Laeni et al., 2021). This persistent disconnect between local needs and global priorities is central to the paradox perspective in the context of flood resilience, where top-down approaches often fail to address the complex realities on the ground (Lewis & Smith, 2014). However, there is a growing recognition that sustainable flood resilience can only be achieved through the meaningful engagement and empowerment of local communities (Herath & Wijesekera, 2020). These communities possess invaluable knowledge and experience in navigating flood risks, which can inform more effective and context-appropriate resilience strategies. Inclusive governance models that prioritize the participation of marginalized groups, such as women and the urban poor, are crucial for addressing power imbalances and ensuring that flood resilience measures are equitable and responsive to local needs (Laeni et al., 2021).

This disconnect between global frameworks and local needs, deeply rooted in power imbalances and differing socio-economic contexts, highlights the broader challenge of achieving sustainable flood resilience in the Global South. Bridging this gap between global priorities and local realities is crucial for overcoming the persistent paradox in flood resilience efforts. A critical challenge in achieving this, revolves around the disconnect between global approaches and local contexts in developing countries (O'Brien et al., 2012). Well-intentioned solutions from the developed world often fail to translate due to several factors. These include the unique socioeconomic and cultural dynamics, the complex power structures, and the limited resources and capacities at the local level (Nkwunonwo, 2020). The result is a persistent paradox where international best practices are not effectively operationalized or simply are unfeasible given the local contexts, leading to the recurrence of flood-related disasters. This local-global disconnect is further exacerbated by the fact that global flood resilience frameworks are often developed without sufficient consideration of the lived experiences and needs of local communities, focusing more only on economical development of a region (Driessen et al., 2016). To address this persistent paradox, a more holistic and context-sensitive approach is needed, one that bridges the gap between global priorities and local realities.

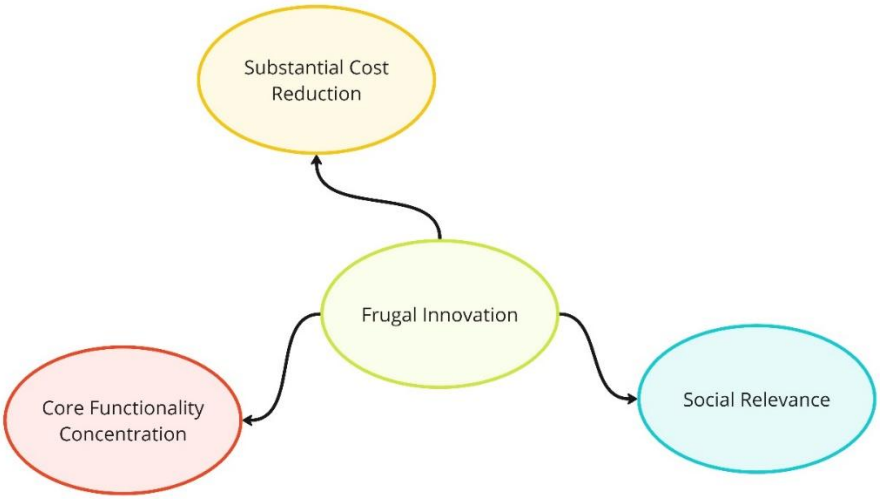
4.3 Frugal Innovation

Frugal innovation, a concept that has gained significant traction in recent years, refers to the process of developing innovative solutions that prioritize cost reduction, core functionality, and social relevance (Weyrauch & Herstatt, 2016). This approach to innovation is particularly crucial in emerging markets, where accessibility, affordability, and sustainability are key drivers of product and service development. At the heart of frugal innovation lies the fundamental principle of maximizing the functionality of a product or service while minimizing the use of resources. This involves a focus on the core features that address the most pressing needs of the target consumers, often those at the "bottom of the pyramid" (Bhatti & Ventresca, 2013). By concentrating on essential functionalities and eliminating unnecessary complexity, frugal innovators can significantly reduce the cost of their offerings, making them more accessible to a wider range of applications. Another core aspect of frugal innovation is its emphasis on social relevance. Instead of simply optimizing for profit, frugal innovators strive to develop solutions that address the real-world challenges faced by underserved communities, such as lack of access to essential services, energy, or healthcare (Bhatti & Ventresca, 2013). This social focus aligns with the United Nations' Sustainable Development Goals, underscoring the potential of frugal innovation to contribute to a more inclusive and sustainable future (Rosca et al., 2017). For instance, the centuries-old practice of utilizing rice terraces in Southeast Asia exemplifies the application of frugal innovation for flood management. (Xiaoying, 2019). These terraces, constructed using local materials and popular knowledge, provide a long-term flood control buffer while requiring minimal external resources. The terraced rice fields also serve as a cost-effective flood control system, while managing floodwaters in a way that supports agricultural productivity. This highlights the social stewardship inherent in frugal solutions, as these terraces continue on to support local communities economically and socially. Moreover, the communal upkeep of the terraces fosters a sense of shared responsibility and ownership, strengthening societal bonds and making the flood resilience strategy more sustainable in the long run (Xiaoying, 2019). By utilizing the landscape's natural features, these terraces provide a low-cost, effective solution that aligns with both environmental and social goals, embodying the essence of frugal innovation.

This becomes particularly relevant in the context of building resilience to ever-worse natural inclemencies, such as flooding, where frugal innovation has the potential to empower underserved

communities with affordable and accessible defenses and resilience which might not otherwise reach them (Khan, 2016). Moreover, the ability to thrive in the face of societal and operational pressures is a hallmark of frugal innovation, further leading innovators to excel in resource-constrained environments, regulatory hurdles, and infrastructure challenges, often through the creative repurposing of existing technologies or the development of new, low-cost solutions (Weyrauch & Herstatt, 2016). These tenets will be discussed in further depth bellow, also taking into account the relevance and potential that frugal innovation has in its application in the Global North with a focus on flood resilience.

Figure 12 : defining Flood Resilience



From Author (2024)

4.3.1 Substantial Cost Reduction:

At the core of frugal innovation is the principle of substantial cost reduction, which aims to make products and services accessible to a wider range of consumers, particularly those at the bottom of the economic pyramid (Weyrauch & Herstatt, 2016). This cost-conscious approach involves streamlining the design and production processes, leveraging local resources, and optimizing for efficiency throughout the value chain. By focusing on the essential features and eliminating unnecessary complexity, frugal innovators can significantly reduce the overall cost of their offerings, making them more affordable and attainable. Furthermore, frugal innovation in infrastructure emphasizes simplified designs that are easy to understand, implement, and have a local focus, reducing the reliance on expensive external expertise and technology (Sheikh et al., 2023). The emphasis on simplicity within the domain of frugal innovation ensures that underserved communities can adapt and maintain solutions with their own resources and knowledge, fostering self-reliance and long-term sustainability, which is particularly relevant in contexts characterized by weak and fragmented governance (Sheikh et al., 2023). Frugal innovation's emphasis on substantial cost reduction can be crucial in these environments, where expensive and complex solutions, while potentially effective in theory, often face significant challenges in implementation and maintenance when reliable governance structures are lacking (Weyrauch & Herstatt, 2016). Instead, frugal innovation offers a more pragmatic and context-tailored approach that can thrive in such resource-constrained settings by prioritizing cost-effective solutions (Bhatti & Ventresca, 2013).

A prime example can be seen in Bangladesh, where communities vulnerable to frequent flooding have successfully implemented low-cost, locally-sourced bamboo structures to elevate homes and protect livestock during floods (Bala et al., 2020). This showcases how frugal innovation, driven by necessity and local ingenuity, can provide effective solutions within a constrained budget. By integrating green infrastructure like rain gardens and permeable pavements, communities can absorb and manage floodwaters more effectively, reducing the reliance on expensive and complex drainage systems which often lack the governance means for their effective implementation and maintenance (Janda et al., 2020). This exemplifies a cost-conscious approach to frugal innovation, focused on substantial cost reduction, also underscores the importance of self-reliance and long-term sustainability. By developing solutions that can be maintained and adapted using local resources and knowledge, frugal innovators empower communities to be self-sufficient, reducing their reliance on expensive external expertise and technology from the "Global North" (Gandenberger et al., 2020) which might in turn be further replicated in another underprivileged location with similar socio-geographic status quo spreading the technology in osmosis like cheap technological propagation (Sheikh et al., 2023). This alignment between frugal innovation's emphasis on cost reduction and the promotion of self-reliance is particularly crucial in resource-constrained environments, where traditional, complex solutions often fail due to the lack of reliable governance structures and the inability of local stakeholders to effectively maintain and adapt them over time (Bhatti & Ventresca, 2013). Frugal innovation, in contrast, offers a more pragmatic and context-tailored approach that can thrive in such settings by prioritizing cost-effective solutions that can be readily adopted and sustained by the communities themselves.

4.3.2 Core Functionality Concentration:

Frugal innovation is characterized by its focus on the core functionalities of a product or service, rather than on extraneous features that can add complexity and cost (Weyrauch & Herstatt, 2016). This principle of concentrating on the essential aspects of a solution is crucial in addressing the needs of resource-constrained consumers. By identifying the most critical functions that meet the users' needs, frugal innovators can streamline the design, production, and delivery processes, leading to significant cost savings. This principle of concentrating on the essential aspects of a solution is crucial in addressing the needs of resource-constrained consumers (Weyrauch & Herstatt, 2016). By identifying the most critical functions that meet the users' needs, frugal innovators can streamline the design, production, and delivery processes, leading to significant cost savings.

This focus on core functionality is particularly evident in the context of flood resilience, where frugal innovators prioritize solutions that directly address the most pressing needs during flooding events. By identifying and concentrating on the essential functions required to mitigate the immediate impacts of floods, such as protecting lives, safeguarding critical infrastructure, and ensuring access to clean water and sanitation, these innovators are able to develop cost-effective solutions that can be readily implemented and maintained by resource-constrained communities (Derickson et al., 2021). This core functionality-driven approach stands in contrast to more complex, heavily engineered flood control systems that require significant capital investment and specialized expertise, often scant in the more underserved parts of the world, making them less accessible and sustainable for vulnerable populations. The emphasis on simplicity and local adaptability is a hallmark of frugal innovation in flood resilience, enabling communities to take an active role in addressing their own challenges through creative, context-specific solutions (Niroumand et al., 2020). For instance (Hartog, 2021) highlights how Shanghai is leveraging the core functionalities of its waterfront and coastline to enhance flood resilience. The city is actively engaged in constructing an urban eco-network, recognizing the natural flood mitigation capabilities of these ecosystems. By

prioritizing the restoration and enhancement of these natural assets, Shanghai exemplifies frugal innovation in flood resilience, focusing on maximizing the inherent functionalities of its environment rather than relying solely on costly and complex engineered solutions (Hartog, 2021).

4.3.3 Social Relevance:

The social dimension of frugal innovation is a crucial aspect that sets it apart from traditional innovation approaches. Rather than solely pursuing profit maximization, frugal innovators strive to develop solutions that address the pressing social and economic challenges faced by underserved communities. This emphasis on social relevance aligns with the United Nations' Sustainable Development Goals, highlighting the potential of frugal innovation to contribute to a more inclusive and sustainable future (Khan, 2016).

However, true social relevance in frugal innovation goes beyond simply targeting solutions at these communities; it requires actively involving them in the innovation process itself (Kahle et al., 2013). This approach recognizes the inherent knowledge and resourcefulness within these communities, acknowledging that they are not merely passive recipients of aid but active agents of change. By tapping into their lived experiences and understanding of local challenges, frugal innovation can foster solutions that are not only effective but also culturally sensitive, sustainable, and empowering (Kahle et al., 2013). This approach aligns with the concept of building local capacity, where communities are equipped with the tools and resources to identify their own needs and develop their own solutions, fostering self-reliance and long-term resilience.

Frugal innovation has the potential to uplift the standard of living for economically disadvantaged communities by solving pressing societal problems through ingenuity and creativity. This social impact is particularly evident in the context of flood resilience, where innovators combined with decision makers stive to develop cost-effective solutions that empower local communities to mitigate the effects of flooding (Guerriero & Penning-Rowsell, 2020). This ideas has been successfully applied in Nepal, where communities vulnerable to flooding have successfully implemented a low-cost, community-based early warning system using recycled materials and simple technology. This system, developed through a participatory process involving local residents, has significantly improved flood preparedness and reduced the impact of floods on livelihood and well-being (Bajracharya et al., 2021).

Furthermore, technologies originating from Global South communities often have an inherent advantage in navigating contexts characterized by weak and fragmented governance (Kahle et al., 2013). These innovations are typically designed with resource constraints and implementation challenges in mind, making them more adaptable and resilient in environments where top-down, resource-intensive solutions from the Global North might struggle to gain traction (Sheikh et al., 2023). This inherent adaptability can be a crucial factor in achieving sustainable and equitable development outcomes.

4.3.4 Global Relevance

While frugal innovation has been primarily associated with emerging economies, its principles and approaches hold immense relevance for addressing societal challenges in developed nations as well. As regions across Europe and North America grapple with the increasing frequency and intensity of flooding events, the lessons and insights from frugal innovation can offer valuable pathways to build resilience in a cost-effective and socially inclusive manner (Green infrastructure and flood management, 2017).

For instance, the city of Rotterdam in the Netherlands has embraced frugal innovation in its efforts to enhance flood resilience. Recognizing the limitations of traditional grey infrastructure, the city has instead focused on integrating nature-based solutions, such as the creation of public spaces that can double as temporary water storage during floods. Initiatives like the "Floating Pavilion" and the "Water Plaza" demonstrate how frugal innovation can reconcile viable business models with long-term societal and environmental goals, showcasing the potential for frugal approaches to be adapted and applied in the European context (Kroll & Gabriel, 2020). Similarly, the city of New York has leveraged frugal innovation to address the challenges of urban flooding. Following the devastating impact of Hurricane Sandy, the city has invested in community-driven initiatives that empower residents to implement low-cost, nature-based solutions to mitigate flood risks (Rosenzweig & Solecki, 2014). These efforts, such as the "Green Infrastructure Grant Program," highlight how frugal innovation can be harnessed to build resilience, foster social inclusion, and drive sustainable development in developed economies (Derickson et al., 2021).

The notion of frugal innovation, with its focus on optimizing functionalities and using resources wisely, aligns closely with the growing emphasis on sustainability and circular economy in European markets closely followed by the American market (Gandenberger et al., 2020). By adopting a frugal mindset, European innovators can develop solutions that not only meet the needs of vulnerable communities but also contribute to long-term ecological and social sustainability (Kroll & Gabriel, 2020). Given the increasing focus on these principles, it becomes clear that frugal innovation, although originating in the global south, has much to offer to the global north, especially with rising inequality and budget constraints associated with climate change and its impacts (Gandenberger et al., 2020). The principles of optimizing functionalities, using resources wisely, and developing socially relevant solutions can be invaluable in addressing challenges faced by vulnerable communities in developed nations as well. By embracing the frugal mindset, European and North American innovators can unlock cost-effective pathways to build resilience, foster sustainability, and promote social inclusion, ultimately contributing to a more equitable and sustainable future for all (Kroll & Gabriel, 2020).

4.4 Contextual Challenges in the Global South

The terms "Global North" and "Global South" are increasingly used to summarize and capture the stark socio-economic and political disparities that exist within the contemporary world. These terms move beyond simple geographical designations, instead representing a complex interplay of historical legacies, power dynamics, and development trajectories (Chitadze, 2023) . The Global North, broadly encompassing North America, Europe, Australia, and Japan, is often characterized by its affluence, advanced infrastructure, and dominant role in global decision-making processes. Conversely, the Global South, which includes Latin America, Africa, Asia (excluding Japan), and Oceania (excluding Australia and New Zealand), often grapples with challenges such as poverty, inequality, and the legacies of colonialism (Dados & Connell, 2012). This divide is not static; it has evolved throughout the 20th century. The post-World War II era witnessed the rise of decolonization movements, dismantling formal colonial structures. However, this period also saw the emergence of new forms of global power imbalances, often framed within the context of the Cold War. The Global South found itself navigating a world order shaped by competing ideologies and economic systems, often with limited agency in shaping their own development paths (Dados & Connell, 2012). The latter part of the 20th century saw the rise of globalization, characterized by increased interconnectedness through trade, technology, and cultural exchange. While globalization presented opportunities for growth and development, it also exacerbated existing inequalities between the

Global North and South. Such historical and contemporary dynamics have shaped the relationship between the Global North and South and will be crucial for understanding and further addressing global challenges of the 21st century, including those related to climate change, disaster risk reduction, mass migration, and sustainable development (Chitadze, 2023).

4.4.1 Contextual Differences in Flood Resilience Strategies

The implementation of effective flood resilience strategies is heavily influenced by the unique socio-economic and institutional contexts of the Global North and Global South (Herath & Wijesekera, 2020). In the Global North, flood risk management has typically focused on macro infrastructure-based approaches, such as the construction of flood protection systems encompassing and protecting a large area or integrated within an overarching system (Laeni et al., 2021). This approach is often facilitated by the availability of financial resources and the presence of established institutional frameworks along with more stability and developed governance (Johannessen & Mostert, 2020). In contrast, the Global South often faces significant resource constraints and institutional weaknesses that hinder the implementation of large-scale, capital-intensive flood resilience measures, in turn hindering rapid recovery after a disaster onslaught. Instead, communities in the Global South have often relied on more locally-driven, community-based strategies to address flood risks (Jonga et al., 2021). These strategies may include the use of nature-based solutions, such as the preservation and restoration of wetlands (Klijn et al., 2021), as well as the incorporation of traditional knowledge and practices into flood preparedness and response (Herath & Wijesekera, 2020). These approaches, while potentially less resource-intensive, may be more adapted to local conditions and communities in the Global South. Moreover, the underlying drivers of flood risk in the Global South are often more complex, with factors such as rapid urbanization, ecological degradation, and socio-economic inequalities playing a significant role (Laeni et al., 2021). In many cases, flood-prone communities in the Global South are also grappling with the broader challenges of sustainable development, where the costs of disaster recovery can divert resources away from long-term investments in infrastructure, social services, and economic growth, presenting thus a sharp and uneasy balance between short-term resilience and long-term development (Mochizuki et al., 2014).

4.4.2 Knowledge Transfer in Flood Resilience

While the Global North has often been at the forefront of developing flood resilience strategies, transferring these approaches to the Global South presents unique challenges. Directly applying resource-heavy solutions developed in the Global North to the Global South often proves ineffective and, at times, even detrimental (Reidpath & Allotey, 2019). This is due to a confluence of factors, including differing socio-economic contexts, governance structures, and cultural perspectives on risk and resilience. One significant challenge is the resource intensity of many flood resilience solutions commonly employed in the Global North, something the Global South more than often does not posses the industry and logistics to accomplish (Nur & Shrestha, 2017). Large-scale infrastructure projects, such as dams, levees, and sophisticated early warning systems, require substantial financial investments, advanced technological expertise, and sophisticated institutional capacity for implementation and maintenance. The burden of flood infrastructure maintenance is often further underestimated; these projects necessitate consistent funding to ensure their long-term structural integrity and preparedness on the eve of disaster onslaught combined with up-to-date early warning systems and often expensive operators (Zevenbergen et al., 2016). The main challenge here is that these strategies require long-term planning which stems from stable institutions and governance which many developing countries in the Global South often lack (Nur & Shrestha, 2017). More then

often such endeavors are deemed too costly and ore do not align with the short-term political goals of the governing regimes .

This mismatch between the requirements of these large-scale solutions and the realities of many Global South contexts highlights a crucial point: the resources required for these projects (i.e., financial, technological, political, and human) are often scarce in these regions (Nur & Shrestha, 2017). This scarcity makes replicating the resource-intensive solutions of the Global North exceptionally difficult, however, this challenge has also fostered innovation. The Global South has developed its own array of innovative, cost-effective, and contextually-appropriate approaches to flood resilience . These approaches, often born out of necessity and shaped by local knowledge, have the potential to benefit not only the Global South but also to complement and enhance the strategies employed in the Global North in the 21st century (Tsekleves et al., 2020).

Furthermore, cultural and societal contexts play a crucial role in shaping flood resilience strategies. Communities in the Global South often possess unique and valuable traditional knowledge and practices for coping with flood risks (Klijn et al., 2021). These practices, often deeply embedded in local customs and beliefs, are sometimes overlooked when transferring solutions from the Global North. Ignoring or undermining such local knowledge can lead to ineffective and unsustainable solutions that fail to resonate with the lived experiences of communities they intend to serve (Nur & Shrestha, 2017). Governance structures and institutional capacity also significantly impact the transferability of flood resilience solutions. The Global South often faces challenges related to weak governance, limited institutional capacity, and, in some cases, corruption (Ogie et al., 2019). These factors can hinder the effective implementation and long-term sustainability of even well-designed flood resilience strategies which attempt to take the local context and status quo into account.

4.5 Urban Expansion and River Degradation in the 20th Century

A legacy of 20th-century urban planning policies in both the Global South and Global North prioritized urban development at the expense of the natural riverine courses. This was done with a focus on designing many cities with a focus on maximizing land for urban use, often by channeling or piping rivers, subsequently reducing the capacity of these natural systems to absorb and manage floodwaters (Sörensen et al., 2016). The drive to "reclaim" land for urban expansion led to the loss of floodplains, wetlands, and other natural buffers that historically mitigated flood risks. These policies have created an urban environment that is increasingly vulnerable to flooding as natural waterways have been diminished or restricted, in turn leading to disastrous consequences during extreme weather events (Itsukushima & Ohtsuki, 2021). The origins of this prioritization of urban land development can be traced towards a range of factors; including rapid population growth, industrialization, and the influence of powerful developmental interests.

These urban expansionist policies originated from the industrialization and urbanization processes in the Global North, particularly in the late 19th and early 20th centuries with the advent of the the steam engine and mass production (Itsukushima & Ohtsuki, 2021). These areas underwent rapid urban growth, driven by industrial development and the need to accommodate growing populations (Wantzen et al., 2022). To make way for factories, transportation networks, and residential areas, urban planners sought to control and "tame" natural waterways and water bodies. Rivers were often seen as impediments to urban progress, resulting in large-scale interventions such as channeling, embankments, and the paving over of rivers (Itsukushima & Ohtsuki, 2021). The rapid expansion of cities in the Global North followed this model, where the emphasis was on reclaiming land rather than preserving the natural ecosystems previously there. Such planning practice and governance

from the Global North were exported to the Global South during colonization and post-colonial development, often presented as symbols of metropolitan prosperity (King, 2015). These imported urban planning frameworks, often technocratic in nature, neglected to adequately consider the needs and perspectives of the broader population, particularly the less privileged segments of society. As a result, this oversight at times exacerbated existing inequalities and perpetuated conditions of poverty (Chatterjee & Chattopadhyay, 2020). Furthermore, this prioritization of foreign, technocratic solutions over locally driven, frugal approaches, often rooted in traditional knowledge and a harmonious relationship with nature, undermined the development of sustainable and context-appropriate urban planning, creating long-term vulnerabilities. (Chatterjee & Chattopadhyay, 2020). This imitation phenomena further intensified throughout the 20th century, where cities in the Global South sought to emulate similar urban expansion strategies involving the channeling of rivers, draining wetlands while converting floodplains into urban centers to fuel rapid economic and population growth (Chatterjee & Chattopadhyay, 2020).

4.5.1 Urban Expansion: Impacts on Rivers and Society

While these policies achieved short-term urban expansion goals, the unchecked urbanization in both the Global North and Global South led to long-term environmental degradation and vulnerability (Fang et al., 2023). Historically in the Global North, the focus on land reclamation for economic development ignored the vital ecological and self-regulating roles played by rivers, wetlands, and floodplains (Itsukushima & Ohtsuki, 2021). By reducing these natural systems, cities became more vulnerable to flooding, a vulnerability that has been magnified by the increasing frequency of extreme events due to increasingly inclement weather patterns (Wantzen et al., 2019). In such cities, urban rivers were largely channelized or covered over, leading to an increased imperviousness of the built environment serves to diminish the land's capacity to absorb water, consequently resulting in recurrent and catastrophic urban flooding, despite recent adaptative measures. Similarly, in cities in the Global South, rapid, poorly regulated urban expansion onto floodplains and riverbanks significantly heightened flood risks (Sörensen et al., 2016). The main difference here is that while cities in the Global North often had the financial and technological capacity to mitigate and diminish some of these issues through infrastructure upgrades and flood management systems, many cities in the Global South continue to struggle with inadequate resources and poor governance structures, leaving them more vulnerable to the impacts of these historical planning decisions (O'Brien et al., 2012).

Figure 13 : Channeling of Rivers: An Urbanistic Error

From “Soluções contra enchentes: especialistas alertam para erros urbanísticos como a canalização de rios, 2020, (https://www.tvsul.tv.br/solucoes-contra-enchentes-especialistas-alertam-para-erros-urbanisticos-como-a-canalizacao-de-rios/)

The environmental consequences of these urban planning decisions are profound and longlasting. By reducing the capacity of natural water systems to manage and absorb floodwaters, cities have became more prone to flooding, particularly during extreme weather events. However, the consequences are certainly more severe in the Global South due to limited resources for upgrading and maintaining flood resilience infrastructure (Rentschler et al., 2022). As rivers are confined to ever-narrower channels, their ability to manage surges in water levels durng heavy rainfall diminishes, leading to urban flooding that overwhelms drainage systems and city infrastructure. In addition to environmental degradation, these policies also have significant social consequences, particularly in the Global South (Wantzen et al., 2019), where the urban poor often live in informal settlements on riverbanks or low-lying areas, and are thus disproportionately exposed to flood risks. As wealthier populations occupy safer urban centers, marginalized communities are pushed into the most vulnerable areas, exacerbating their exposure to floods and limiting their access to post-disaster recovery resources and services (Rentschler et al., 2022). This social stratification is a direct result of urban policies that prioritized land reclamation over equitable, sustainable development.

4.5.2 20th-Century Planning: Unchecked Expansion to Vulnerability

The planning ideologies of the 20th century, rooted in the modernization and industrialization goals of the Global North, heavily influenced urban policies in the Global South (Chatterjee & Chattopadhyay, 2020). These ideologies were driven by a desire for economic progress and industrial growth, often at the expense of environmental and social considerations. The prevailing approach was to manage natural environments through technological interventions, such as dams, levees, and drainage systems, while neglecting the benefits of incorporating and leaving room for nature in urban planning and design. (Loggia et al., 2020). This approach was replicated across many cities in the Global South, where rapid population growth and urbanization were seen both as necessary and inevitable to achieve economic development (Wantzen et al., 2019). In the Global South, these ideologies were adopted by post-colonial governments eager to modernize their cities and attempt to compete on the global economic stage (Randolph & Storper, 2021). The result was a focus on infrastructure-heavy solutions that prioritized urban expansion over environmental sustainability. However, as climate change has intensified and extreme weather events have become more common, the limitations of this approach have become increasingly apparent. Cities that rely on outdated flood management systems based on 20th-century models are ill-equipped to handle the unpredictability of modern climate challenges (Takin et al., 2023).

Figure 14: Inequality & Vulnerability

From "Agência Brasil, 2023, (https://agenciabrasil.ebc.com.br/geral/noticia/2023-12/museu-da-mare-no-rio-tera-acervo-na-internet-com-mais-de-mil-itens)

Additionally, cities in the Global South have experienced recent population booms, which have extended further into the 21st century in contrast to cities in the Global North, in turn placing further pressure on often poorly maintained and already congested systems (Wantzen et al., 2019). This continuous population surge is expected to intensify in the upcoming years, especially if socioeconomic inequalities remain at a high, further exacerbating the vulnerability of these regions towards climate-induced flood risks. The strain on infrastructure in rapidly urbanizing cities will only grow as population increase and already inadequate flood resilience systems are pushed to their limits (Nur & Shrestha, 2017). This phenomenon of unrestrained urban expansion serves to perpetuate the heightened risks associated with climate change while also underscoring how the infrastructure built to manage water flows in the 20th century is now woefully inadequate for the unpredictable and extreme weather events seen today (Itsukushima & Ohtsuki, 2021). In cities where natural river systems have been altered or degraded, the inadequate infrastructure struggles to cope with the growing climate risks. This issue is particularly acute in the cities of the Global South, where rapid and often unplanned urbanization continues without adequate foresight or investment in planning and preparing for the future impacts of climate-induced floods along with the usage of often archaic and outdated methods and solutions (Nur & Shrestha, 2017). With limited resources and governance challenges, these cities face heightened vulnerabilities as their altered natural systems struggle to provide the necessary flood resilience in the face of growing climate risks (Nur & Shrestha, 2017).

4.5.3 Pathways to Restoring Natural Systems and Achieving Flood Resilience

To address the legacy of these historical policies, cities across the globe must shift toward a sustainable urban planning that integrates flood resilience with the restoration of natural water systems. For cities in the Global South specifically, this can mean adopting frugal solutions as a way to overcome reliance on foreign intervention and governance while proving adaptation and knowledge building (Loggia et al., 2020). This often relies in traditional nature-based solutions that can help restore the natural capacity of rivers, wetlands, and floodplains to absorb floodwaters (Fang et al., 2023). Therefore, these approaches tend to include re-establishing floodplains, creating green spaces, and implementing urban water management strategies that can significantly enhance flood resilience and involve the community (Takin et al., 2023). While efforts to restore natural systems and shift away from river burial are underway across the globe, progress in the Global South is often

too little, too late (Wantzen et al., 2019). These initiatives are frequently small-scale and lack the necessary scope and urgency to positively impact flood resilience. Instead, many cities in the Global South continue to rely on traditional engineering techniques, such as constructing larger channels or pipes to redirect water (Loggia et al., 2020). However, these interventions often exacerbate problems by merely shifting flood risks downstream, where the volume of water overwhelms already stressed river systems.

Moreover, the continued dependence on these infrastructure-heavy solutions reflects a broader challenge: while nature-based solutions are increasingly discussed, the actual implementation is often underappreciated and problematic (Nelson et al., 2020). Projects are frequently fragmented, poorly executed, or hampered by high costs, making them inaccessible to resource-constrained areas. This over-reliance on outdated and inefficient solutions further delays progress toward sustainable flood resilience and leaves cities vulnerable to intensifying climate risks (Nelson et al., 2020). In contrast, cities in the Global North, where many have recognized the long-term benefits of restoring natural waterways, have begun to reverse the damage caused by 20th-century urban policies (Loggia et al., 2020). Initiatives like the Room for the River program in the Netherlands—which creates space for rivers to overflow naturally during floods—provide a successful avant-garde model for integrating nature-based solutions into urban planning with its largest challenge being the integration of a plethora of several stakeholders, their motifs, wants and don'ts for land use within its scope (Rijke et al., 2012), thus making the problem somewhat "complex". Such approaches, while promising, are still not widely adopted in the Global South, where systemic issues in governance, planning, and resource allocation hinder their implementation in such an endeavour.

4.6 Overcoming Systemic Barriers to Flood Resilience in the Global South

The recurring failures of flood resilience frameworks in the Global South are rooted in a combination of structural, governance, and socio-historical factors. These failures are driven by several key factors that highlight why existing models have been unable to break the cycle of vulnerability and achieve sustainable flood resilience. This paper will procced to outline the various factors underpinning the mentioned deadlock.

4.6.1 Lack of Long-Term Planning

A critical flaw in current flood resilience mechanisms in the Global South is the absence of a comprehensive, long-term plan. This failure is deeply rooted in the region's political instability and oscillations in governance priorities and motivation. Governments in these regions are more then often subject to frequent and unexpected changes, whether through elections, coups, or other forms of political turnover, which disrupt the continuity needed for long-term, sustainable planning (Lindersson et al., 2023). The focus shifts from building resilient, future-proof infrastructure to short-term, "reactive projects" aimed at delivering immediate, and most importantly visible results. In the current digital age, these political oscillations are further compounded by the rise of fake news and misinformation, leaving a distorted public perception of climate risks and environmental management in its wake (Cook, 2019). Politicians, influenced by public opinion and swayed by misinformation, may deprioritize or even reject scientifically sound flood resilience measures. In many cases, political leaders might even seek to capitalize on crisis situations, engaging in political one-upmanship by promoting quick, but often low-quality infrastructure projects designed to gain public favor (Rasmussen et al., 2020). These reactive developments are typically focused on emergency relief rather than addressing the underlying vulnerabilities that lead to recurring flood disasters.

Political one-upmanship also encourages the allocation of public funds to highly visible projects, such as temporary flood barriers or superficial upgrades to drainage systems, without addressing the root causes of flood risk (Gawel et al., 2016). These projects are often hastily approved and poorly executed, resulting in low-quality infrastructure that deteriorates quickly and fails to withstand upcoming and ever-more extreme weather events. This creates a vicious cycle of investment in infrastructure that is not ineffective and ends up diverting resources away from more sustainable, long-term resolutions. In addition, the instability in governance often results in abrupt policy shifts (Gawel et al., 2016). Long-term flood resilience strategies are discarded or revised by successive administrations, further complicating efforts to establish a cohesive, enduring approach to flood management. As political leaders prioritize immediate returns on investment, there is little room for the kind of forward-thinking planning required to prepare for the increasing frequency and intensity of climate-induced floods (Rasmussen et al., 2020).

The May 2024 floods in Rio Grande do Sul serve as a prime example of the consequences of short-termism. Despite historical warnings about the region's vulnerability, successive governments failed to invest in adaptive infrastructure that could evolve with changing flood risks (Rocha, 2024). Instead, political actors opted for reactive, short-term measures that collapsed under the weight of extreme weather, leaving communities devastated and unprepared. By not investing in adaptable, resilient strategies and infrastructure, regions such as this remain locked in a cycle of vulnerability, constantly responding to disasters and their onslaught instead of trying to proactively mitigate them. This lack of forward-thinking planning leaves communities unprepared for the increasing severity and unpredictability of flooding caused by climate change, perpetuating the cycle of flood vulnerability in the Global South (Rentschler et al., 2022).

4.6.2 Competing Values, Social Inequality, and Poor Regulation

One of the primary barriers to achieving effective flood resilience in the Global South lies in the persistent tension between economic development priorities and the need for environmental and social sustainability. Urbanization and industrial expansion are often prioritized over effective flood risk mitigation, leading to the continuous encroachment on natural floodplains, wetlands, and rivers (Rentschler et al., 2022). This push for economic growth inadeptly results in decisions that prioritize immediate profits and infrastructure development, frequently at the expense of long-term flood resilience (Gawel et al., 2016).

In this context, the widening gap between rich and poor further exacerbates the consequences of flooding. Research has consistently shown that the wider the socioeconomic disparity, the higher the mortality rate and long-term impacts of floods on low-income communities worldwide (Lindersson et al., 2023). Wealthier urban populations often benefit from more robust infrastructure, better housing, and quicker emergency services and response, whereas poorer communities are often confined to informal settlements in high-risk floodplains or low-lying riparian areas (Lindersson et al., 2023). These marginalized communities face disproportionately higher risks due to inadequate housing, lack of access to emergency services, and a greater exposure to the impacts of flood events. The failure of flood resilience frameworks to adequately address these disparities ensures that flood impacts are not only more severe for the poorest but also that recovery efforts are slower and less effective. These dynamics perpetuate a cycle where the poorest communities suffer the most and recover the least, leaving them perpetually vulnerable to the next flood (Rentschler et al., 2022).

Despite the existence of regulations that prohibit settlement in high-risk flood plains; these rules are often poorly enforced or entirely ignored by the governing bodies. Weak governance, political pressures, and corruption often allow informal settlements to expand unchecked in flood-prone

areas (Rentschler et al., 2022). Rapid urbanization, lack of affordable housing, and inadequate urban planning force low-income populations into the most vulnerable areas, with little support to improve their living conditions or access safer locations. When resettlement programs are proposed, they often suffer from ineffective planning, underfunding, and poor execution (Cernea, 2021). The lack of long-term strategy in these programs means that affected populations are either not relocated at all or moved to areas that lack the necessary infrastructure, job opportunities, and social services, perpetuating the cycle of poverty and vulnerability (Cernea, 2021). In some cases, communities resist resettlement efforts, as the alternative housing offered is far removed from economic centers, leaving them worse off than before. Meanwhile, the vacated floodplain areas are frequently redeveloped for commercial purposes, benefiting private interests while further endangering poor communities forced to relocate to other vulnerable zones (Cernea, 2021).

Another key failure in the current flood resilience mechanisms in the Global South is the lack of an effective and rehearsed first-response planning system (McDermott, 2022). Flood-prone areas are often ill-prepared to respond quickly and effectively when a disaster strikes. Emergency response teams are underfunded, uncoordinated and sometimes even lack the training and resources to properly manage a flood crisis. Moreover, the lack of systematic drills and rehearsals contribute to the general to unpreparedness within the communities for immediate flood response, leaving society disorganized and fractured in the event of a natural disaster (Perera et al., 2020). This lack of preparedness extends beyond the immediate flood event to the recovery phase. The absence of clear, well-coordinated post-disaster recovery measures and plans leads to a fragmented response, where multiple levels of governance fail to collaborate effectively (Perera et al., 2020). This inefficiency and lack of coordination perpetuate the impacts of the disaster, keeping communities vulnerable and preventing them from recovering in time before the next flood strikes, henceforth maintaining the vicious cycle of flood unpreparedness (Rentschler et al., 2022).

4.6.3 Fragmentation of Governance and Lack of Coordination in Flood Management

A key challenge in achieving sustainable flood resilience in the Global South lies in the fragmentation of governance across different levels of government. This fragmentation results in a failure to coordinate comprehensive flood management strategies that span across broader regions, such as river basins or floodplains, which are inherently interconnected (Takin et al., 2023). The lack of a unified governance framework leads to conflicting agendas, inefficiencies, and gaps in accountability. This disjointed approach to governance not only complicates flood response efforts but also perpetuates the vulnerability of at-risk communities. For instance, in many countries, the responsibility for flood management is divided between different government agencies, each with its own mandates, resources, and priorities.

The absence of macro-level planning across interconnected regions in the Global South, particularly in river basins, coastal zones, and urban floodplains, has severe implications for flood resilience (Rentschler et al., 2022). Floods are not confined to municipal or state boundaries; they affect entire river systems and regional ecosystems, requiring integrated planning and cooperation across jurisdictions and governmental levels (Takin et al., 2023). However, flood resilience measures are often implemented in isolation, with little regard for their downstream or upstream impacts. This piecemeal approach fails to address the complexity of flood systems and ends up limiting the effectiveness of integrated efforts. Moreover, high level agencies often operate independently of one another, resulting in often paradoxically contradictory policies and priorities (Takin et al., 2023). For instance, while the federal government may have flood control policies in place, state

governments may focus on industrial expansion in flood-prone areas, and municipalities might prioritize urban development over flood risk mitigation. The lack of alignment across these levels of governance creates confusion, delays in decision-making, and resource misallocation (Farahmand et al., 2020). This further exacerbates the risks posed by floods, as no single agency takes responsibility for comprehensive flood management.

4.6.4 Lack of Community Engagement and Participation

Another critical shortcoming of the current governance structure is the lack of meaningful community engagement and participation in flood resilience planning. Vulnerable communities are more than often marginalized from the decision-making processes related to flood resilience planning (Nur & Shrestha, 2017). Top-down governance approaches tend to focus on technocratic solutions devised by experts, policymakers, and external consultants, with little input from the local populations who are directly affected by floods (Nur & Shrestha, 2017). This disconnect between decision-makers and communities can lead to a lack of trust in flood resilience action, in turn contributing to its poor implementation and compliance within the domain o flood risk regulations.

In many cases, local communities possess invaluable knowledge of the land, its water systems, and historical flood patterns, but this expertise is largely left to the sidelines. Indigenous and rural communities in the Global South may have cultivated traditional flood management approaches, such as leveraging natural indicators for flood forecasting or adopting sustainable agricultural practices tailored to periodic inundation events (Xiaoying, 2019) . However, failing to engage these communities results in their valuable knowledge and expertise being overlooked, consequentially leaving them disempowered and further marginalized from effective flood resilience strategies. Moreover, community engagement is essential for ensuring that flood resilience strategies are socially and culturally inclusive and appropriate (Nur & Shrestha, 2017). When communities are not involved in planning processes, flood mitigation measures ultimately fail to account for local needs, priorities, and social imperatives. For instance, resettlement programs often displace communities from their homes and livelihoods without considering the socioeconomic impacts of relocation and how that shapes the community's resilience or lack thereof (Cernea, 2021). In the absence of sufficient input from affected populations, these programs end up being poorly implemented while also encountering resistance from the very communities they aim to protect (Cernea, 2021).

4.6.5 Perpetuation of the Vicious Cycle of Disaster Vulnerability

The failure to effectively coordinate flood resilience planning across different levels of governance, engage local communities, and prepare for immediate flood responses perpetuates the vicious cycle of flood vulnerability described within the body of this study. Without integrated, long-term strategies, flood-prone areas are left exposed to repeated disasters, with each flood further degrading previously developed infrastructure, deepening poverty, and eroding the social fabric of affected communities (O'Brien et al., 2012). The lack of post-disaster coordination and recovery planning ensures that communities are unable to rebuild effectively, leaving them even more vulnerable to the next flood. Moreover, the disjointed nature of flood resilience governance in the Global South contributes to the marginalization of vulnerable population; particularly the poor, women, and ethnic minorities, who are disproportionately impacted by recurring flood disasters and their consequences (Choudhury & Haque, 2016).

In addition, the failure to engage communities and incorporate their knowledge and needs into flood resilience strategies ensures that solutions remain top-down and technocratic, disconnected from the realities on the ground (Nur & Shrestha, 2017). This approach reinforces a cycle of mistrust

between governments and the populations they are supposed to protect, undermining the effectiveness of flood resilience measures and further entrenching the vulnerabilities of the community. The long-term consequences of this fragmented and ineffective governance structure are then clear; without coordinated macro-area planning, community participation, and rehearsed first-response systems, flood-prone regions will continue to experience increasing frequency and intensity of disasters (O'Brien et al., 2012) . Therefore, the governance systems currently employed in the Global South, are ill-equipped to address the growing risks posed by climate change and rapid urbanization. Breaking this cycle will require better coordination across levels of governance along with a fundamental shift toward a more inclusive, community-driven plethora of flood resilience strategies that prioritizing long-term sustainability over short-term economic gains (Nur & Shrestha, 2017).

4.7 Institutional Frameworks for Flood Resilience

Institutional frameworks refer to the complex web of rules, regulations, and organizational structures that govern and shape societal processes (Farahmand et al., 2020). These frameworks play a crucial role in determining the resilience of communities to environmental challenges, such as the threat of floods (Gilissen et al., 2016). Successful institutional frameworks can facilitate coordinated, adaptive responses to disaster management, while failures can exacerbate vulnerability and undermine resilience efforts (Muhonda et al., 2014). Essentially, they provide a framework for action and interaction, setting the "rules of the game" for how things work in a particular context. These frameworks are especially important for sustainability transitions, which often involve significant societal shifts and require coordinated action from diverse stakeholders. This is because effective institutional frameworks provide the mechanisms for stakeholder engagement, coordination, and conflict resolution. They establish platforms for dialogue, negotiation, and collaborative decision-making, ensuring that diverse voices are heard and considered (Schoon & Cox, 2018).

4.7.1 The Role of Institutional Frameworks in Flood Resilience

Institutional frameworks play a significant role in shaping the resilience of communities to floods. Successful frameworks can facilitate coordinated, adaptive responses to disaster management, while failures can exacerbate vulnerability and undermine resilience efforts (Hegger et al., 2016). Institutional frameworks contribute to flood resilience in several key ways. They can establish mechanisms for coordinated, adaptive disaster management responses, or alternatively, exacerbate vulnerability and undermine resilience efforts if they fail to function effectively. For example, well-designed frameworks can enable early warning systems, disaster planning, and post-disaster recovery efforts (Gilissen et al., 2016). They can also facilitate the integration of scientific knowledge, community-based expertise, and traditional ecological knowledge to inform decision-making and improve flood preparedness (Almutairi et al., 2020). Importantly, institutional frameworks also influence whether frugal innovations are legitimized and scaled. When institutional mechanisms are rigid or overly technocratic, they may unintentionally marginalize such bottom-up initiatives. Conversely, adaptive frameworks that embrace decentralization and inclusivity can enable frugal innovations to flourish by recognizing their value in resource-constrained settings.

Conversely, institutional failures can undermine resilience by creating barriers to cross-scale coordination, inadequate funding for infrastructure maintenance, or a lack of inclusive governance processes that consider the needs of marginalized communities (Gim et al., 2019). As (Mian, 2014) notes, there is a need to better understand "how an alternative framework and the mechanism for

driving a change towards it" can help communities cope with future flood challenges through "adaptive governance" approaches. While institutional frameworks in the Global North have often focused on structural flood protection measures, such as dikes and levees, recent literature has emphasized the need for a more diversified approach that includes spatial flood adaptation, storm water management, community preparedness, and emergency responsiveness (Meng et al., 2020). This shift in perspective recognizes the limitations of traditional flood control measures and the importance of building resilience through a range of complementary and more adaptive strategies. Successful institutional frameworks in the Global South must similarly adopt a more holistic and adaptable approach, moving beyond rigid structures and incorporating local knowledge, community-based solutions, and flexible governance mechanisms (Yasmin et al., 2019).

Such integrative perspective can further grant access to flood preparedness to communities which are often devoid of capabilities to do so due to a complex confluence of factors, leaving them at the mercy of the rain patterns. These tend to include the historical legacies of colonialism, poor and fragmented governance structures, as well as the disproportionate impacts of climate change leading to more frequent and severe weather extremes in these regions (O'Brien et al., 2012). By embracing a more process-oriented, adaptable, and inclusive approach, institutional frameworks can better support frugal innovation and enhance flood resilience in these vulnerable communities (O'Brien et al., 2012). This shift towards flexibility and local empowerment is crucial, as it allows institutional frameworks to better respond to the unique social, economic, and environmental contexts of the Global South, rather than imposing rigid, one-size-fits-all solutions imported from the Global North. Through this adaptive and participatory approach, institutional frameworks can play a vital role in building the capacity of marginalized communities to withstand and recover from the devastating impacts of floods (Fang et al., 2023).

4.7.2 Challenges and Adaptations in Institutional Frameworks: Global North vs. Global South

Institutional frameworks for flood resilience face a range of common challenges, both in the Global North and the Global South. One key challenge is the tendency for frameworks to be overly rigid and centralized, failing to adapt to the diverse local contexts and needs of communities. This becomes even more challenging when the solution or governing body is exported from one country to another, as the "status quo" and entrenched stakeholders in the recipient country may resist changes that disrupt existing power structures and resource flows (Dewulf et al., 2019). Another challenge is the lack of inclusive governance processes that engage a wide range of stakeholders, including marginalized communities, in decision-making. This can lead to the prioritization of flood protection measures that benefit certain groups over others, while failing to address the unique vulnerabilities and needs of the most at-risk populations (Herreros-Cantis et al., 2020). This highlights the importance of ensuring that institutional frameworks for flood resilience are developed through a collaborative process that involves both national and local governments, as well as the communities they serve.

However, institutional frameworks imported from the Global North often fail in the Global South because they do not account for local complexities and governance challenges unique to the region where they are attempted. The failure of these transplanted frameworks can be attributed to their rigid, technocratic-focused frameworks and governance, which lack the flexibility needed to respond to the discretionary and resource-intensive nature of service delivery in flood resilience efforts and practices (Pritchett & Woolcock, 2003). By overlooking local governance systems, social structures, and resource limitations, these frameworks often exacerbate existing vulnerabilities rather than

working to foster resilience. This highlights the critical need for more adaptable and participatory models that empower local stakeholders and communities to be actively involved in decision-making, ensuring that institutional frameworks are tailored to their specific needs and realities (Pritchett & Woolcock, 2003). In this context, transition management might offer a way of fidning compromise thus breaking the mentioned deadlock regarding flood resilience in the Global South (Yasmin et al., 2019). This approach emphasizes the importance of a long-term policy vision combined with short-term experimental learning to enable governance frameworks to adapt iteratively over time (Voß et al., 2009). This adaptive process is particularly relevant in the Global South, where fragmented governance structures make rigid, top-down frameworks less effective. By allowing for iterative experimentation and deliberation, transition management encourages a more flexible, reflexive governance approach that can evolve with changing socio-political and environmental contexts (Voß et al., 2009).

Furthermore, the resilience and long-term application of institutional frameworks in many countries, especially in the Global South, is often hindered by individual power dynamics, political campaigning, and political instability (Dewulf et al., 2019). The transient nature of political leadership and the influence of entrenched stakeholders who resist changes that disrupt existing power structures and resource flows can undermine the continuity and effectiveness of institutional frameworks designed to enhance flood resilience (Gersonius et al., 2016). This resistance is often rooted in the historical legacies of centralized governance, where power has traditionally been concentrated in elite groups chosen by the colonial power, further complicating efforts to implement adaptive and community-centered governance structures (Pritchett & Woolcock, 2003). Another challenge involves the frequent lack of long-term vision and commitment to maintaining these frameworks. Short-term political cycles often prioritize immediate, visible results over sustained investment in flood resilience measures, leading to a neglect of crucial maintenance and updates (Zevenbergen et al., 2016). This can result in the gradual degradation of infrastructure, erosion of institutional knowledge, and a decline in the effectiveness of flood resilience strategies over time. These challenges are particularly acute in regions where governance structures are fragmented, resources are scarce, and the impacts of climate change disproportionately affect marginalized communities (Herreros-Cantis et al., 2020).

Thus, by emphasizing co-evolutionary processes between policy, stakeholders, and governance structures, the transition management approach fosters more inclusive and adaptable institutional frameworks (Yasmin et al., 2019). These frameworks are better equipped to withstand the ebb and flow of political cycles while empowering local stakeholders to take ownership of flood resilience efforts (Voß et al., 2009). Such measures might also provide a way to navigate the paradoxes inherent in flood resilience governance, where strong frameworks are seen as essential but often struggle to adapt to the local contexts in the Global South. By creating more responsive and participatory models that address the unique challenges and needs of each community, transition management can help mitigate these challenges (Voß et al., 2009).

4.7.3 Paradox Perspective of Institutional Frameworks

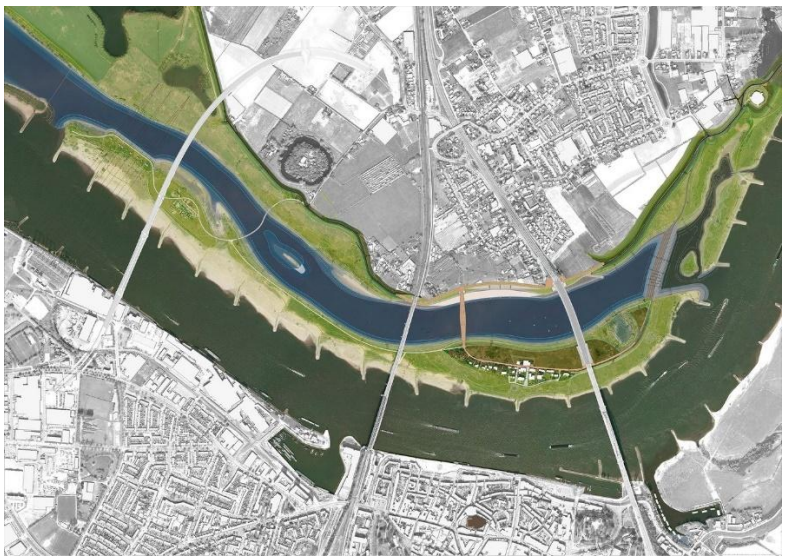
The paradoxical nature of institutional frameworks for flood resilience, particularly when imported from the Global North to the Global South, is a critical consideration. These frameworks, often designed and implemented in the context of developed countries with well-established governance structures, advanced infrastructure, and ample resources, can struggle to adapt to the realities of the Global South, where the "status quo" and entrenched stakeholders may resist the changes required to implement such frameworks effectively (Odeh, 2010). In the Global South, institutional

frameworks are often confronted with a complex web of historical, social, economic, and political factors that can impede their successful implementation (Yasmin et al., 2019). For example, the legacies of colonialism, persistent power imbalances, and limited resources can create significant barriers to the adoption and adaptation of institutional frameworks designed in the Global North, as the construct of the society, decision-making and institution are effectively different than those in developed countries (Odeh, 2010). Moreover, the self-perpetuating cycles of resource distribution, stakeholder influence, and political decision-making can further undermine the effectiveness of these imported frameworks, as they collide with the existing "status quo" and struggle to gain traction within the local context (Yasmin et al., 2019). This paradox highlights the crucial need for a more nuanced and context-sensitive approach to institutional frameworks for flood resilience (Smith & Lewis, 2011). On one hand, there is a recognized need for strong institutional frameworks in the Global South. On the other hand, international institutional frameworks do not always work in the Global South, where progress can sometimes be quicker and perhaps more effective even in the context of institutional voids. This is paradoxical because while strong frameworks are seen as essential, they can be ineffective or counterproductive if not adapted to local conditions.

4.7.4 "Room for the River Program" in the Netherlands

One example of a successful institutional framework for flood resilience is the "Room for the River Program" implemented in the Netherlands. This program adopted a process-based approach that involved giving rivers enough room to rise and expand during flood events, without the built environment becoming inundated (Rijke et al., 2012). This case is especially relevant to this study because it demonstrates how institutional frameworks can actively enable frugal innovation when they embrace flexibility, long-term vision, and nature-based principles over rigid technocratic infrastructure. By prioritizing a more holistic and adaptive approach to flood management, the "Room for the River Program" represented a departure from the traditional focus on flood protection infrastructure, such as dikes and levees (Rijke et al., 2012). Instead, the program sought to create a more dynamic and resilient relationship between the river, the landscape, and the communities living along its banks.

Figure 15 : Room for the River Nijmegen



From “Room for the River Nijmegen” by HNS Landschapsarchitecten, 2015, (https://www.hnsland.nl/en/projects/room-river-nijmegen/)

The program's success can be attributed to several key factors, including the strong institutional and legal frameworks that supported its implementation, the engagement of a wide range of stakeholders in the decision-making process, and the long-term commitment to maintaining an adaptive and flexible approach to flood risk management (Rijke et al., 2014). Moreover, the program's emphasis on giving "room" to the rivers, rather than solely relying on hard engineering solutions, also reflects a growing recognition of the importance of working with natural processes and ecosystems to enhance flood resilience. Therefore , the "Room for the River Program" in the Netherlands provides a valuable case study for understanding how institutional frameworks can be designed and implemented to support more resilient and sustainable approaches to flood risk management (Rijke et al., 2014). Its success highlights the importance of developing institutional frameworks that are adaptive, inclusive, and responsive to the unique challenges and opportunities present in different geographical and socio-political contexts.

Additionally, the "Room for the River Program" in the Netherlands can also be viewed as an example of frugal innovation, even though it was developed in a high-income, industrialized country (Kroll & Gabriel, 2020). Frugal innovation is typically associated with resource-constrained environments and involves creating affordable and accessible solutions by minimizing the use of high-cost technologies. In this program, the emphasis is on working with nature by allowing rivers to expand naturally during flood events, which avoids the need for extremely complicated solutions where a heavily engineered solutions are employed (Bhatti & Ventresca, 2013). This adaptive approach, which leverages natural processes, can be seen as cost-effective and resource-efficient, aligning with the principles of frugal innovation.

However, the program does face challenges when evaluated against the societal relevance axis of frugal innovation. One significant issue is the need for land expropriation, which involves reallocating land from its current uses to create space for rivers to expand (Goossen, 2018). This process often sparks debates over land use and ownership, which are sensitive and contentious issues within society . The requirement to balance flood resilience with the rights and livelihoods of local landowners and communities makes the implementation of such a program complex. These social and political dimensions highlight the difficulty of achieving consensus and the need for careful negotiation and compromise between parties to attain the ends proposed by the program (Goossen, 2018).

This in turn also characterizes the Room for the River as a complex solution where the institutional frameworks must be highly adaptable to navigate socio-political challenges and resistance. This in turn also characterizes the "Room for the River" as a complex solution where the institutional frameworks must be highly adaptable to navigate socio-political challenges and resistance (Baccarini, 1996). Complex solutions often benefit from the use of a paradox perspective to reach such compromises (Lewis & Smith, 2014). The paradox perspective acknowledges that institutional frameworks must address contradictory, interrelated, and persistent challenges. For example, while strong institutional frameworks are often necessary, they must also be flexible enough to adapt to local conditions and stakeholder needs, here exemplified by the greater need of attaining societal flood resilience versus the individual will to use the land as one sees fit (Snel et al., 2021). Recognizing that consensus is often never fully attainable, the program emphasizes ongoing negotiation, adaptation, and learning to manage and mitigate conflicts effectively.

Despite these challenges, the "Room for the River Program" demonstrates that even within the context of developed nations, principles of frugal innovation such as simplicity, cost-efficiency, and leveraging natural systems can be effectively applied to create sustainable and resilient flood

management solutions (Rijke et al., 2014). The program's approach, which avoids complicated and extremely costly solutions, makes it potentially also applicable to the Global South. However, this applicability hinges on overcoming the complex socio-political challenges which tend to be more prevalent in the Global South. If these complex issues can be managed, the "Room for the River" model could offer a viable, cost-effective flood management strategy in resource-constrained environments. This reflects the ongoing debate between the perceived effectiveness of universal, one-size-fits-all solutions versus the critical need to adapt approaches to the unique local conditions, power dynamics, and socio-economic realities present in diverse geographical and political settings (O'Brien et al., 2012). Successful implementation of flood management strategies requires a deep understanding of the complex interplay between institutional frameworks, stakeholder interests, and contextual factors, which can vary greatly between the Global North and Global South (Takin et al., 2023). Highlighting this nuance is crucial to avoid oversimplifying the transferability of solutions and to promote more thoughtful, context-specific approaches to enhancing flood resilience worldwide.

4.8 Comparative Analysis: Frugal Solutions vs. Traditional Methods

Frugal innovation has emerged as a promising approach to address the unique challenges of resource-constrained environments, particularly in the context of flood resilience (Busch et al., 2018). Unlike traditional flood resilience methods, which often rely on extensive and high-cost infrastructure, such as the construction of levees, dams, and drainage systems, frugal innovation focuses on developing cost-effective, context-specific, and sustainable solutions (Weyrauch & Herstatt, 2016). Such traditional methods typically require significant financial investments and are dependent on long-term planning and political continuity, which can be impractical in regions with weak institutional frameworks and limited resources, particularly when referring to the Global South (McDermott, 2022). In contrast, frugal innovation prioritizes core functionality and social relevance while minimizing resource use, making it a more accessible and affordable approach for underserved communities and the goal of sustainable flood resilience.

One of the key advantages of frugal innovation is its ability to address the needs of underserved populations in a more inclusive manner. Frugal solutions tend to be more accessible and affordable, catering to the specific requirements of local communities (Kroll & Gabriel, 2020). However, it is important to acknowledge that, due to their novelty and context-specificity, frugal innovations are often untested and experimental, requiring careful consideration of potential uncertainties such as long-term performance, scalability and maintenance costs (Hill et al., 2023).

Conversely, traditional flood resilience methods, such as the construction of hard engineering structures, have a longer track record and are societally perceived as more reliable and robust (Zevenbergen et al., 2020). Yet, these conventional approaches have also been criticized for their potential to harm riverine ecosystems, increase long-term flood risk, and impose significant financial burdens on local communities and governments (Matczak & Hegger, 2021) while also being less adaptable to the rapidly changing climate and demographic landscapes, limiting their effectiveness in the long term. Furthermore, frugal innovation emphasizes the wise use of resources, minimizing waste and environmental impact, making it a more sustainable approach compared to traditional methods (Brem et al., 2020). In the context of flood defenses, frugal innovation frequently involves nature-based designs that leverage and rejuvenate natural ecosystems to regulate water flow and alleviate the impacts of flooding. This approach offers effective flood protection while also generating environmental and social co-benefits, such as enhanced biodiversity and improved community well-being (Dhyani et al., 2020).

Table 3 : Comparative Analysis of Frugal Innovation and Traditional Flood Resilience Methods

Aspect	Frugal Innovation	Traditional Methods
Cost	Low-cost, accessible, and resource-efficient	High initial investment; long-term maintenance costs
Adaptability	Highly adaptable to local contexts; leverages local knowledge and resources	Less adaptable; dependent on large-scale infrastructure
Environmental Impact	Minimizes environmental impact; often involves nature-based solutions	Can disrupt ecosystems and natural water flow
Implementation Speed	Rapid deployment; minimal reliance on external support	Slower to implement; requires extensive planning and political stability
Community Involvement	High community engagement; context-specific and culturally appropriate	Typically top-down approach; limited community input
Scalability and Reliability	Untested on larger scales; potential uncertainties in long-term performance	Proven reliability in many contexts but may be less effective as conditions rapidly change
Long-term Sustainability	Promotes sustainable practices by integrating with natural systems	May require frequent updates and upgrades to keep pace with changing climate conditions
Technocratic vs. Socio-geographic	Grounded in socio-geographic contexts; emphasizes local engagement and solutions	More technocratic, relying on technical expertise and centralized control
Complexity vs. Complicatedness	Considered complex due to context-specific adaptation and multiple interacting factors	Considered complicated due to technical expertise and large-scale management but follows established procedures
Social Relevance	High social relevance; aligns with local needs and enhances community resilience	Lower social relevance; can be disconnected from local realities and needs

4.8.1 Cross-Regional Comparisons: Global South vs. Global North

The implementation and outcomes of frugal innovation in flood resilience vary significantly across different regions, especially when comparing the Global South and the Global North. In the Global South, frugal innovation has gained traction as a means to address the pressing needs of marginalized communities that often lack access to traditional flood resilience infrastructure (Kroll & Gabriel, 2020) Successful examples include the development of low-cost flood monitoring systems, innovative water harvesting techniques, and community-based early warning systems, all

of which have demonstrated remarkable effectiveness in improving flood preparedness and response (Hossain et al., 2021). One notable success story is found in Bangladesh, where the introduction of floating gardens, known as "baira," has provided a resilient agricultural solution in flood-prone areas (Bala et al., 2020). These gardens, constructed from water hyacinths and bamboo, allow communities to continue farming during the monsoon season when much of the land is submerged (Bala et al., 2020). This innovative practice ensures food security while also sustaining livelihoods in a region traditionally characterized by vulnerability to flooding. Moreover, it promotes an adaptation mindset, encouraging communities to live with more inclement weather rather than simply trying to resist it. By leveraging the community's inherent will to adapt and remain in their homeland, these solutions foster a proactive approach to climate resilience, encouraging participatory planning to potentially overshadow the deadlock involved with applying effective flood resilience (Takin et al., 2023), to thrive amidst increasingly unpredictable environmental conditions. These solutions are often driven by necessity, leveraging local knowledge and resources to create context-specific, sustainable innovations that can be rapidly deployed and maintained with minimal external support (O'Brien et al., 2012). The emphasis on practicality and adaptability allows these frugal innovations to thrive in environments with limited financial resources and weak institutional frameworks (Weyrauch & Herstatt, 2016). The emphasis on practicality and adaptability of frugal innovations allows them to thrive in environments with limited financial resources and weak institutional frameworks, offering a key advantage over traditional flood resilience methods that are often less compatible with the realities of governance and social structures in the Global South (Weyrauch & Herstatt, 2016). Moreover, technocratic frameworks designed in the Global North often fail when directly applied to the Global South due to the fragmented nature of governance in developing countries (Pritchett & Woolcock, 2003). Frugal innovation aligns with adaptive governance processes by emphasizing long-term resilience goals alongside short-term, flexible responses (Bhatti & Ventresca, 2013). This iterative approach, where local solutions evolve based on practical feedback and changing needs, also reflects principles of transition management (Voß et al., 2009). Such models can help to ultimately overcome the rigid, top-down frameworks provided by the Global North, thus promoting a governance that adapts to socio-political and environmental shifts, making these solutions more sustainable and adaptable in the Global South, where they have a better chance of finding compromises for often paradoxical challenges (Voß et al., 2009).

In contrast, the adoption of frugal innovation in the Global North has been more gradual, as these regions tend to have greater access to financial resources and established infrastructure (Kroll & Gabriel, 2020). However, the rising challenges associated with climate change, such as increased frequency and severity of flooding, have begun to highlight the unfeasibility of traditional, capital-intensive approaches (O'Brien et al., 2012). Such solutions will also have to possess ever-more robust designs challenging the availability of resources and the ability of a society to adapt to large-scale and complex issues (Sörensen et al., 2016). The North Sea Closure Project, and its discussions around constructing giant dams to protect against rising sea levels, illustrates the potential pitfalls of this approach (Groeskamp & Kjellsson, 2020). This massive infrastructure proposal has led to a mindset that adaptation is only achievable through the construction of increasingly larger barriers. This belief overlooks the reality that such barriers may ultimately prove insufficient, and their sheer scale and complexity can hinder long-term sustainability and adaptability, even in the Global North (Rasmussen et al., 2023). The notion that society must be protected by ever-larger and more expensive barriers creates an illusion that adaptation is never truly attainable, risking the continuous escalation of solutions that may not be sustainable in the long run (Groeskamp & Kjellsson, 2020).

4.8.2 Lessons Learned: Frugal Innovation vs. Traditional Flood Defense Techniques

The comparative analysis of frugal innovation and traditional flood defense techniques offers critical insights into their respective strengths and weaknesses, as well as the potential for their integration in addressing flood resilience. Both approaches have distinct advantages that can be strategically leveraged to enhance flood resilience in diverse contexts (Sörensen et al., 2016). However, their effectiveness depends technological and adaptive strategies employed but also on the governance and institutional frameworks that support their implementation. However, the effectiveness of these approaches is contingent on the technological and adaptive strategies employed, while also depending on the present institutional frameworks to facilitate or hamper their implementation (Matczak & Hegger, 2021).

4.8.3 Technological and Adaptive Perspectives

From a technological standpoint, frugal innovation excels in its ability to provide cost-effective, context-specific solutions that are particularly well-suited for resource-constrained environments. As demonstrated by the success of floating gardens in Bangladesh and low-cost early warning systems in various parts of the Global South, frugal innovations can be rapidly deployed and maintained with minimal external support. These solutions emphasize adaptability, leveraging local knowledge and resources to create resilient systems that can withstand the challenges posed by climate change (Bala et al., 2020). However, the novelty and context-specific nature of frugal innovations often mean that they are untested on a larger scale, raising questions about their long-term performance, scalability, and maintenance costs (Hossain, 2021).

The novel and context-specific nature of frugal innovations often limits their large-scale evaluation, which raises concerns about their long-term effectiveness, ability to scale, and maintenance requirements (Hossain, 2021). While frugal innovations can be highly innovative and effective in their local contexts, their untested nature on a larger scale raises questions about their long-term performance and scalability. Therefore, scaling up frugal innovations often requires overcoming challenges related to standardization, supply chain integration, and institutional support, which can be difficult to achieve (Hossain et al., 2016). Additionally, the maintenance and upkeep of these context-specific solutions over an extended period may require significant resources and ongoing community engagement, which could limit their widespread adoption and sustained impact. Therefore, more comprehensive evaluation and research are needed to better understand the long-term feasibility and scalability of frugal innovation approaches to flood resilience (Hossain, 2021).

In contrast, traditional flood defense techniques, such as the construction of levees, dams, and drainage systems, have a proven track record of effectiveness in mitigating flood risks, particularly in the Global North (Pearson et al., 2018). These methods are often perceived as more reliable and robust due to their extensive history and the societal trust they have garnered over time (Zevenbergen et al., 2020). However, they are also capital-intensive, require long-term planning, and can have significant environmental and financial impacts. Moreover, as climate change intensifies, these traditional approaches may struggle to adapt to rapidly changing conditions, highlighting the need for more flexible and innovative solutions (Matczak & Hegger, 2021).

However, traditional flood defense techniques are also capital-intensive, requiring significant upfront investments and long-term planning and maintenance. These large-scale infrastructure projects can have significant environmental impacts, such as disrupting natural ecosystems and altering water flow patterns (Rasmussen et al., 2023). Additionally, the financial burden of

constructing and maintaining these defenses can strain government budgets, limiting resources for other essential community needs. Moreover, as climate change intensifies, these traditional approaches may struggle to adapt to rapidly changing conditions, such as more frequent and severe flooding events, sea-level rise, and shifting weather patterns, particularly if they attempt to face ever more challenging weather loads (Groeskamp & Kjellsson, 2020). This highlights the need for more flexible and innovative solutions that can better withstand the dynamic challenges posed by the evolving climate (Matczak & Hegger, 2021).

4.8.4 Integrating Frugal Innovation with Traditional Infrastructure

One of the most promising avenues for combining frugal innovation with traditional flood defense techniques lies in the integration of nature-based solutions with conventional infrastructure. Frugal Innovation in the context of flood resilience often takes the form of nature based or nature complementing designs (Opperman & Galloway, 2022), thus utilizing and enhancing natural processes to provide ecosystem services that act as flood regulation and are therefore critical for long-term resilience (Takin et al., 2023). For example, the restoration of wetlands, the creation of floodplains, and the implementation of green infrastructure, such as urban forests and permeable surfaces, can significantly reduce the volume and speed of water entering traditional drainage systems, thus mitigating flood risks (Dhyani et al., 2020).

Moreover, traditional infrastructure, such as levees, dams, and drainage systems, can be complemented by these nature-based approaches, creating a hybrid model of flood defense (Opperman & Galloway, 2022). This model provides for immediate flood protection while also enhancing the sustainability of the infrastructure and reducing the strain on these systems during extreme weather events. This promotes a diversified portfolio of flood risk management that combines the reliability and robustness of traditional engineered solutions with the adaptive capacity and ecosystem benefits provided by nature-based approaches (Loggia et al., 2020). For instance, wetlands can act as natural sponges, absorbing excess water during heavy rains, which reduces the load on levees and prevents them from breaching. Similarly, floodplains can provide space for rivers to overflow safely, reducing the risk of flooding in downstream urban areas (Loggia et al., 2020). The integration of Nature Based Solutions with traditional infrastructure also supports biodiversity and creates multifunctional landscapes that offer recreational and aesthetic benefits, contributing to the overall well-being of communities. By incorporating green spaces into urban environments, these combined approaches enhance the quality of life of the communities while simultaneously building resilience to climate impacts (Mwendwa & Giliba, 2012).

4.8.5 Enhancing Governance and Institutional Frameworks

The combination of frugal innovation and traditional techniques extends beyond the technical aspects of flood resilience; it also necessitates the development of inclusive and effective governance frameworks. Traditional flood defenses often rely on top-down approaches, where decisions are made by centralized authorities with little input from local communities. While this model has been effective in regions with strong institutional frameworks, it can lead to a disconnect between the needs of communities and the solutions provided, particularly in the Global South (Yasmin et al., 2019).

Frugal innovation, on the other hand, emphasizes community involvement and the utilization of local knowledge, ensuring that solutions are context-specific and culturally appropriate (Weyrauch & Herstatt, 2016). By combining this bottom-up approach with the top-down structure of traditional governance, it is possible to create hybrid governance models that are both inclusive and effective.

This seemingly paradoxical approach, merging decentralized community engagement with centralized planning and resource allocation, can lead to more contextually appropriate and resilient flood management strategies and compromise among the stakeholders (Herk et al., 2013). Additionally, the integration of frugal innovation into traditional governance frameworks can enhance the flexibility and adaptability of flood management strategies (Takin et al., 2023). Traditional infrastructure projects are often characterized by long planning and implementation timelines, making them less responsive to emerging challenges. By incorporating frugal innovation, which is typically more agile and adaptable, governance frameworks can become more dynamic, capable of responding to new information and changing conditions more effectively (Loggia et al., 2020).

Finally, combining frugal innovation with traditional flood defense techniques enhances long-term sustainability by creating flood management strategies that are both adaptable and maintainable (Zevenbergen et al., 2020). Traditional infrastructure frequently requires substantial financial and technical resources for ongoing maintenance, which can overburden local governments, particularly in resource-limited contexts (Takin et al., 2023). Additionally, the increasing frequency and severity of inclement weather events due to climate change can render the original design parameters of such infrastructure insufficient to achieve the desired goals of flood resilience (Hossain & Kalyanapu, 2012). For example, as sea levels rise, coastal wetlands can naturally migrate inland, maintaining their protective role against storm surges without requiring human intervention (Dhyani et al., 2020). Therefore, the integration of frugal solutions, such as nature-based designs, can reduce the maintenance burden and enhance the long-term viability of flood management systems, making them more resilient to evolving climate conditions, proving to be potentially the ultimate solution for the flood defenses of the following decades (Hill et al., 2023).

4.9 A Hybrid Institutional Framework for Flood Resilience

The literature review points towards the necessity of an adaptive institutional framework for achieving flood resilience in the Global South, one that not necessarily shuns elements from the Global North, but that can incorporate them in a nuanced enough manner to be effectively applied in diverse socio-geographic and economic settings. This adaptability is crucial, as frameworks developed for resource-rich, well-governed contexts often fail to address the unique challenges of regions with fragmented governance, limited resources, and socio-economic disparities (Dados & Connell, 2012). The framework must be flexible, allowing for the inclusion of both traditional, infrastructure-heavy approaches and more context-sensitive, low-cost solutions. In this context, frugal innovation emerges as a potential catalyst for enhancing said resilience. Frugal solutions prioritize lowers costs, core functionality and social relevance, making them highly suitable for environments where resources are constrained and local engagement is vital. However, frugal innovation alone may not be sufficient when employed alone. While it addresses immediate needs and is more adaptable, it lacks the scalability and robustness that traditional methods offer. This points to the need for a combined approach, one that seeks to integrate frugal innovations with traditional flood resilience methods to create a comprehensive, layered strategy (Matczak & Hegger, 2021). Given this complexity, decision-makers must adopt a paradoxical perspective that recognizes and manages inherent tensions and unsolvable conflicts between different approaches. Rather than seeking to eliminate these contradictions, they should aim for a level of compromise that enables effective flood resilience, thus breaking the deadlock (Smith & Lewis, 2011). This involves balancing the control and reliability of traditional methods with the flexibility and social relevance of frugal innovations, adapting to local contexts while learning from global practices. The development of

such a hybrid framework requires a governance model that is adaptable and collaborative, capable of bridging gaps between top-down policies and bottom-up, community-driven initiatives (Raub et al., 2024). Finally, the governance mechanisms must embrace these paradoxes not as roadblocks, but as opportunities to craft more context-sensitive and adaptive strategies.

5 Data Analysis

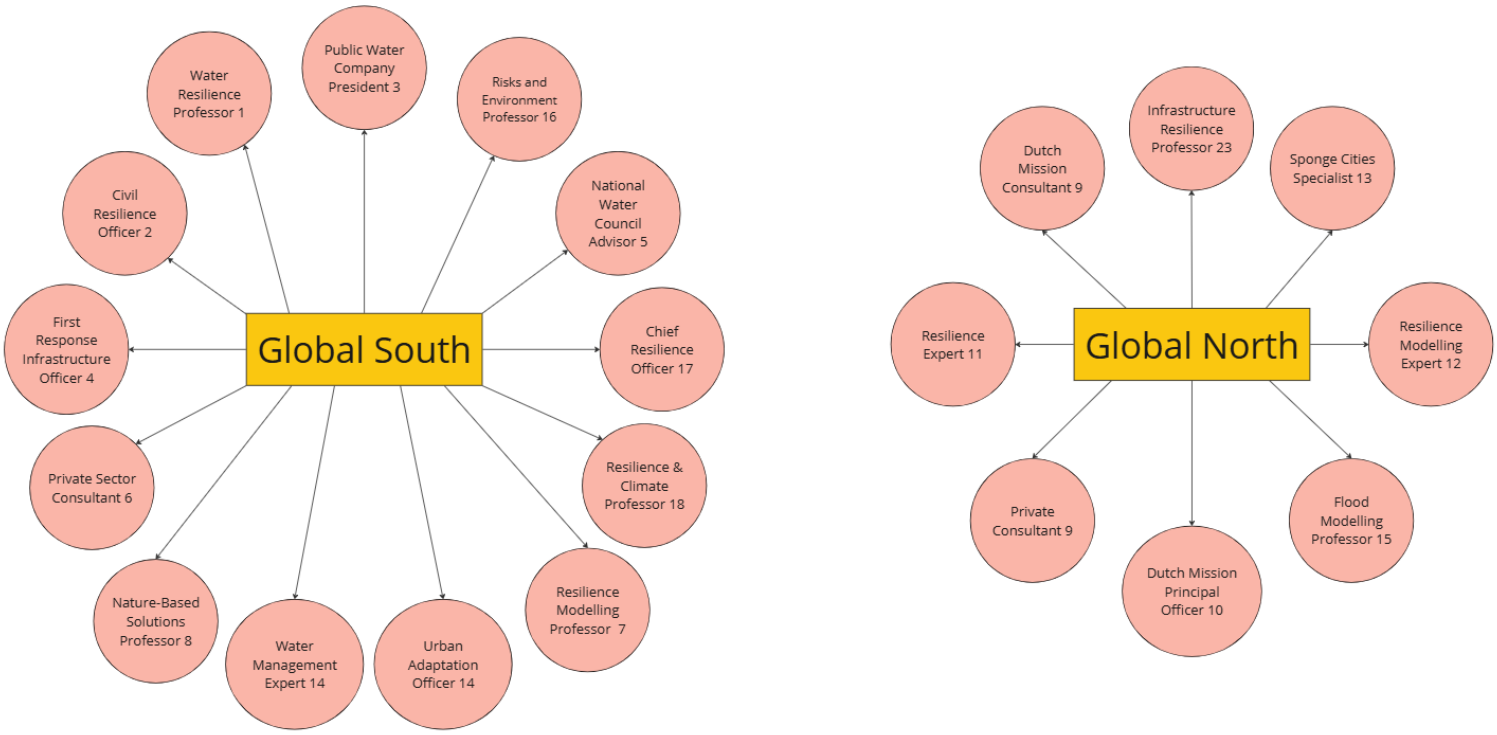
This chapters introduces and illustrates the diverse relationships and interactions among stakeholders interviewed by this study, reflecting the multifaceted and geographically varied nature of flood resilience initiatives and their application within the built environment. These stakeholders include representatives from academic institutions, government agencies, private consulting firms, and international missions; with a specific focus also given to stakeholders which have interacted with the case study of the 2024 Floods in Rio Grande do Sul, Brazil. This mapping process captures the essence of this study, which interplays the connections between actors across different levels of governance and geographic regions, emphasizing how expertise from both the Global North and Global South intersects or fails to, in order to address the shared challenges of flood resilience. The literature review played a foundational role in informing the research topic, highlighting key tensions between technocratic and frugal resilience approaches, and guiding the formulation of interview questions. In parallel, the 2024 Rio Grande do Sul floods served as a contextual anchor for this study, not only shaping the conceptual framework but also helping to identify relevant interviewees and influencing the direction of empirical data collection.

Each interviewee contacted by this research contributes a unique perspective, informed by their socio-geographic context and professional background. For example, stakeholders in Brazil, India, and Tanzania offer firsthand insights into implementing flood resilience strategies in resource-constrained environments, while experts from the Netherlands, the United States, and China provide perspectives on the transfer of technocratic frameworks and innovations across different socio-geographic settings along with the peculiarities of flood resilience mechanisms in their places of work. The interviews ultimately also reflect a remarkable geographic diversity, with participants hailing from across four continents. This diversity ensures that the study incorporates a wide range of viewpoints, from localized, community-driven resilience strategies to large-scale, infrastructure-focused solutions. Such a broad spectrum of insights enhances the study's capacity to explore the interplay between technocratic and frugal, adaptive approaches, highlighting the contextual nuances essential for achieving sustainable and inclusive flood resilience, particularly given the context of the Global South.

Figure 18 provides a visual representation of these relationships, while Table 4 offers a detailed breakdown of the interviewees, including their roles, affiliations, geographic contexts, and areas of expertise. To streamline the analysis, the stakeholders have been grouped into five overarching categories based on their areas of expertise and focus. These categories will be explained in depth in the body of this chapter and will serve as a basis for discussing the findings in the data analysis chapters. Additionally, these categories will play a pivotal role in establishing and applying the proposed governance-sensitive framework, based on the Dynamic Equilibrium Model (Smith & Lewis, 2011) and practical toolkit for flood resilience. This combination of geographic and professional diversity, coupled with a structured categorization of expertise, is central to achieving the study's objective of addressing the complexities of flood resilience within the Global South in a holistic manner, ultimately hoping to contribute to the breaking of the aforementioned Deadlock of Flood Resilience (Section .3.1.9).

The network diagram presented in Figure 18 represents the 20 stakeholders interviewed for this study, categorized into two overarching groups: Global South and Global North. This initial distinction highlights the geographic diversity of perspectives, with stakeholders from the Global South offering localized, resource-constrained insights and those from the Global North contributing technocratic frameworks and solutions. Each node represents a unique expertise or role, reflecting the wide array of professional backgrounds included in this study. The connections illustrate the interplay of governance, policy, and innovation across these global contexts, underscoring the collaborative nature of addressing flood resilience challenges.

Figure 16 : Stakeholders Network Map



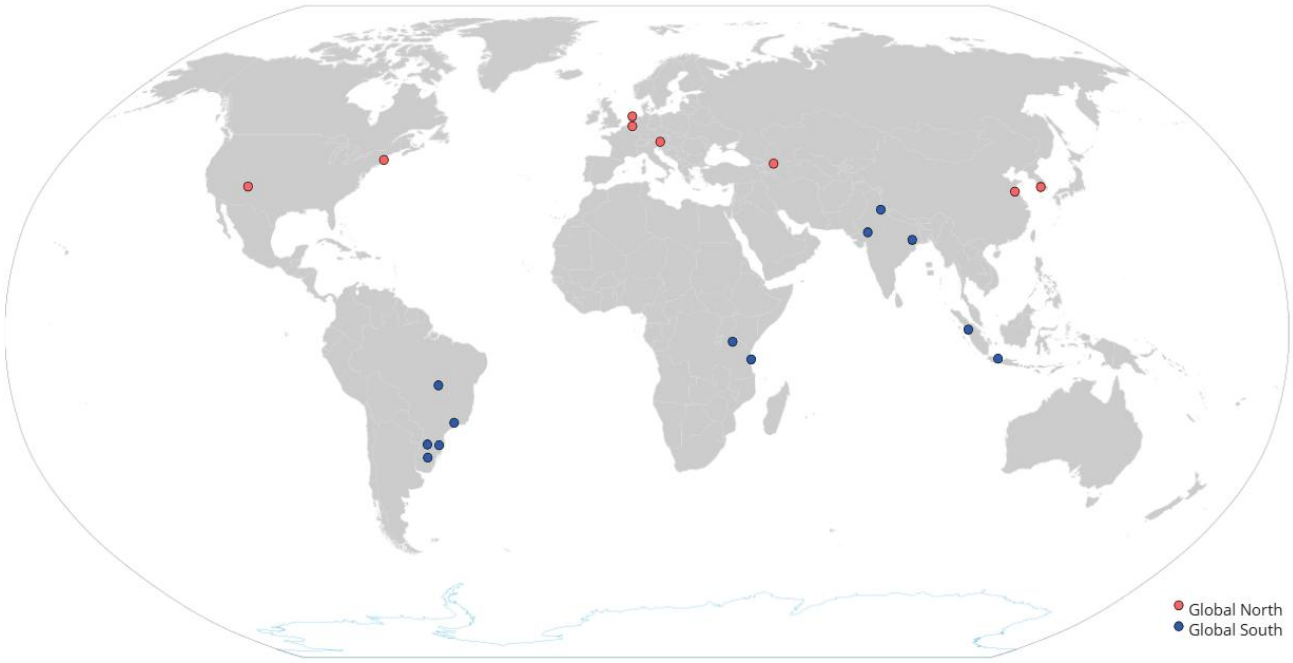
From Author (2024)

To further contextualize the origins of the participants, a world map (i.e., Figure 19) displays their geographic distribution, divided into the Global North and Global South. This visualization highlights the diverse range of perspectives contributing to the research, spanning different governance systems, economic contexts, and approaches to flood resilience.

Within the Global South, Brazil stands out due to its central role in the case study, with multiple stakeholders offering insights into its ongoing efforts to address flood resilience challenges, especially following the severe 2024 floods in Rio Grande do Sul. Additionally, interviewees from countries such as Indonesia, India, and Chile represent nations at a similar stage of development as Brazil, where resource constraints and governance complexities shape the strategies for achieving resilience. Tanzania also contributes to this discussion as a country striving to develop and implement resilience measures to meet the pressing challenges of the 21st century. From the Global North, experts from China and the United States bring contrasting perspectives on infrastructure and resilience, particularly regarding the role of the state in flood resilience efforts. China has been included in the Global North in this study due to its rapid rate of infrastructure development along with its economic and technological advancements over the last 20 years, furthermore, China's centralized, large-scale approach contrasts with the decentralized, often reactive and market influenced model of the United States, offering a comparative analysis of contrasting governance

systems. The Netherlands is also prominently featured as a country with a long-standing tradition and expertise in flood resilience, exemplified by its recent collaboration with Brazil through the Dutch Mission to advise the 2024 floods in Rio Grande do Sul. Contributions from Armenia and Austria offer additional insights into how flood resilience strategies are applied globally, showcasing variations in how infrastructure and governance approaches adapt to local challenges. This diverse geographic representation emphasizes the global relevance of flood resilience, while also enriching the study's by perspective by integrating varied approaches and lessons to its analysis.

Figure 17 : Geographic Distribution of Interviewees

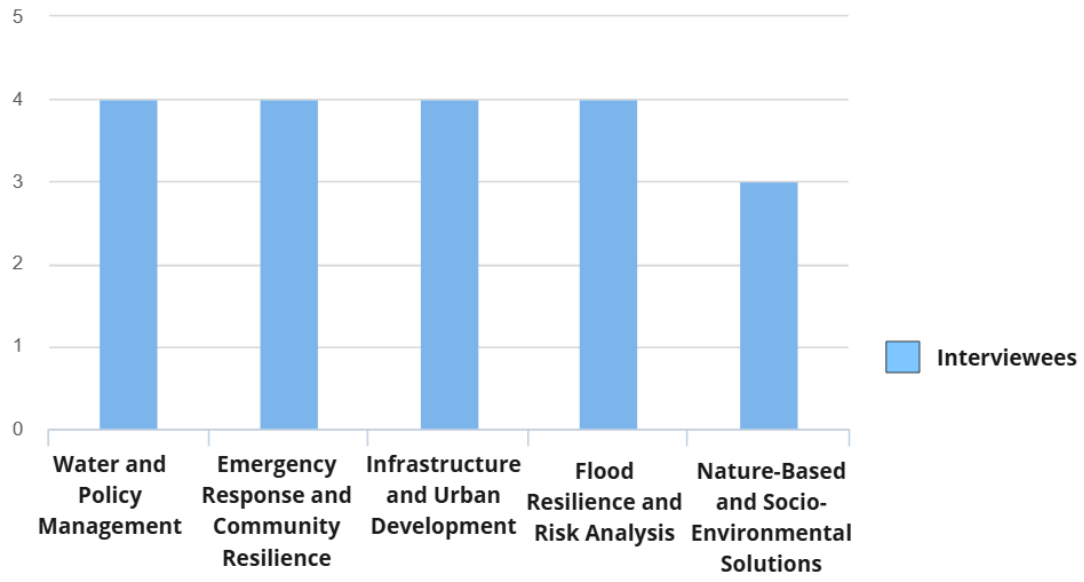


From Author (2024)

5.1 Interviewee Characterization

Additionally, a bar chart displayed in Figure 20 categorizes the interviewees based on their areas of expertise, reflecting the breadth of knowledge represented in the study. The five categories presented are Water and Policy Management, Emergency Response and Community Resilience, Infrastructure and Urban Development, Flood Resilience and Risk Analysis, and Nature-Based and Socio-Environmental Solutions. Each category highlights a distinct focus area, ranging from strategic governance and technical expertise to community-centered approaches and innovative nature-based solutions. These groupings offer a comprehensive framework for understanding the diverse perspectives that inform this research. Furthermore, these categories will be used to identify themes and parallels within the interviewees' responses, examining their concordance or dissonance with the study's assumptions and contributing to the establishment of the proposed governance-sensitive model. They form the basis of the in-depth discussions presented in the following sections.

Figure 18 : Expertise of Interviewees



From Author (2024)

5.1.1 Water and Policy Management

This category comprises interviewees with expertise in water resilience, water infrastructure management, and water policy. These stakeholders play a vital role in understanding the governance and strategic mechanisms necessary for managing water resources and mitigating flood risks. Their perspectives reveal the systemic challenges of integrating long-term policy frameworks with immediate infrastructure needs. They emphasize the importance of resource allocation, effective inter-agency coordination, and fostering public-private partnerships to enhance water management strategies.

5.1.2 Emergency Response and Community Resilience

Stakeholders in this category focus on disaster preparedness, emergency response mechanisms, and community-driven resilience initiatives. Their insights underscore the importance of rapid response systems and the role of firefighting infrastructure in mitigating the immediate impacts of floods. Equally significant is their emphasis on community engagement, which empowers local populations to participate in resilience planning and preparedness efforts. These interviewees also highlight the logistical and governance challenges associated with coordinating large-scale evacuations and recovery processes in diverse settings.

5.1.3 Infrastructure and Urban Development

This category includes experts in infrastructure consulting, development, and urban planning, with a focus on flood resilience. These stakeholders contribute valuable knowledge on designing and implementing infrastructure solutions that balance technical robustness with local socio-economic realities. Their perspectives highlight the importance of adaptive urban planning that addresses the unique needs of communities while aligning with broader resilience objectives. They also stress the challenges of integrating technocratic, large-scale approaches with localized, context-sensitive strategies.

5.1.4 Flood Resilience and Risk Analysis

Flood resilience and risk analysis form a critical focus of this study, with interviewees specializing in flood risk modeling, resilience planning, and flood management policies. These stakeholders provide in-depth knowledge of predictive modeling techniques, vulnerability assessments, and actionable strategies for risk reduction. Their contributions bridge the gap between theoretical models and practical applications, ensuring that flood resilience measures are both evidence-based and adaptable to diverse contexts. They also highlight the importance of a proactive approach in addressing the evolving nature of flood risks.

5.1.5 Nature-Based and Socio-Environmental Solutions

This category is centered on interviewees advocating for nature-based solutions and socio-environmental resilience. These experts highlight the potential of integrating natural systems, such as wetland restoration and green infrastructure, into flood resilience efforts. Their perspectives emphasize the dual goals of environmental conservation and socio-economic inclusion, with a focus on empowering communities through localized and frugal innovations. They stress the importance of leveraging traditional ecological knowledge and fostering community-based initiatives to achieve sustainable, long-term resilience.

5.2 Interviewee Profiles and Expertise Overview

Table 4 presents a comprehensive overview of the interviewees, highlighting their varied affiliations, geographic contexts, and expertise categorized into the five thematic classifications. The inclusion of stakeholders from academic institutions, government agencies, and private sectors ensures a diverse pool of perspectives. Each interviewee's role, as outlined in the table, served as a key identifier, enabling the alignment of their expertise with the broader themes of the study. This structure reflects the deliberate effort to integrate a wide range of insights critical to the research's objectives.

Table 4 : Interviewees List

Interview Number	Role	Affiliation	Geographic Context	Expertise
1	Water Resilience Professor	Federal University, Porto Alegre, Brazil	Global South	Water and Policy Management
2	Civil Defense President	Civil Defence Infrastructure, Porto Alegre, Brazil	Global South	Emergency Response & Community Resilience
3	Water Company President	Municipal Water Company, Porto Alegre, Brazil	Global South	Water and Policy Management
4	Commander of Emergency Services	Military Firefighting Command, Porto Alegre, Brazil	Global South	Emergency Response & Community Resilience
5	National Water Council Advisor	National Water Council, Brasilia, Brazil	Global South	Water and Policy Management

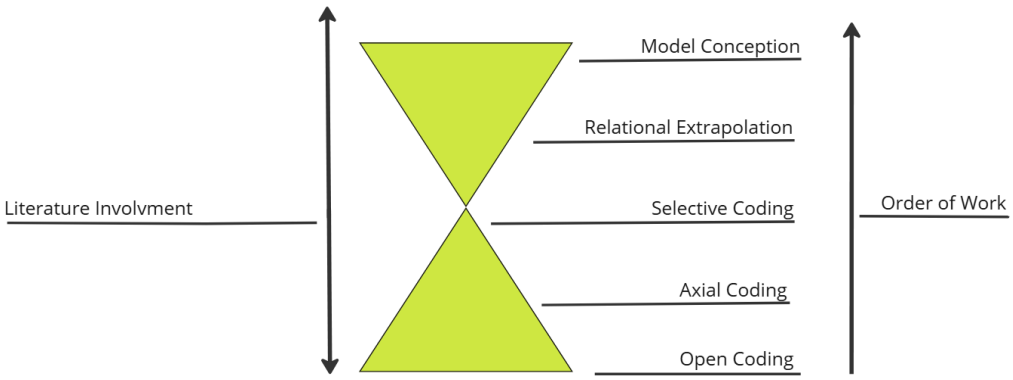
6	Infrastructure Consultant	Infrastructure Sector, Porto Alegre,Brazil	Global South	Infrastructure and Urban Development
7	Resilience Modelling Professor	Federal University, Chandigahar, India	Global South	Infrastructure and Urban Development
8	Nature-Based Solutions Professor	Federal University, Roorkee, India	Global South	Nature-Based & Socio-Environmental Solutions
9	Dutch Mission Consultant	Dutch Mission, Den Haag, NL / Private Consulting, Sao Paulo, Brazil	Global North	Infrastructure and Urban Development
10	Dutch Mission Principal Officer	Dutch Mission, Den Haag, NL	Global North	Water and Policy Management
11	Resilience Professor	Private University, Boston, USA / Federal University, Kharagpur, India	Global North	Flood Resilience & Risk Analysis
12	Sponge Cities Specialist	Infrastructure Sector, Shanghai, China / Private University, Vienna, Austria	Global North	Infrastructure and Urban Development
13	Water Management Expert	Infrastructure Sector, Arusha, Tanzania	Global South	Nature-Based & Socio-Environmental Solutions
14	Chief Resilience Officer	Infrastructure Ministry, Dar es Salaam, Tanzania	Global South	Flood Resilience & Risk Analysis
15	Urban Adaptation Officer	Infrastructure Ministry, Bali, Indonesia	Global South	Emergency Response & Community Resilience
16	Resilience & Climate Professor	Public University, Bandung, Indonesia	Global South	Emergency Response & Community Resilience
17	Infrastructure Resilience Professor	Private University, Phoenix, USA,/ Public University, Yerevan Armenia	Global North	Nature-Based & Socio-Environmental Solutions
18	Professor Urban Resilience	Private University, Phoenix, USA,/ Public University, Seoul, Korea	Global North	Flood Resilience & Risk Analysis
19	Urban Resilience Researcher Federal University, Porto Alegre, Brazil	Federal University, Porto Alegre, Brazil	Global South	Flood Resilience & Risk Analysis

5.3 Thematic Analysis

This study adopts a grounded theory-inspired methodology, incorporating an abductive research approach to systematically analyze qualitative data. By refining insights from the aforementioned expert interviews into structured themes and continuously engaging with the literature, the study hopes to contextualize the emerging findings. (Conaty, 2021). The coding process follows three key stages: open coding, where raw data is deconstructed into distinct conceptual elements; axial coding, which identifies patterns and relationships among such elements; and selective coding, where higher-order themes are compounded to structure the findings. This method ensures a rigorous yet flexible analytical process, allowing for an iterative interplay between empirical data and the theoretical constructs. Furthermore, by utilizing an abductive approach, the study moves beyond purely deductive or inductive reasoning, instead attempting to iterate between theoretical insights and emerging data patterns to refine its framework (Conaty, 2021).

The study presents an hourglass model (i.e., Figure 21) as a visual representation of this conceptual process. This model depicts how raw qualitative data is systematically refined into structured thematic insights, which are then extrapolated into relational patterns and applied into discussions. The base of the model consists of open codes, which are directly extracted from the interviews, capturing governance tensions, institutional constraints, and resilience paradoxes pertaining to interactions with frugal innovation. These are then clustered into axial codes, grouping related concepts into overarching themes that provide a structured foundation for interpretation. At the narrow center, selective coding synthesizes the axial codes into broader conceptual categories that highlight key governance and resilience paradoxes regarding frugal innovation but also discussing issues of governance fragmentation. As the model expands again, the middle of the inverted triangle represents relational extrapolation, where thematic interconnections are examined, thus emphasizing how paradoxes interact within governance, policy, and institutional frameworks, particularly regarding the Global South but also with insights from the developed world. Finally, at the top of the model, quote discussion links extracted themes back to interview excerpts, illustrating real-world applications and expert perspectives to be compounded on a conceptual model regarding relations between the insights and their dependencies.

Figure 19: Abductive Hourglass



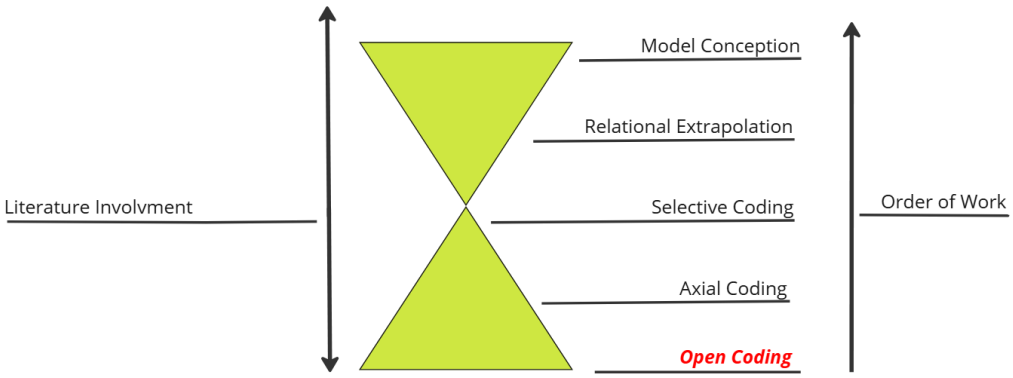
From Author (2024)

5.3.1 Open Coding

In this section, the key factors identified through the body of the expert interviews are examined, focusing specifically on issues pertaining to the paradoxes of frugal innovation in flood resilience. These factors were systematically analysed using the qualitative data analysis software Atlas.ti,

where they were categorized into two distinct groups: open codes and furthermore axial codes. The open codes represent a diverse set of factors extracted directly from the interview transcripts, capturing the various paradoxes, governance challenges, and institutional constraints articulated by the interviewees. These open codes serve as the foundational element for understanding the complexities and tensions inherent in applying frugal innovation to flood resilience in the Global South. The open coding process deliberately avoided preconceived categories, instead taking an abductive approach to identify novel concepts. This allowed emerging patterns to guide the analysis, rather than forcing the data into predetermined theoretical concepts.

Figure 20 : Abductive Hourglass - Open Coding

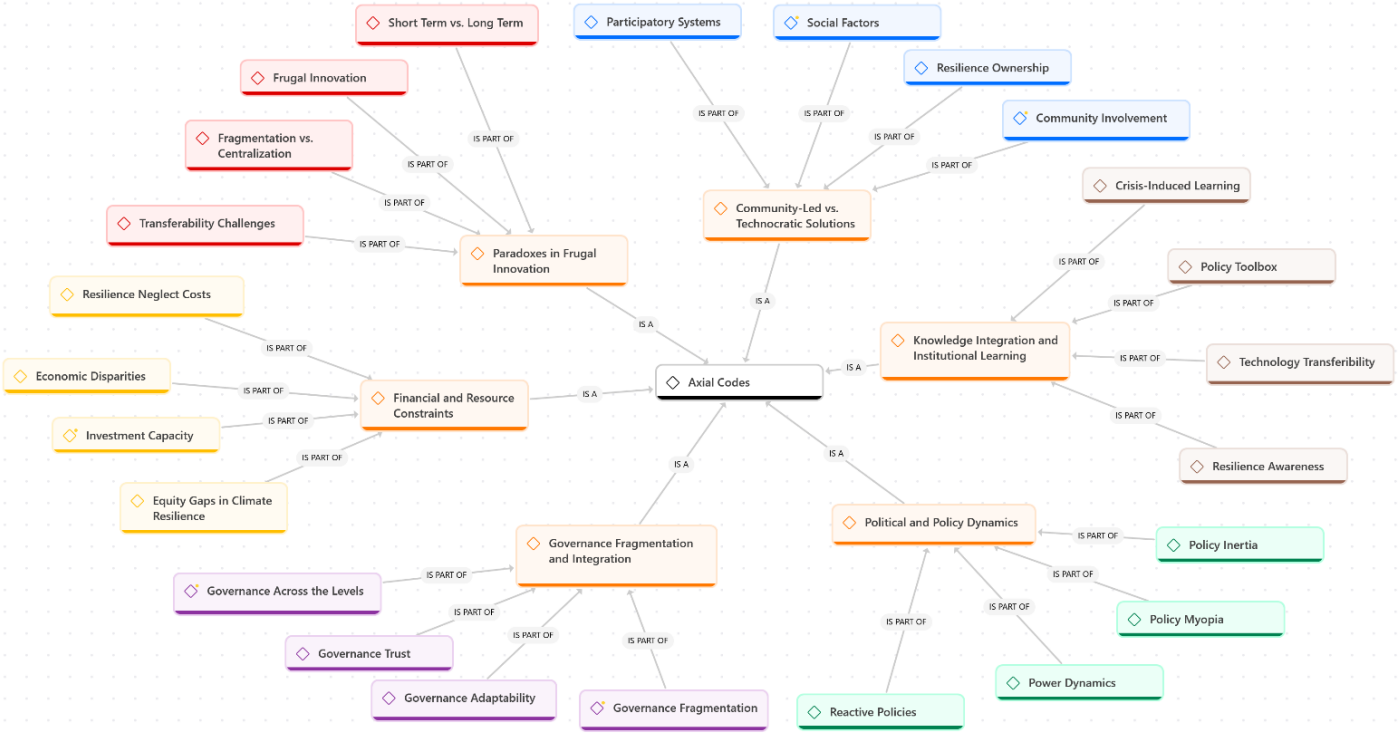


From Author (2024)

This abductive approach recognizes that flood resilience paradoxes may not fit neatly into conventional categories and thus required a more exploratory coding strategy. Subsequently, these open codes were then systematically **organized into six axial code categories**, which grouped related challenges into overarchingthemes. Through this axial coding process, interrelated factors were clustered together based on conceptual similarities and affinities, allowing for a structured and coherent framework for analysis. In total, 202 open codes were abductively identified and grouped into six major axial code categories based on shared proximity and affiliation. They are as follows:

1. **Community-Led vs. Technocratic Solutions** – Exploring tensions and issues between grassroots, frugal approaches and top-down, technocratic flood resilience frameworks.
2. **Financial and Resource Constraints** – Examining limitations in funding, affordability, and access to the necessary resources for implementing solutions.
3. **Governance Fragmentation and Integration** – Addressing the issues pertaining to fragmented governance structures and further efforts toward policy integration.
4. **Knowledge Integration and Institutional Learning** – Investigating how knowledge transfer and learning from past resilience efforts shape policy outcomes.
5. **Paradoxes in Frugal Innovation** – Analysing interrelated contradictions between cost-effective, frugal solutions and more traditional flood resilience strategies.
6. **Political and Policy Dynamics** – Understanding how political interests, regulatory barriers, and regulatory environments influence flood resilience measures.

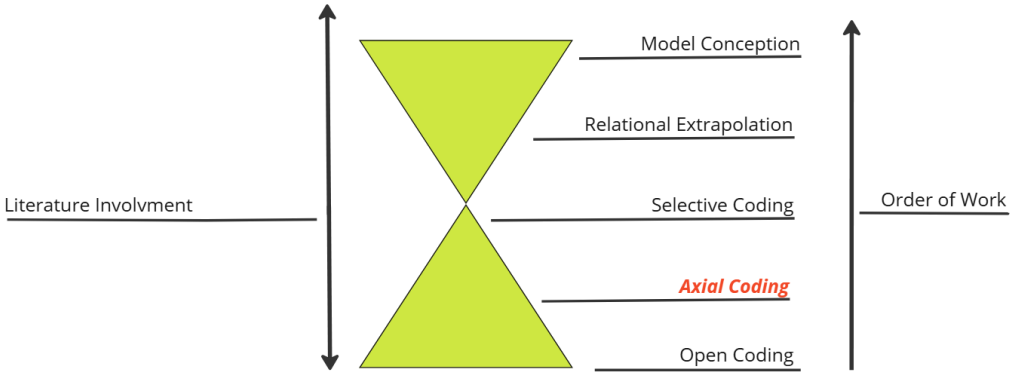
Figure 21 : Axial Code Relations



From Author (2024)

Furthermore, the categorization of the open codes into the six axial code groups offers a more structured framework to allow for the investigation of the paradoxes inherent in applying frugal innovation to flood resilience efforts to be conducted. This categorization serves to further support the co-occurrence analysis in the upcoming sections by showing how different challenges interact and overlap different interrelated dimensions**.** Additionally, in Figure 23, the four open codes with the highest density in the body of the interviews were included under their corresponding axial codes to provide a visual representation of the depth and variety of responses given by participants, despite the topic having some pre-established themes and ideas a full list of all the basic codes can be examined in Appendix C**.** To further explore the relationships between these challenges, a Code-Document analysis was then conducted within the bounds of the interviewee groups, as previously described in Section 5.1 pertaining to interviewee characterization. The co-occurrence analysis enabled a deeper understanding of how paradoxes intersect across different domains of frugal innovation and its application. Additionally, By identifying patterns within the co-occurrence, it was possible to assess how paradoxes are interconnected within specific expertise areas and how they manifest.

Figure 22 : Abductive Hourglass - Axial Coding



From Author (2024)

Therefore, by employing an abductive research approach, this analysis hoped to move beyond a rigid deductive or purely inductive reasoning (Conaty, 2021). Instead of assuming thematic structures, the open coding process was intentionally designed to capture emergent and interesting patterns attached to tailored insights from the interviewees. This iterative process allowed the research to remain open to unexpected paradoxes, governance tensions, and socio-political dynamics that might be inherent to frugal innovation for flood resilience (Conaty, 2021). Grounded in abductive reasoning, the study maintained a continuous interplay between empirical data and theoretical constructs, facilitating the refinement of conceptions acquired during the literature review while allowing space for new theoretical perspectives to emerge. This methodological flexibility is particularly critical in examining paradoxes, where competing and contradictory forces interact in complex ways**.** Furthermore, the Code-Document analysis within the six axial code groups, as shown in the figure 25, provides an additional layer of systematic validation**,** ensuring that emergent themes are not isolated observations but interconnected realities, the Code-Document table disserted in terms of individual interviewees is also presented on Appendix D**.** Finally, through this engagement between theory, and researcher interpretation**,** the study embraces an exploratory abductive stance**,** offering a more nuanced, reflexive, and empirically grounded understanding of how paradoxes in frugal innovation shape flood resilience efforts in the Global South**.**

5.3.2 Analysis of Axial Codes

Figure 23 : Code-document Analysis of Axial Codes

		Emergency Re... 4 256	Flood Resilienc... 4 251	Infrastructure... 4 297	Nature-Based... 3 180	Water and Poli... 4 327	Totals
Community-Led vs. Technocratic Solutions	15 286	52	88	56	40	50	286
Financial and Resource Constraints	24 285	47	69	48	42	79	285
Governance Fragmentation and Integration	59 945	171	173	213	132	256	945
Knowledge Integration and Institutional Learning	20 376	77	65	91	45	98	376
Paradoxes in Frugal Innovation	57 740	121	148	160	101	210	740
Political and Policy Dynamics	38 475	97	86	107	63	122	475
Totals		565	629	675	423	815	3107

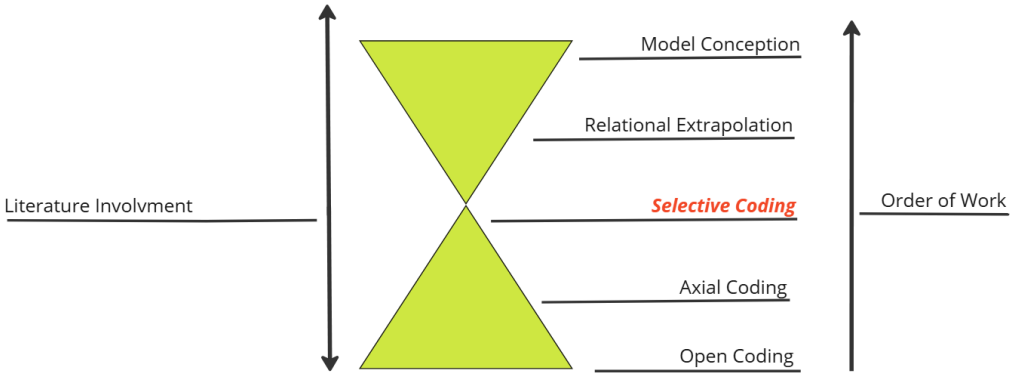
From Author (2024)

The co-occurrence analysis provides valuable insights into how the key themes identified in the study intersect across different domains of flood resilience expertise. As illustrated in the co-occurrence graph, the two most prevalent themes emerging from the interviews are:

1. **Governance Fragmentation and Integration (945 occurrences)**
2. **Paradoxes in Frugal Innovation (740 occurrences)**

These findings reinforce the central paradoxes of flood resilience in the Global South, where institutional fragmentation and competing governance structures often create barriers to the integration of resilience, especially given the novelty and often misunderstanding of what pertains to frugal innovation and its scope. The high occurrence of Governance Fragmentation and Integration suggests that misalignment between agencies, policy inconsistencies and jurisdictional overlaps remains a dominant challenge within flood resilience efforts, given the geographic diversity of the interviewees, this offers an interesting insight on the fact that this phenomena is spread worldwide. Meanwhile, the significant presence of Paradoxes in Frugal Innovation highlights the tensions between low-cost, adaptive strategies and conventional resilience frameworks, further supporting the research question on how paradoxical issues influence complex and long-term problems like flood resilience outcomes. Notably, the Water and Policy Management interviewee group contained the highest number of coded occurrences, reflecting the depth and breadth with which these participants discussed governance challenges, policy implications, and institutional complexities, being them potentially the largest interface between policy and their forthcoming form the world of ideas to actual application. Their ability to articulate nuanced perspectives on policy trade-offs and inter-agency coordination further highlights the role of governance structures in shaping flood resilience strategies. Finally, the selection of these two more prevalent axial groups will inform the discussion in the two subsequent sections, where selective coding dissection will be applied to the most frequently occurring quotes within the two aforementioned dominant axial coding's to further inform the extrapolation of key thematic insights, before dissecting the quotes. This step is made necessary given the breadth and openness of the interviewee answers and insights and to avoid redundancy and provide a clear path through the core arguments.

Figure 24 : Abductive Hourglass : Selective Coding



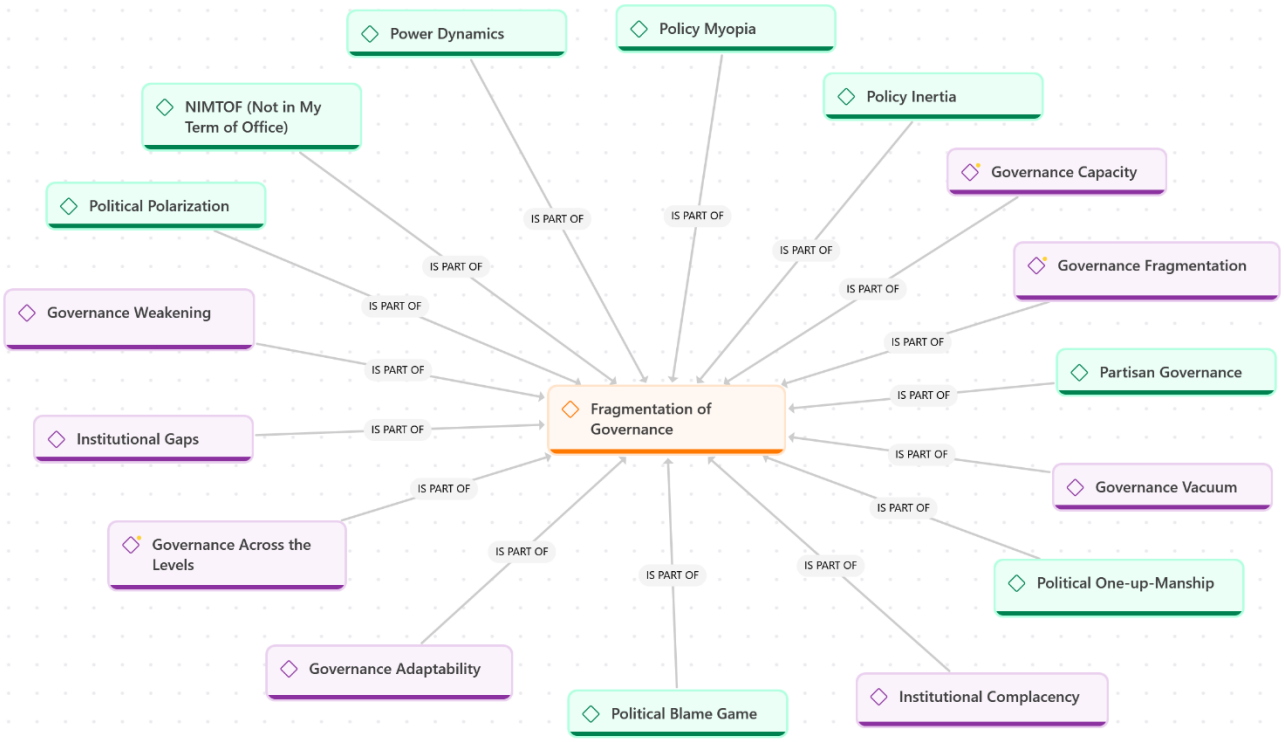
From Author (2024)

5.3.3 Selective Coding: Governance Fragmentation

The governance-related obstaclesuncovered in the interviews are consistent with those examined in the academic literature, underscoring their importance in shaping flood resilience governance across the Global South. By comparing empirical observations with theoretical perspectives, this study hopes to construct a comprehensive framework that encapsulates the key governance

fragmentation challenges impacting the implementation of resilience strategies. For this, analysis the open codes with the most affinity with the issue of governance fragmentation where selected, having a selection process that prioritized open codes exhibiting the strongest thematic alignment with governance fragmentation, as indicated by their conceptual linkages and co-occurrence densitys within the interviewees and their respective groupings.

Figure 25 : Fragmentation of Governance Network



From Author (2024)

The code-document table displayed below provides insights into which basic codes showed more density within the array of interviews conducted during this study, pertaining to systemic governance fragmentation affecting flood resilience. The width and spread of governance fragmentation challenges, identified through an abductive coding approach, can be seen through the diversity of interconnected issues raised across research participants.

Figure 26 : Code-Document Analysis of Governance Fragmentation

	Emergency Re...	Flood Resilienc...	Infrastructure...	Nature-Based...	Water and Poli...	Totals
Governance Across the Levels	10	12	23	9	35	89
Governance Adaptability	22	22	31	19	29	123
Governance Capacity	12	12	12	9	28	73
Governance Fragmentation	29	22	32	18	55	156
Governance Trust	10	17	28	8	20	83
Governance Vacuum	4	1	5	4	9	23
Institutional Gaps	13	7	12	9	23	64
NIMTOF (Not in My Term of Office)	6	4	8	2	4	24
Partisan Governance	1	11	5	2	8	27
Policy Inertia	17	11	13	14	21	76
Policy Myopia	11	21	10	12	16	70
Political Blame Game	3	5	12	5	8	33
Political One-up-Manship	9	10	8	5	3	35
Political Polarization	1	5	5	3	2	16
Power Dynamics	6	10	10	3	10	39

From Author (2024)

Among the governance fragmentation factors identified, the most prevalent is:

Governance Fragmentation (156 occurrences)

This finding highlights how overlapping jurisdictions, unclear responsibilities, and institutional misalignment hinder effective flood resilience governance. Fragmented governance often leads to policy inconsistencies, delays in decision-making, and limited coordination across different levels of government, reinforcing the need for an integrated governance approach.

Other significant governance fragmentation-related factors include:

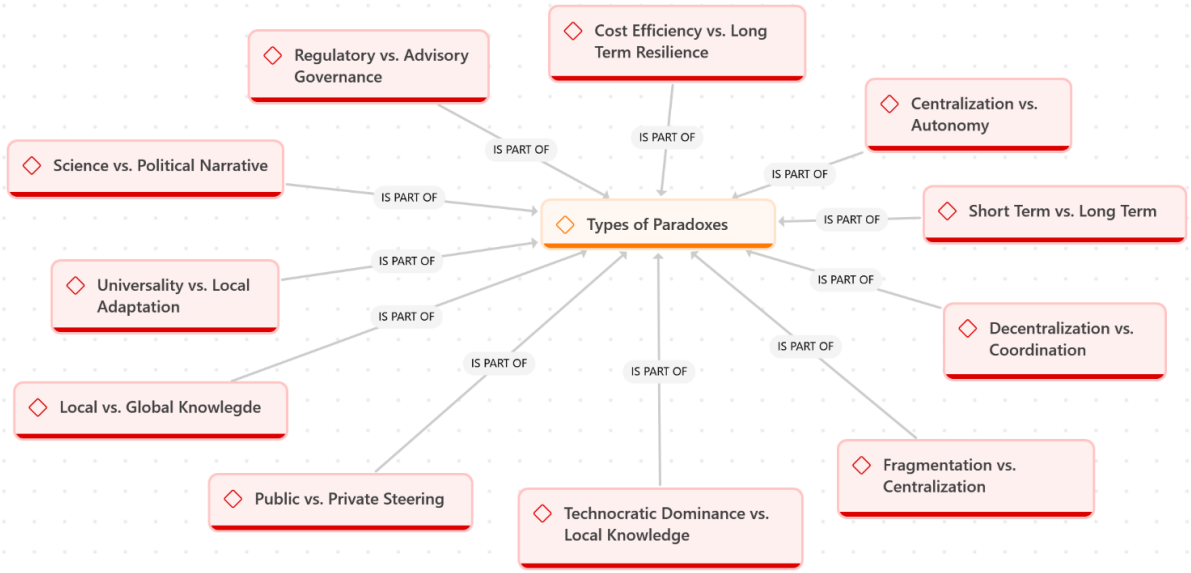
- ***Governance Adaptability (123 occurrences)*** – Highlighting the tension between rigid governance frameworks and the integrative need for adaptive approaches.
- ***Governance Across the Levels (89 occurrences)*** – Demonstrating the disconnect between national, regional and local governance structures within flood risk management.

These governance fragmentation challenges, when examined across different expertise domains (e.g., water policy, infrastructure, nature-based solutions), reveal systemic governance failures that hinder effective flood resilience planning.

5.3.4 Selective Coding: Types of Paradox

The paradoxes uncovered through the interview analysis are consistent with those identified in the existing literature, underscoring their significance in shaping flood resilience governance across the Global South accompanied by insights from experts from the Global North and how their issues pertain and relate to flood resilience. By comparing the empirical observations with theoretical perspectives, this study develops a comprehensive framework that encapsulates the key tensions affecting the implementation of frugal flood resilience strategies.

Figure 27 : Types of Paradoxes



From Author (2024)

The code-document table of paradox types displayed bellow found within the interviews provides crucial insights into the recurring paradoxes which shape flood resilience efforts. These paradoxes, categorized as open codes, emerged through an abductive approach in the coding process, also being characterized by a vast width and spread of answers. This further refined and complements the insights acquired in Section 3.1 of the literature review pertaining to the paradoxes identified within literature scrutiny. Ultimately several patterns were found regarding paradox types and relations, yet paradoxes not identified within the literature review were found and described during the interview process.

Figure 28 : Code-Document Analysis of Types of Paradoxes

	Emergency Re... 4 256	Flood Resilienc... 4 251	Infrastructure... 4 297	Nature-Based... 3 180	Water and Poli... 4 327	Totals
Paradox: Centralization vs. Autonomy 42	6	8	12	1	15	42
Paradox: Cost Efficiency vs. Long Term Resilience 16	1		1	1	13	16
Paradox: Decentralization vs. Coordination 29	8	3	6	1	11	29
Paradox: Fragmentation vs. Centralization 43	1	17	16	3	6	43
Paradox: Local vs. Global Knowlegde 30	8	7	7	1	7	30
Paradox: Public vs. Private Steering 14		1	2	1	10	14
Paradox: Regulatory vs. Advisory Governance 9				1	8	9
Paradox: Science vs. Political Narrative 14	2	2	3	2	5	14
Paradox: Short Term vs. Long Term 80	6	20	16	7	31	80
Paradox: Technocratic Dominance vs. Local Knowle... 40	6	7	16	3	8	40
Paradox: Universality vs. Local Adaptation 28	1	4	13	5	5	28
Totals	39	69	92	26	119	345

From Author (2024)

Among the paradoxes identified, the most prevalent is:

Short Term vs. Long Term (80 occurrences)

The identification of the prevalent paradox between short-term and long-term resilience strategies aligns closely with the literature review, where the paradox of short-term vs. long-term resilience strategies was consistently highlighted as a major barrier to sustainable flood resilience. The deadlock of flood resilience, as discussed in prior sections, exemplifies this paradox, where governments and policymakers often prioritize immediate, cost-effective solutions a the expense of long-term adaptive strategies. The extrusion of such relationship shall be further scrutinized for comparable and competing insights between the proposed conceptual framework and literature review insights.

Other significant paradoxes include:

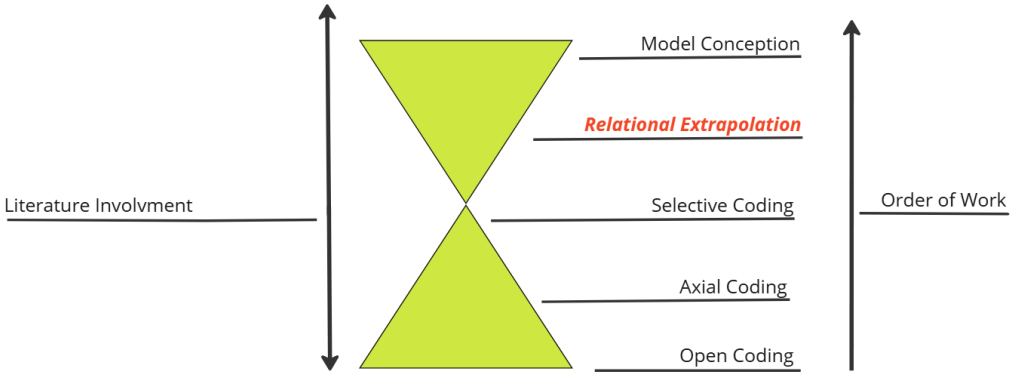
- ***Fragmentation vs. Centralization (43 occurrences)*** – Reflecting tensions between diverging institutional structures, where fragmented governance models compete with more centralized approaches within the realm of flood management.
- ***Centralization vs. Autonomy (42 occurrences)*** – Highlighting governance challenges relating to top-down policy control clashes with local decision-making autonomy within flood resilience planning.

These paradoxes, when examined across different expertise domains (e.g., water policy, infrastructure, nature-based solutions), reveal systemic tensions that impact the implementation of flood resilience strategies. By comparing these findings with the literature review, this study reinforces the theoretical relevance of paradox perspective too investigating complex and self-reinforcing problems such as flood resilience, validating their role in shaping policy trade-offs towards governance streamlining. Further discussion and dissection on the specific insights and quotes from the interviewees, including how the paradox of short-term vs. long-term resilience presents itself within the domain of flood resilience planning for frugal innovation, will follow in the subsequent sections.

5.4 Relational Extrapolation for Model Conception

In this section, this study shall detail the systematic process undertaken to identify and structure the thematic codes that underpin the six highlighted selective codes on the previous two sections, pertaining to governance fragmentation and paradoxes presented within frugal flood resilience. Having also been informed by the fact that fragmentation of governance is a key factor in shaping resilience challenges, this process moved to inform a rigorous code co-occurrence analysis, ensuring that the most recurrent and interconnected factors were selected for relational exploration. The analysis followed a data-driven abductive approach, drawing from empirical patterns in the interview dataset while aligning with theoretical constructs (Conaty, 2021) in the areas of governance, policy inertia, and most notably frugal innovation.

Figure 29 : Abductive Hourglass - Relational Exploration



From Author (2024)

5.4.1 Selected Code Relations

To ensure that the thematic framework reflected empirical significance, the selection of codes was guided by their Code Co-Occurrence density analysis within the interview dataset and performed within Atlas.ti software. The initial set of governance-related, policy-driven, and institutional factors was cross-referenced to determine their frequency of co-occurrence with other identified governance challenges. The selection criteria required that codes exhibit a minimum threshold of 25 co-occurrences with other governance-related codes identified in previous steps. This threshold ensured that only the most interconnected and thematically significant codes were considered for integration into forthcoming conceptual model. Thereafter, these selected codes were compared to the six selective codes identified in the two preceding sections, forming the rows of the following Code Co-Occurrence table and further helping to assess the relational strength of the 6 selective codes and he whole body of codes found within the interviews. This comparison allowed for the identification of key thematic intersections between governance challenges and the refined insights shown on the interviews. As shown in Figure 31 (Co-Occurrence Table), the codes that met this key criterion include:

- ***Crisis-Induced Learning***
- ***Governance Capacity***
- ***Institutional Gaps***
- ***Institutional Legitimacy***
- ***Policy Inertia***
- ***Policy Myopia***
- ***Social Factors***

Figure 30 : Selective Code Co-Occurrence

	Crisis-Induced Le...	Governance Ca...	Institutional Gaps	Institutional Legit...	Policy Inertia	Policy Myopia	Social Fa...
Centralization vs. Autono...	2	2	1	3	2	1	3
Fragmentation vs. Centra...	2	5	1	8	5	1	4
Governance Across the L...	1	6	7	5	4	4	4
Governance Adaptability	12	8	5	9	7	4	5
Governance Fragmentati...	8	11	21	2	17	12	7
Short Term vs. Long Term	16	7	3		10	6	4

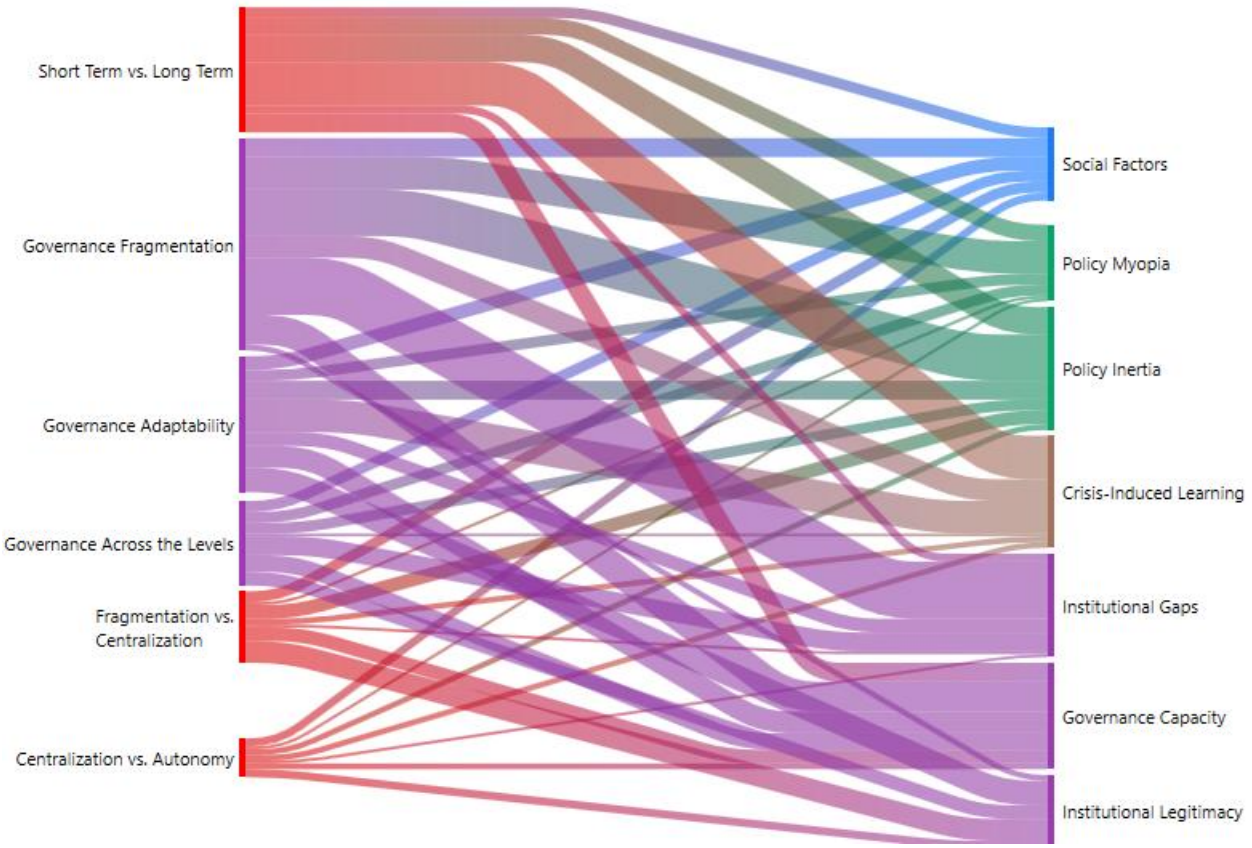
From Author (2024)

The table above) visually represents these connections, illustrating how frequently these codes appear together in the interview dataset. Higher co-occurrence counts suggest deeper interconnections between Fragmentation Mechanisms and the paradox of Short-Term vs. Long-Term resilience approaches.

5.4.2 Informing the Conceptual Model

To further validate the relational strength of the selected codes, a Sankey diagram was generated to illustrate the interconnections between the selective coding and the basic codes that met the predefined criteria. This visualization emphasizes the codes that exhibit the strongest relationships within the dataset, with wider flow bands indicating higher co-occurrence and thus relationship. Additionally, it highlights the systemic significance of Governance Fragmentation, Policy Inertia, and Institutional Legitimacy as central structural constraints that shape frugal innovation efforts in flood resilience. Furthermore, the diagram underscores the embeddedness of Social Factors and Crisis-Induced Learning within governance considerations, demonstrating their proposed crucial role in shaping institutional responses to resilience planning. Building on these insights, the model was structured to capture the multi-level governance constraints that influence decision-making in flood resilience, illustrating the interdependencies between the areas, particularly highlight the spread of institutional legitimacy, governance adaptability, and policy inertia. It further highlights the tensions that arise between crisis-driven learning and fragmented governance responses, reflecting the challenges in developing cohesive and adaptive resilience strategies. The axial coding is also represented within the Diagram, aligning it with the coloring displayed on figure 32.

Figure 31 : Selective Coding Relations



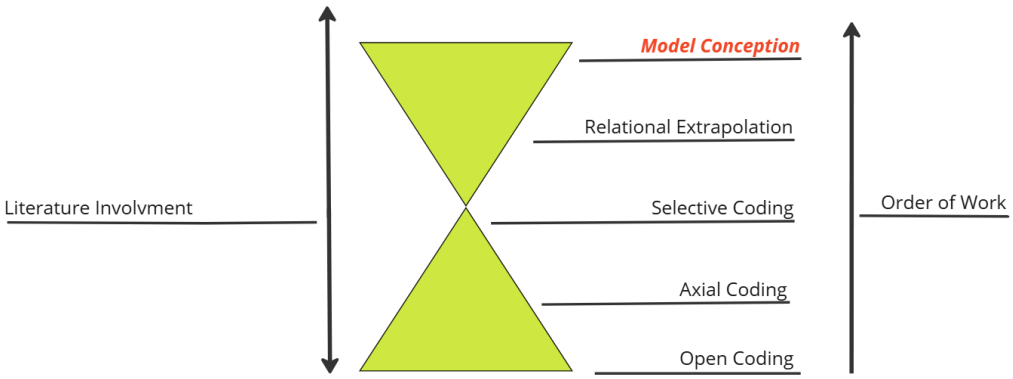
From Author (2024)

By mapping these interactions, the Sankey diagram reinforces the decision to construct the conceptual model around these interrelated governance and policy mechanisms. This empirically grounded approach ensures that the model reflects the recurring narratives and governance dilemmas as expressed by multiple interview participants. The prominence of the selected codes in terms of co-occurrence density and further explored thematic interconnectivity prompted the development of an integrated governance model. Therefore, this model shall be designed to investigate how each of these factors influences frugal flood resilience. These relations and their respective individual dynamics will be further explored on the upcoming sections where data will be dissected and woven into a cohesive theoretical conceptualization.

5.5 Model Conception

This section delves further into the previously discussed extrapolated relations between the selected codes. It systematically explores each code, along with their respective relations and positioning in relation to one another, drawing on direct quotations from the interviews to illustrate how these governance dynamics surface in practice with respect to the topic at hand.

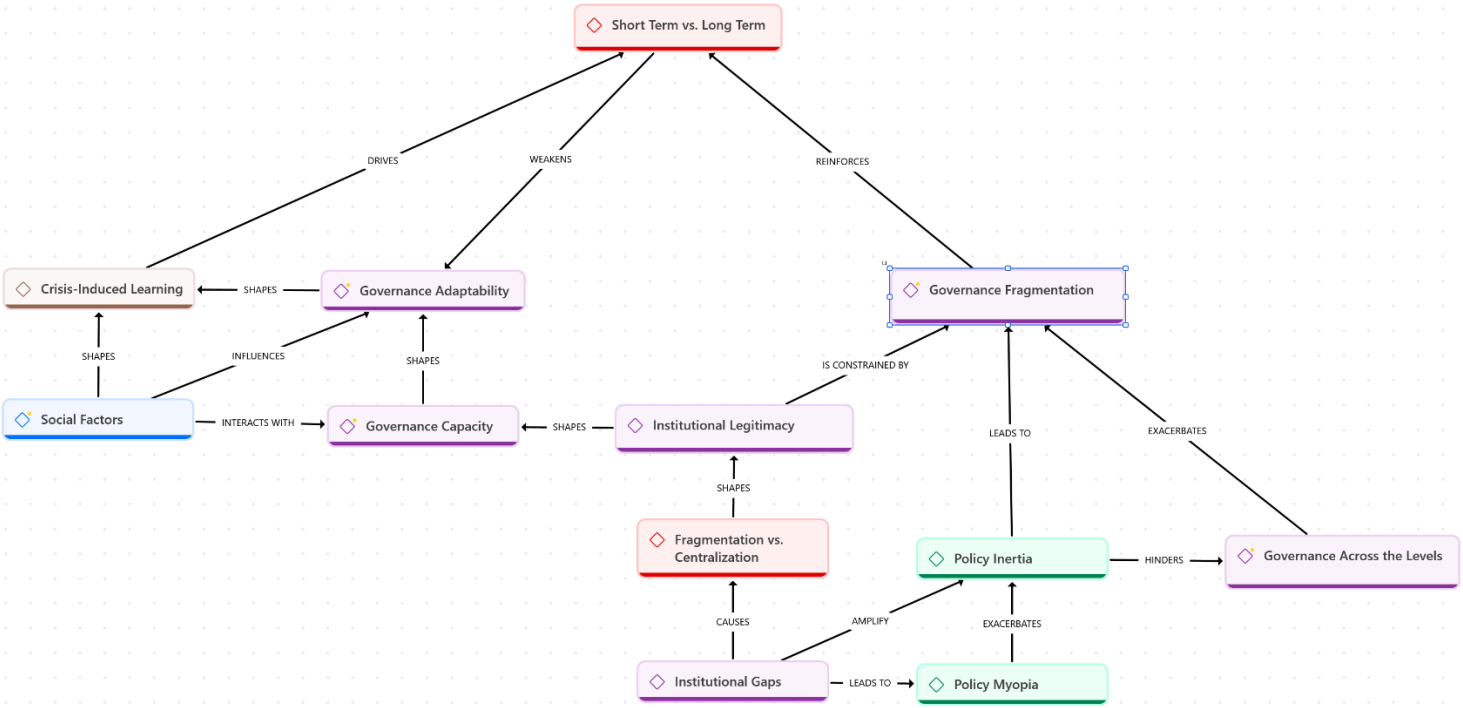
Figure 32 : Abductive Hourglass - Model Conception



From Author (2024)

Building upon the empirical foundation established through Code Co-Occurrence Analysis, the constructed conceptual model attempts to visually capture the interconnectedness of the governance, institutional and policy factors that underpinning the paradox of Short-Term vs. Long-Term Planning in flood resilience. The model illustrates how multiple systemic constraints and reinforcing mechanisms can contribute to the governance challenges that shape resilience in decision-making. By elucidating these key governance tensions, the model aims to unpack the mechanisms through which short-term priorities endure and long-term adaptive strategies remain constrained.

Figure 33 : Short vs. Long Term Planning Relations Model



From Author (2024)

The following sections break down these relationships in greater detail, examining how institutional fragmentation, governance misalignment, and short-termism collectively constrain adaptive resilience strategies. By analyzing the systemic barriers posed by governance silos, policy inertia, and political disincentives, the discussion underscores the structural limitations that hinder the adoption of long-term flood resilience measures. These sections also highlight opportunities for improving governance structures while aligning technical, social, institutional and finally financial legitimacy to create pathways for integrating frugal innovation into flood resilience governance. This exploration ultimately aims to identify key leverage points within governance frameworks where systemic changes can facilitate a shift from reactive, short-term interventions to proactive, long-term adaptation strategies while engaging with the valuable input provided through the interviews.

5.5.1 Institutional Fragmentation and the Governance Deficit in Flood Resilience

A key aspect of this fragmentation is the discrepancy between institutional capacity at different governance levels, particularly between municipal and state institutions, compounded to the higher professional quality of academic institutions, local to the area where resilience is to be applied. As interviewee no. 10 noted: *"You see that there is an enormous discrepancy between the institutional capacity at municipal and state level and the professional quality of the academic institutions, which is a problem because mostly the politicians at those governance levels, they listen or they should listen to their own organizations. So if you have, and I've seen this also in other countries, if you have strong bodies in the governance system, they are usually much more effective in bringing things to the attention of their governors, of their politicians, than the academic sector is."* This observation highlights how institutional fragmentation undermines policy alignment and constrains the integration of expert knowledge into decision-making processes. Thus, in contexts where municipal and state agencies lack robust technical capacity, their ability to develop and implement resilience strategies is compromised, often resulting in an over-reliance on short-term, reactive measures rather than more evidence-based, long-term resilience planning, potentially also subjected to

political oscillations. Furthermore, the disconnect between research institutions, societal needs and further policy implementation exacerbates this cycle of reactive governance. Even when academic research generates innovation or highlights systemic vulnerabilities, the absence of strong institutional mechanisms to bridge research with policymaking more often than not prevents academic insights from influencing flood resilience strategies effectively. This potentially also underscores a window for frugal innovation to attempt a different angle of regime penetration due to its perceived grassroots or socially adaptable nature added to its idea of lesser costs and relative simplicity.

This governance deficit further reflects a broader paradox: while fragmentation can provide stronger institutional frameworks for flood resilience, excessive measure of it undermines knowledge integration and decision-making efficiency. The competing forces of decentralization and institutional autonomy result in misaligned policies, where municipal priorities may contradict broader regional or even national strategies. As interviewee no. 10 also noted: *"I see a large disconnect between the three levels of governance. And I also see historical reasons for how these things have developed. You already mentioned it yourself, the extinction of DNOS. What you can then see is that, obviously, the extinction may have had some kind of reason that I don't know. Let's say there were political or economic reasons for it, whatever it was. But what you see is that, let's say, the level of integrated responsibility that was eventually held by that department was not distributed or allocated to another body. Basically, meaning that infrastructure itself was left with those on whose territory it resides."* This observation reinforces how the absence of institutional coordination can lead to fragmented governance, leaving flood resilience responsibilities ineffectively reallocated in turn contributing to critical infrastructure oversight often dispersed among localized authorities that may lack the capacity or mandate for long-term planning. While this quote specifically reflects governance challenges in flood resilience in Brazil, similar patterns of institutional fragmentation can be observed in other contexts where decentralized governance leads to inefficiencies in disaster preparedness and response, as seen in the breadth of the interviewees, where several different interviewees had similar opinions on the issue at hand. Consequently, the model suggests that overcoming governance fragmentation requires thus stronger institutional coordination while also having mechanisms to elevate “expert knowledge” within decision-making processes, thus ensuring that flood resilience planning is guided by both empirical evidence and practical governance realities, not just the latter.

5.5.2 Policy Inertia, Governance Fragmentation, and the Constraints on Frugal Innovation

The interplay between policy inertia and governance across the levels is also crucial in this discussion. The model makes a case for the fact that governance fragmentation amplifies misalignment across different governance levels, further impeding coordination while slowing institutional responses to flood-related risks. Moreover, policy inertia leads to a lack of institutional adaptation, making governance structures rigid and unresponsive, further deepening fragmentation. As a result, local-level governance bodies struggle to implement long-term strategies, often defaulting to short-term, ad-hoc responses to flood-related challenges instead of using integrative policies. This inertia is particularly problematic for frugal innovation, as governance structures that prioritize reactive measures over long-term planning might overlook integrating low-cost, adaptable solutions that require institutional commitment and awareness, supported by academic institutions and that outlives short-term political cycles; this also displays a resistance to innovation. Interviewee no. 5 highlighted this phenomenon by emphasizing how flood resilience initiatives often face a recurring cycle of political mobilization immediately following a disaster, only for this momentum to dissipate within months after the disaster onslaught: *"There is always a great*

deal of political mobilization during and immediately after disasters, but it dissipates within months. In just a few months, it fades away and is no longer a priority, and there is no organization or institution to keep the necessary maintenance and prevention actions alive." This observation further underscores a structural weakness in institutional continuity, where the absence of power separation or permanent governance mechanisms results in flood resilience being treated as a temporary, reactive concern rather than an ongoing policy priority. For frugal innovation to succeed, resilience strategies must be embedded within long-term institutional structures rather than being contingent on fleeting political attention following disasters, even more so if under post-disaster public pressure. Without established institutions to sustain long-term planning efforts, governance bodies are left often vulnerable to electoral cycles, shifting political agendas, misinformation spread, reinforcing the broader inertia that prevents systemic adaptation.

Furthermore, policy inertia is compounded by the lack of policy penetration within governance structures due to their fragmentation, allowing inertia to spread not only between agencies of similar authority and hierarchy, but across different governmental levels. A disconnect between municipal, state and federal responsibilities results in unclear leadership and accountability gaps, in turn leading to inconsistent resilience measures, leaving assets unmaintained and relinquished to own devices. This aforementioned misalignment particularly impacts the implementation of frugal solutions, as governance fragmentation hinders the ability of different institutional levels to coordinate and integrate innovative, cost-effective, involving approaches to flood resilience. As interviewee no. 7 explained: *"But within government structure, there would be multiple levels of, for example, bureaucracy from federal, ward and finally city level that a solution has to pass through. Now, unification of decisions to translate various best engineering practices into resilience also has to go through all these hurdles that engineering would encounter at each of these particular levels. Another weakness that I see here is that sometimes we miss the holistic overall picture by doing things this way."* This statement highlights the multi-layered complexity of governance structures, where technical solutions for flood resilience cannot be effectively implemented without navigating political and bureaucratic hurdles and obstacles at each level, even if an agency has motivation and technical backing to do so. While best practices in flood engineering exist, their translation into actionable policies is hampered by this misalignment across governance scales.

This governance misalignment reinforces the inertia that prevents systemic adaptation, as flood resilience strategies must overcome multiple institutional bottlenecks before getting a chance of being enacted. In many cases, the absence of an integrated decision-making framework results in fragmented “one-off” solutions that address localized concerns without considering broader regional or systemic flood resilience objectives. This fragmented approach directly limits the uptake of such solutions, as their effectiveness often depends on a systems-level perspective rather than isolated, “one-off” interventions. Furthermore, this lack of a systematic governance approach limits the ability of governments to proactively mitigate flood risks, thus leaving communities vulnerable to recurrent disasters in turn perpetuating poverty and inequality cycles. Addressing these challenges requires institutional reform to improve governance coordination added to mechanisms that ensure policy continuity beyond immediate disaster responses. Without this, flood resilience strategies will continue to be dictated by short-term political cycles, and the potential of frugal innovation will remain largely untapped, despite its capacity to provide sustainable, community-driven flood adaptation strategies thus helping to break such cycle.

5.5.3 Short-Termism in Governance and the Structural Barriers to Frugal Innovation

The model depicts an iterative and self-reinforcing cycle, where governance inefficiencies, institutional weaknesses, and policy failures perpetuate one another, collectively sustaining a governance landscape dominated by short-term priorities, as highlighted throughout this study. The paradox of short-term vs. long-term Resilience is thus not an isolated challenge but rather a product of deeply embedded cycle of governance failures and limitations. Such governance landscape also significantly impacts the adoption of frugal innovation, as it thrives in environments where adaptive strategies are prioritized rather than neglected by authorities, leading them to only applied as "one-off" initiatives. Interviewee no. 19 illustrated this issue by explaining how political cycles and governance structures favor short-term responses, thus neglecting long-term resilience strategies: *"Now, the moment I have a solution in place that solves my immediate problem, any long-term thinking automatically stops, especially if its unorthodox. Why? Why would I do it? Why would I spend my time thinking about a long-term solution if all is momentarily handled?"* This statement highlights how governance systems tend to prioritize immediatism over sustainable, long-term strategies, reinforcing institutional complacency. Ultimately, once a crisis has been temporarily averted, there is little incentive to invest time, political capital, or financial resources into structural changes that could prevent future disasters, especially in environments with strife competition for limited resources.

Interviewee no. 18 further elaborated on how electoral cycles create structural disincentives for long-term resilience planning, reinforcing the NIMTOF (i.e., Not In My Term of Office) mentality, where elected officials avoid projects that extend beyond their tenure, focusing instead on personal political capital: *"I think in general terms, not limited to any specific country, you see that the electoral cycle is very adverse in this respect as well. Elected officials, they have like four years or sometimes five to show their worth and make sure they are re-elected. Well, would you like to focus on a very technical issue like flood protection, something that might never happen in the time that you are in office?"* This statement underscores a critical governance shortcoming, where flood resilience initiatives, especially those necessitating multi-decade commitments, struggle to gain momentum as they do not align with the short-term incentives inherent in political office. This political disincentive structure is particularly detrimental to frugal innovation, as its success depends on incremental and societal adaptation which does not necessarily have this "monument building" attribute favored by political-one-upmanship. Thus policymakers, bound by re-election concerns and immediate political gains, prioritize visible, short-term projects over infrastructure investments that may not yield results within their term. The result is a persistent cycle where long-term resilience is systematically deprioritized, reinforcing reactive disaster management rather than proactive flood mitigation strategies. Moreover, this short-termist approach is not merely a political preference but an institutionalized governance failure, where the mechanisms that should drive long-term planning are systematically politicized. Political debate and alteration is naturally a characteristic of democratic governance, whose efficiency this study wishes not to evaluate; yet this study does suggest that some issues are too strategic and consequential to fall under relinquishment of oscillations and partisan policies. In this context, frugal innovation faces structural barriers to adoption, as governance mechanisms fail to support innovative solutions, even if grassroots developed. The absence of institutional continuity, lack of financial incentives for proactive resilience building and ultimately the fragmentation across governance levels all compound to the reinforcement of this paradox. Therefore, without systemic change, flood resilience efforts will continue to be dictated by political cycles, rather than by the scientific and infrastructural needs required for long-term adaptation.

5.5.4 Institutional Legitimacy and the Viability of Frugal Innovation in Flood Resilience

A crucial structural dimension of the model is the role of institutional legitimacy, which directly shapes how crisis-induced learning processes take place. Institutions that lack legitimacy struggle to effectively integrate lessons learnt from past disasters as well initiatives and efforts which might have been taken or attempted, thereby weakening long-term planning capabilities. Similarly, social factors influence governance capacity, and in turn, governance capacity shapes adaptability, reinforcing either flexibility or rigidity in enactment of policy responses. These relational dynamics underscore how institutional inadequacies, fragmented decision-making processes, and reactive policy orientations collectively perpetuate the predominance of short-term approaches over comprehensive, long-term adaptation strategies. As interviewee no. 19 noted: *"And then, when you move past this technical part, I think you start entering more into the social aspect, interacting with people, raising awareness. So this is the minimum, you know, the very least that needs to be done, even just to get the community to start engaging, to start understanding the risks they are exposed to."* This perspective highlights how solutions to flood resilience must go beyond purely technical considerations while also taking into account the social dimension. Without adequate engagement, risk awareness and societal participation, even the most technically sound solutions may face resistance or fail to achieve their long-term effectiveness and sustainability. The integration of social factors into governance adaptability is therefore essential to ensuring that resilience measures are both effective and accepted by local populations. In this context, frugal solutions present an opportunity to enhance flood resilience by leveraging on low-cost, adaptable, and potentially also ecologically aware approaches that extend beyond purely technical solutions. As interviewee no. 12 explained: *"But we also need to inform the local people and the governments that frugal solutions not only deal with the flooding issues, but also they bring co-benefits, like the ecological benefits, the social benefits, which is also important for the society, as we have limited spaces, both above and underground.*
So frugal solutions can offer a synergistic solution to not only deal with the flooding, but also bring other benefits. And in that sense, people can understand that even though the failure of those nature-based solutions happens during the big events, we still have the motivations to promote them in the future, just because they have more co-benefits that we normally, those grey infrastructures cannot offer to our city." This statement underscores the multi-dimensional value of frugal innovations for flood resilience, emphasizing that their viability extends beyond cost-efficiency to include broader ecological, social and spatial benefits. Unlike traditional "grey" infrastructure solutions, which often require significant capital initial investment and dynamic financial planning, frugal approaches prioritize adaptability and grassroots accessibility, making them more viable within governance structures characterized by institutional constraints and financial limitations.

Building on this, interviewee no. 1 elaborated on the multi-dimensional nature of legitimacy in governance, emphasizing the dimensional interdependencies of technical, social, institutional, and financial legitimacy: *"Imagine that in a context like Brazil, we have a certain legitimacy—actually, not just Brazil, but the whole planet—a technical legitimacy, a plan. So this idea falls within the scope of technical and scientific legitimacy, a legal framework. Then comes social legitimacy. Imagine Porto Alegre. I ask you: people have homes there, some good, some bad. Should they leave? That area should be for vegetation and subject to flooding. Should they leave? What I am saying is that there is a kind of social legitimacy, let's call it that. After that, there is what I would call institutional legitimacy. The city government has engineers, trained professionals who understand this language, the organizational structure, the human resources of the municipality—or the agency, which does not exist, but should exist. So here, I am talking about institutional legitimacy. Finally, I mention financial legitimacy. There must be resources. If I have to relocate people, I will have to expropriate*

land, I will have to pay for it, I will have to buy the land, and so on. Where does the solution lie? In the overlap of these different dimensions. So I need to have technical legitimacy, social legitimacy, institutional legitimacy, and financial legitimacy." This perspective highlights how the legitimacy of an institutional response depends on multiple, interrelated and often also contradicting dimensions; technical, social, institutional, and financial, each of which must align for governance measures to be both accepted and effectively implemented in a space hereby mentioned as legitimacy convergence. Moreover, this is also particularly relevant for frugal innovation, as its success relies on overcoming aforementioned institutional and financial barriers while simultaneously addressing social and technical legitimacy concerns. Ultimately, the adoption of frugal innovation in flood resilience depends on the ability of governance structures to integrate these legitimacy dimensions into proper decision-making, ensuring that these solutions gain institutional traction rather than being dismissed and sidelined due to systemic hurdles and constraints.

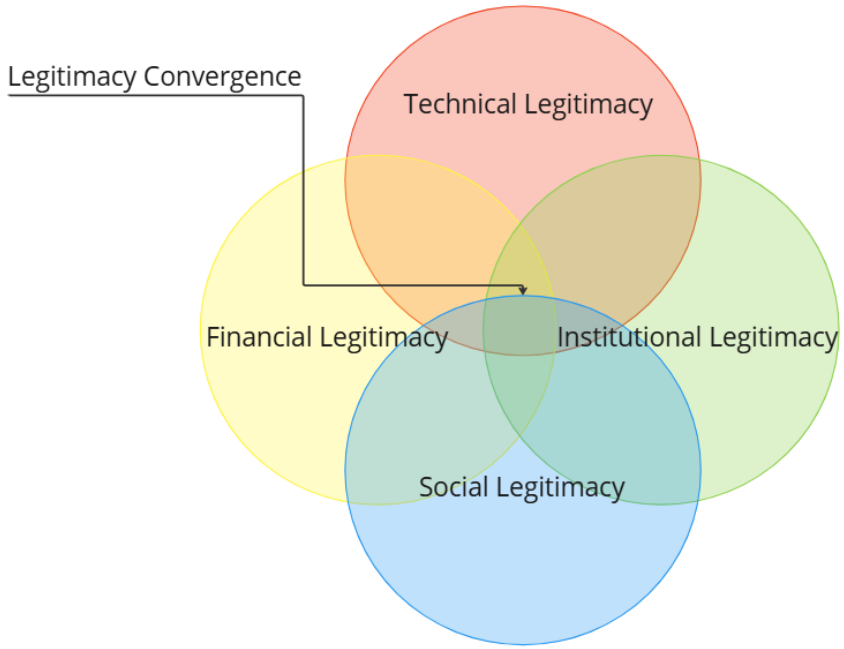
5.5.5 Overcoming Governance Barriers to Long-Term Resilience

The preceding discussion highlights how institutional fragmentation, policy inertia, and short-termism collectively reinforce the paradox of Short-Term vs. Long-Term Planning in Resilience in flood governance. These governance failures systematically constrain the adoption of frugal innovations, as they prioritize reactive, high-cost infrastructure solutions over low-cost, adaptable, and community-driven approaches in an effort to engage with political capital associated with them. Institutional fragmentation then leads to misaligned policies while policy inertia prevents adaptive governance mechanisms while simultaneously short-termist decision-making perpetuates a cycle of temporary interventions rather than sustainable, long-term strategies. However, while these structural constraints present formidable barriers, institutional legitimacy emerges as a critical enabler of potential systemic change. The findings indicate that legitimacy is a multi-dimensional construct, where each of the dimensions plays a pivotal role in determining whether frugal solutions can be integrated into mainstream governance frameworks. Thus, without broad legitimacy across these dimensions, flood resilience policies remain vulnerable to fragmentation, inconsistent adoption and political volatility. Consequently, the next chapter builds upon these insights by defining the four legitimacy dimensions, analyzing their interactions, and assessing how their convergence influences the adoption of sustainable flood resilience . This discussion is key to understanding why the paradox of Short-Term vs. Long-Term Resilience is persistent, and more importantly, what governance shifts are required to break the inertia that inhibits transformative adaptation in flood resilience governance.

5.6 The Role of Legitimacy in Frugal Flood Resilience

The viability of long-term flood resilience strategies, particularly those involving frugal innovation, is in accordance with this study fundamentally shaped by legitimacy. Without legitimacy across multiple dimensions, solutions shall struggle to gain traction within the governance systems they must interact with. The paradox between short-term and long-term resilience is not just a function of political cycles or institutional inertia, but is deeply embedded in the way legitimacy is constructed and maintained across different governance interdependencies and interfaces.

Figure 34 : 4 Legitimacies Prototyping



From Author (2024)

Legitimacy functions as a key conduit through which policies, practices and innovations transition from mere conceptualization to potential implementation. When governance structures fail to recognize or integrate certain solutions, these approaches often end remaining marginalized, regardless of their potential and technical soundness. The findings presented earlier indicate that legitimacy in flood resilience is not singular but rather a multi-faceted construct that must be sustained on the long term scale. Based on this conceptual framework, this study defines legitimacy by encompassing four critical aspects:

1. ***Technical Legitimacy*** – The perceived reliability, scientific basis, and engineering soundness of a solution.
2. ***Institutional Legitimacy*** – The extent to which governance structures formally recognize and support an approach.
3. ***Social Legitimacy*** – The level of acceptance and engagement from affected communities and stakeholders.
4. ***Financial Legitimacy*** – The ability to secure resources and funding for sustained implementation.

Each of these dimensions interacts with the governance constraints outlined in the previous sections, outlined by the selective codes, thus reinforcing the systemic barriers that hinder the adoption of long-term resilience strategies. Frugal innovation, in particular, often faces challenges in securing legitimacy across all four dimensions, as it competes with established paradigms that prioritize large-scale, high-cost infrastructure, nevertheless seeing potential benefits with its socially involving dimensions.

5.6.1 Technical Legitimacy: The Scientific and Engineering Foundations of Resilience

Technical legitimacy refers to the scientific validity, engineering robustness, and practical feasibility possessed by a solution or initiative. It determines whether a given intervention is recognized as technically sound by experts, engineers and policymakers responsible for implementation, along with readiness and availability. In the context of frugal innovation, achieving technical legitimacy can be particularly challenging, as these solutions tend to prioritize adaptability and cost-efficiency over the standardized, high-investment models that typically define traditional flood management paradigms. A key concern within technical legitimacy is that governance structures often favour highly engineered solutions, even if such might not necessarily be more robust or more comprehensive, over alternative, nature-based interventions. This is reflected in the tendency of decision-makers to prioritize grey infrastructure, such as levees, dams, and drainage systems, due to their perceived reliability and measurable proofness. This study has found that a mix of several complimenting methods does indeed lead a solution to have more soundness and technical legitimacy in the long run. As interviewee no. 12 noted, even in large-scale government-led initiatives such as the Sponge City initiative seen in China, concerns persist regarding the ability of more non-traditional approaches to handle severe climate: *"I think China also faced with such confusion or misunderstandings and misinformation along the way since Sponge City was initiated in 2014, so 11 years ago. So we also have such critics or doubts from the local level and from the academia that the frugal and more adaptable and potentially also nature-based solutions cannot deal with the big events, like the extreme events."* This skepticism reveals a key barrier to frugal innovations: technical legitimacy does not just pertain to scientific soundness but also about perceptions of reliability and accountability. Decision-makers may resist frugal innovations if they are seen as unproven or lacking engineering rigor, despite their demonstrated success in various contexts, particularly with resource constrains.

Therefore, technical legitimacy is often linked to risk perception. The fear of failure, particularly in the face of extreme weather events, can lead to institutional inertia, where established solutions are chosen not necessarily because they are the best option for the local context, but because they are perceived as "safe" through a lens that value importing solutions from the Global North. Interviewee no. 11 further emphasized this point: *"There is always some level of resistance even if it's mental resistance. When some countries are thought of as the "robustness" world's leaders, I tend to buy more into whatever comes from them - something that is grassroots doesn't tend to have that appeal."* This statement highlights a key challenge in introducing innovative flood resilience strategies, decision-makers and institutions often exhibit a preference for solutions endorsed by established engineering paradigms from the Global North, while novel or locally developed alternatives face heightened scrutiny and skepticism. As a result, frugal innovations may struggle to gain traction, not necessarily due to technical inferiority, but because of ingrained biases that favour conventional infrastructure approaches, in a cycle potentially inspired by legacies of colonialism. Thus, beyond engineering feasibility, contextual adaptation plays a crucial role in determining technical legitimacy. Technical solutions must be designed with the local environment, governance capacity, and infrastructural constraints in mind to ensure their feasibility. Given this interviewee no. 7 highlighted this issue: *"We do not blindly apply a model developed for an unmanaged system to a managed system. We try to account for all these interventions using the best models picked globally and contextualize them to India. Of course, it results in much better accuracies or reliability of the models that develop henceforth."* This insight underscores that technical legitimacy goes beyond universal engineering principles; it also necessitates the contextualization of solutions to align with

local, often diverging, conditions and realities. Models and interventions that have worked in one setting cannot be assumed to be directly transferable to another without appropriate adjustments to governance structures, environmental conditions, and societal needs. Frugal solutions, in particular, require a different validation framework; one that considers adaptability, scalability and integration with existing systems, rather than strict adherence to conventional engineering standards alone in order to achieve their full potential.

Table 5 : Key Determinants of Technical Legitimacy

Factor	Explanation	Interview Source
Engineering Reliability	Solutions must demonstrate robustness and performance under extreme conditions to become credible among engineers and policymakers.	*Interviewee 7: "I think that particular balance is what many of us aspire to achieve even in our research or the central message that we try to build around the resilience that let us not blindly do cut copy paste of a model developed somewhere else, apply it here and then get surprised it is not working. Yes it was not supposed to work in first place because it has not been contextualized well enough."*
Risk Perception	Decision-makers tend to favor conventional solutions perceived as 'safe,' making it harder for novel approaches to be accepted and integrated.	*Interviewee 11: "even if we use frugal solutions, one thing that people sometimes say about Things like that and you know, they need some better understanding, can you evaluate the longer terms? We talked about short term long term and we make a case sometimes for frugal solutions based on longer term. Yes, But then people will still say can you evaluate?*
Contextual Adaptation	Technical models must be adapted to local environmental, infrastructural, finally and governmental conditions to ensure feasibility.	*Interviewee 16: "The challenge is often in adapting the solution developed at one place to another. Sometimes we get overly technology-focused and fail to understand that technology, while useful, must be adapted to the local context. What worked in the Netherlands may for instance not work the same way in Jakarta"*
Validation Framework	Frugal solutions require alternative validation methods that emphasize adaptability, scalability, and integration within existing resilience frameworks.	*Interviewee 8: "So I would not blame people who are going towards frugal solutions to safeguard their community, but I think the onus is on us as researchers, as developers of these frameworks, to heavily contextualize various resilience frameworks that would fit our needs."*

Ultimately, for frugal innovations to gain technical legitimacy, they must demonstrate reliability through empirical evidence, pilot projects and comparative analysis which allow for their holistic benefits to society to also be captured. The integration of academic research, performance data and real-world applications can help counteract institutional skepticism. However, this alone is often not enough; technical legitimacy must also align itself with institutional and financial legitimacy to ensure these solutions move beyond experimental phases and into mainstream flood resilience planning, while naturally respecting social legitimacy.

5.6.2 Institutional Legitimacy: Governance Structures and Decision-Making Authority

Institutional legitimacy refers to the extent to which a flood resilience solution is recognized, endorsed and further integrated into formal governance structures along with decision-making frameworks. It determines whether an intervention aligns with existing policies, regulatory mandates and institutional priorities, thus directly shaping its ability to be adopted, scaled and sustained. In the context of frugal innovation, institutional legitimacy presents a substantial challenge, as governance structures tend to favor centralized and technocratic, over more decentralized and community-driven approaches.

A key factor influencing institutional legitimacy is the fragmentation of governance across multiple levels and between interfacing agencies. Flood resilience decision-making often involves a complex web of municipal, state, and national agencies, each operating within distinct political and regulatory constraints and following a fragmented bureaucratic modus operandi. In the case of Porto Alegre, Brazil, this fragmentation has been particularly evident during the May 2024 Floods, exacerbating challenges in flood resilience implementation as interviewee no. 2 noted: *"I see a large disconnect between the three levels of governance. And I also see historical reasons for how these things have developed, exemplified by the extinction of DNOS. What you can then see is that, obviously, the extinction may have had some kind of reason that I don't know. Let's say there were political or economic reasons for it, whatever it was. But what you see is that, let's say, the level of integrated responsibility that was eventually held by that department was not distributed or allocated to another body. Basically, meaning that infrastructure itself was left with those on whose territory it resides."* This institutional disconnect generates gaps in accountability and coordination, resulting in inefficient implementation of flood resilience measures. Frugal innovations, which often rely on flexible and interdisciplinary governance approaches, struggle to gain traction within such rigid structures.

Another crucial dimension of institutional legitimacy involves the dominance of formal expertise and bureaucratic resistance to change. Traditional governance systems tend to prioritize formal expertise and technical credentials, often dismissing locally developed, grassroots solutions that do not fit within established institutional frameworks. Echoing this viewpoint, interviewee no. 6 observed that: *" You see that there is an enormous discrepancy between the institutional capacity at municipal and state levels and the professional quality of academic institutions, which is a problem because mostly the politicians at those governance levels, they listen only to their own organizations. And you dont always have a strong technical and community involving body in the governance system, such are usually much more effective in bringing things to the attention of their governors, of their politicians."* This statement highlights a deeper structural issue: decision-makers tend to rely primarily on internal institutional bodies for guidance, but these bodies often lack either the technical capacity or the mechanisms for meaningful community participation needed to support innovative and most importantly, context-sensitive solutions. Consequently, even when frugal innovations demonstrate technical validity and local relevance, they may struggle to gain institutional legitimacy if they are not championed by governance structures equipped to recognize and integrate such approaches.

Table 6 : Key Determinants of Institutional Legitimacy

Relevant Factor	Explanation	Interview Source
Governance Coordination	Decision-making authority is effectively structured across	*Interviewee 12: "China also underwent governance reform and is still reforming. It is not*

	multiple governance levels, ensuring accountability and implementation of frugal solutions through clear roles and collaboration.	*uniform across every city, but in places like Beijing, Shanghai, or Shenzhen, they have already established a Water Affairs Bureau, which consolidates all water-related affairs into a single entity. This integration allows for a more consistent and coherent water management plan."*
Adaptive	Institutions demonstrate flexibility by fomenting innovation and adapting to new developments and oscillations while maintaining necessary regulatory oversight, thus fostering a balance between stability and adaptability.	*Interviewee 9: "We could have this tool in Brazil that other countries don't have, for example, a set of principles such as decentralized and participatory management, with structures like basin committees, basin agencies, and financing mechanisms through water usage charges, which, despite having several issues, could be leveraged, so to speak, to act in this area."*
Technocratic Balance	Governance structures integrate technical expertise with community-driven knowledge, ensuring that technical validation is complemented by practical, on-the-ground knowledge for more inclusive decision-making.	*Interviewee 17: "We have a clash between highly technological solutions and approaches that are more grounded in local realities. If we only rely on science and engineering without considering local conditions, we create a disconnect between the solutions and their real applicability. The challenge is to integrate technical knowledge with the practical experience of the affected communities."*
Institutional alignment	Regulatory frameworks and policies are designed to facilitate the sharing of context-specific knowledge across different levels of institutions, ensuring that the unique benefits of frugal innovation are leveraged to enhance flood resilience.	*Interviewee 3: "For example, the Paraíba do Sul River basin has already established its basin agency and basin committee, which take a holistic view of the entire basin. All relevant stakeholders are represented there. One issue that could be addressed is the underrepresentation of civil defense agencies within these committees."*

Institutional legitimacy is closely tied to technical legitimacy, as governance bodies often require scientific validation and expert approval before adopting new approaches. However, as discussed in the previous section, institutional frameworks tend to prioritize large-scale, capital-intensive solutions over adaptive, grassroots alternatives. This creates a paradox where decision-makers demand grey- based frameworks which don't end up being developed, while institutional constraints prevent innovative frugal solutions from being integrated into policy strategies. The subsequent section will examine the dimension of Financial Legitimacy, investigating how funding mechanisms, budgetary priorities, and economic incentives can shape the viability of flood resilience solutions. Additionally, it will explore how frugal innovation must navigate financial barriers to achieve widespread adoption.

5.6.3 Financial Legitimacy: Economic Feasibility and Investment Priorities

Financial legitimacy refers to the degree to which a flood resilience solution aligns with funding structures, budget allocations and investment priorities. In the context of frugal innovation, financial legitimacy tends to be more favorable, as traditional flood resilience measures often require large-scale, capital-intensive infrastructure projects, which are nevertheless favored by governments and

international financial institutions. Contrastingly so, frugal solutions tend to emphasize low-cost, locally sourced alternatives, which may not fit within conventional financing models, but have a tendency of being much cheaper in comparison and thus potentially easier to penetrate the socio-technical system. A core challenge to financial legitimacy is the mismatch between budget cycles and long-term resilience needs. Flood resilience planning is frequently constrained by short-term budget cycles, thereby limiting the capacity of governments to invest in cost-effective solutions that generate long-term benefits. Interviewee no. 5 highlighted this issue: *"There is always a big political mobilization during and immediately after a disaster, but this dissipates within months. In a few months, the issue is no longer discussed, and there is no institution that keeps the necessary maintenance and prevention actions alive."* This observation underscores how flood resilience funding is reactive rather than proactive, favouring high-cost emergency interventions over sustained, and preventative and often incremental strategies. Because frugal innovations are typically preventive in nature and rely on consistent investments rather than large lump-sum infrastructure funding (i.e., also favored by political-one-upmanship), they struggle to achieve financial legitimacy within existing budgetary frameworks since they often require the coordination and mobilization of multiple stakeholders across sectors and governance levels.

A critical factor determining financial legitimacy is the reliance on external funding sources, such as international aid, development banks, and public-private partnerships. A majority of large-scale flood resilience initiatives are financed through loans, grants, or private-sector collaborations, which tend focus on traditional, high-visibility infrastructure projects over decentralized, low-cost alternatives. As Interviewee 9 observed: *"The whole idea of state reform in Brazil, before ACPI, was that the government played a very direct role in infrastructure construction and even in the operation of some economic sectors, such as mining, oil and gas, and electricity. However, there was an exhaustion of investment capacity. The perception, in summary, was to shift the role of the state towards a more regulatory function, seeking to attract private capital to carry out infrastructure investments, which never actually happened."* This shift from direct government intervention to a more regulatory role meant that infrastructure financing became increasingly dependent on private investment and external funding, in the case of Brazil, this shift in policy did not end up providing successful outcomes due to market's unwillingness to invest in a sector (i.e., infrastructure) deemed to be secondary in priority, at least in a near time horizon, thus highlighting once more the paradox between long vs. short term planning. This dynamic limits the widespread adoption of resource-efficient flood resilience strategies, reinforcing the structural challenges of financial legitimacy.

Nevertheless, some countries have attempted to involve market-based strategies for flood resilience, which rely mainly on private sector involvement, insurance mechanisms and financial instruments such as resilience bonds, shifting financial risk and some degree of responsibility from governments to private markets. These approaches aim to leverage private capital for resilience investments, reducing the direct fiscal burden on public institutions. However, this transition also raises concerns about who ultimately bears the cost of risk mitigation and how financial resources should be distributed. As interviewee no. 6 noted: *" So why not let the market take the risk in resilience as well? I mean, who takes the risk in terms of insurance, right? It is the market ultimately. It's the insurance companies, and then the insurance companies who insure the insurers, and then they go to the market, this could provide for wondrous results if well policed."* This perspective underscores an interesting perspective regarding the market's role in absorbing climate-related risks, within a larger debate over governmental interventionism, or the lack thereof. While such mechanisms can incentivize investment in preventive infrastructure and disaster mitigation, they may also reinforce existing inequalities by prioritizing high-value assets and well-insured regions over vulnerable, under-resourced and vulnerable communities. Resilience bonds and insurance-based solutions require careful regulatory oversight to ensure that financial incentives align with long-term goals rather than short-term profit motives. This kind of policy may not easily transferable

to the developing country contexts where many frugal innovations potentially can be adopted, as the financial markets are not as independent or even developed leading to predatory practices allowing for resources to be deviated from original purposes, besides potentially negating any grassroots developments that might spring from such vulnerable tracts of society. Thus, without policy interventions that promote equitable financial access, market-driven strategies risk deepening existing disparities in flood resilience funding.

This dynamic is reinforced by a general institutional risk aversion, where decision-makers prefer funding established solutions over experimenting with new approaches. Even if frugal innovations have lower costs and higher long-term benefits, the reluctance to invest in innovation that potentially carries a prejudice due to perceived "lack of sophistication" might further limit their financial legitimacy. Financial legitimacy is ultimately closely tied to institutional legitimacy, as governance structures determine which projects receive funding and how budget allocations are made. While frugal innovation offers a scalable, cost-effective approach to flood resilience, its financial viability relies on policy reforms that enable flexible, long-term funding mechanisms rather than short-term, reactive expenditures.

Table 7 : Key Determinants of Financial Legitimacy

Factor	Explanation	Interview Source
Long-Term	Long-term financial planning integrates flood resilience into ongoing investments, ensuring consistent funding over a large timespan.	*Interviewee 5: "So financing is not only for construction but also for maintaining the infrastructure and non-structural actions, such as zoning risk areas, mapping, and monitoring. The source of financial resources to sustain all of this is also not outlined in policies."*
Diverse	A mix of international aid, development bank financing along with local investments ensures flexibility in funding models, allowing for infrastructure and projects to thrive.	*Interviewee 11: " Some people have been saying there is a need for more private-public government partnerships, or other alternatives to handle this overall thing. But in the U.S., at least, it's easier when we say that, okay, there is an impact on the market, and the market will take care of some of these risks"*
Incentives	Incentives should be structured to support not only high-visibility preventive participation and diversity in funding over a consistent amount of time.	*Interviewee 15: "Although I think advances in science and technology together with financial incentives could change this, especially if, in some cases, the private sector and the markets gradually begin to take over."*
Risk-Aware	Funding mechanisms should integrate structured risk assessment, enabling decision-makers to support both conventional and innovative solutions instead on relying on perceived costs.	*Interviewee 2: "You must have disaster declarations, emergency, public calamity, and emergency mechanisms that allow for quick financial transfers from the federal government directly to municipalities when they need to respond to disasters. To carry out works, assist the population, and even provide health assistance."*

5.6.4 Social Legitimacy: Community Acceptance and Participatory Governance

Social legitimacy refers to the extent to which a flood resilience solution is accepted, understood and embraced by local communities, stakeholders and finally broad society. Unlike financial or technical legitimacy, which are often determined by institutions and policymakers, social legitimacy is shaped by public perception, cultural attitudes and direct interfacing with the community. In the context of frugal innovation, social legitimacy is a critical element, as many frugal solutions rely on decentralized, community-driven strategies rather than top-down, frameworks. In such contexts, even the most technically sound and financially feasible solutions can fail if they lack local acceptance and engagement, independent of them being characterized as frugal or not. Furthermore, one of the key challenge for frugal innovations to achieve social legitimacy is the lack of public awareness and risk perception of solutions that might not necessarily include traditional methods in their scope. Interviewee no. 13 emphasized the role of social engagement in strengthening adaptation efforts: *"So it's only true that our education and awareness campaigns need to be restructured in a way that weaves all the factors which makes people, or a community, want to stay in the flood prone areas and then have them understand the risks, even if measures are in place."* This statement underscores how technical solutions alone are insufficient; without proper community engagement and education, even well-designed flood resilience strategies may face resistance or lack local buy-in. Frugal solutions, which often depend on local participation and grassroots implementation, thus require strong community awareness to be successfully adopted.

Another barrier to social legitimacy is the resistance to change and cultural preferences for more conventionally established infrastructure solutions. Large-cale, government-led projects often symbolize progress and modernity, making them more socially acceptable than nature-based and low-cost frugal solutions. This challenge was highlighted by interviewee no. 18 who noted this phenomenon within Korea: *" In Korea, many people think that frugal, more nature based solutions will not solve the problem. They think it's just a big kind of "ideal-world case solution", something that is more of a symbolic political effort rather than a functional and established one."* This reflects a growing but also debatable shift in societal attitudes, where people recognize the benefits of frugal solutions but may still have more trust in conventional flood defenses due to their perceived reliability and effectiveness. Overcoming this preference potentially requires sustained education, demonstration projects and participatory planning processes that actively involve local communities. Also given the long-term benefits of including a mix of traditional and more innovation might bring.

Social legitimacy is also closely connected to trust in governance and institutional decision-making processes. If local communities lack confidence in policymakers, engineers, or planners, they will be less inclined to support or engage with resilience initiatives. Interviewee no. 10 emphasized this challenge, noting how it can weaken institutional credibility: *"Now, maybe reflecting a little bit on Rio Grande do Sul, well, you, of course, have a difficult situation there also because at municipal and state and federal level, you have three different political parties or groups that take responsibility. It was my impression that, let's say, the different bodies tried to work together, but there were also, let's say, apart from institutional fragmentation, there were also these political frictions, let's call it like that, that you could see, ultimately hampering the idea of a united front to solve the problem."* This underscores how resilience revolves around more then simply technical knowledge, but also referring to how governance structures interact with local realities. When institutional fragmentation and political tensions shape decision-making, communities may resist relocation efforts, reject adaptation measures or distrust government-led resilience programs. To enhance

social legitimacy, frugal flood resilience strategies must be co-designed with local communities, ensuring that solutions are:

Table 8 : Key Determinants of Social Legitimacy

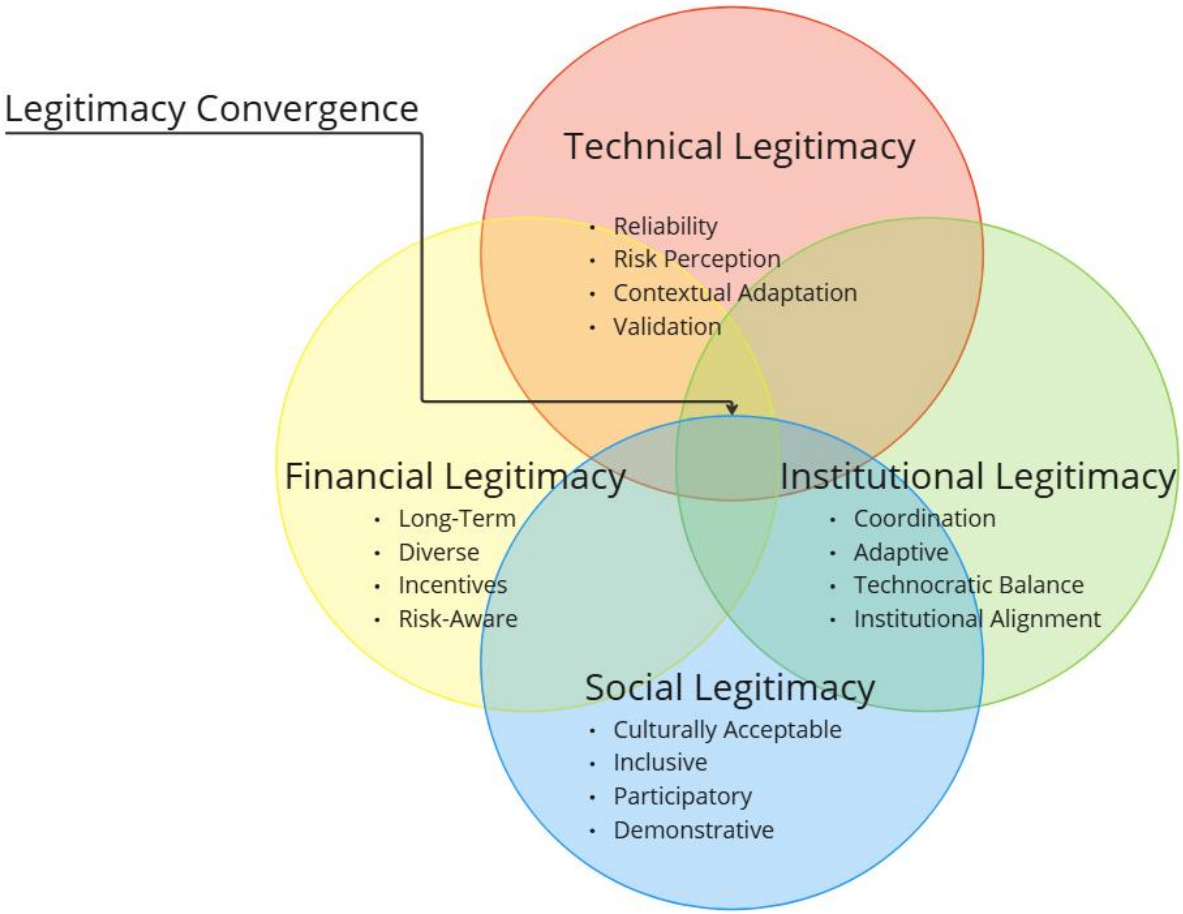
Relevant Factor	Explanation	Interview Source
Culturally Acceptable	Solutions should align with local customs, traditions and daily realities to ensure acceptance and integration.	Interviewee 15: *"The thing is, yes, I would say local knowledge, local practices, as how we name it, it's local, so it suits local level where it grows. So I would not say that, let's say for example, practices that are good for a particular local area of a particular island in Indonesia will directly be applicable to a local area, let's say in South America, for example. Natural circumstances, social environments, and they are different."*
Inclusive	Decision-making processes should actively involve local leadership, ensuring that diverse voices are considered within resilience planning and avoiding further conflicts.	Interviewee 7: *"So how you are empowering local communities, although we talk about politics and power dynamics, sometimes the inherent power dynamics at much smaller scale also makes community resilient because a lot of issues would be handled at village scale or at ward scale or at city scale just because there is a decentralization of power."*
Participatory	Local communities should be actively involved in the co-creation of resilience solutions, or at minimum, informed about the measures being implemented. This fosters a sense of ownership and commitment among residents, which enhances the likelihood of long-term success.	Interviewee 9: *"So, yeah, I would advocate for making every effort possible to bring together, let's say, international knowledge or call it innovative knowledge, can also be from a university, even in the same area, and local knowledge, which I would see distinctly more at the community level, at the knowledge of local systems. Bringing that together and making sure that becomes productive for the development of strategies is very important."*
Demonstrative	Successful small-scale implementations can build confidence in frugal solutions, demonstrating their effectiveness and further increasing public support.	Interviewee 5: "So we defined a new methodology because the first one was very qualitative, based on experience, and did not have much data from state civil defense agencies. So we interacted with these agencies to understand their experiences, which cities they knew were frequently flooded and impacted the most. At that time, it was more of a qualitative analysis. Today, we have a historical database."

This This participatory approach ensures that flood resilience measures are not unilaterally imposed, but rather integrated into the social fabric of communities, enhancing the likelihood of long-term success. Moreover, social legitimacy cannot be separated from institutional legitimacy; if people trust institutions and feel that their voices are heard, they are more likely to embrace and adopt resilience measures in their interfaces with society. By integrating participatory governance with frugal innovation, policymakers can hope to build public confidence thus ensuring that flood adaptation strategies are both acceptable and effective. With the four dimensions of legitimacy now

established, (i.e., technical, institutional, financial and social) the next section will examine how these elements converge to determine the overall viability of frugal innovation in flood resilience.

5.6.5 Legitimacy Convergence

Figure 35 : 4 Legitimacies



From Author (2024)

The long-term viability of frugal approaches to flood resilience relies not only on the individual presence of the aforementioned technical, institutional, financial and social legitimacies, but also on their convergence and mutual reinforcement. This intersection of legitimacy factors is what constitutes legitimacy convergence, a condition where a solution is technically sound, institutionally recognized, financially viable and ultimately also socially accepted. These dimensions must interact in a way that facilitates sustainable implementation and scalability, also hoping to foment a balance or equilibrium between often competing areas**.** Legitimacy convergence represents the threshold beyond which frugal solutions transition from experimental grassroots alternatives to integrated components of flood resilience governance**.** When only one or two dimensions of legitimacy are present, an innovation remains marginalized**,** failing to gain traction due to resistance from institutions, financial constraints or a lack of overall public support.

When all four dimensions of legitimacy are aligned, the innovation finds space to moves beyond isolated "one-off" initiatives becoming integrated into mainstream policy frameworks, thus ensuring its long-term sustainability. The process of achieving legitimacy convergence is particularly complex in the Global South, where governance structures are often more fragmented, financial resources are constrained and institutional frameworks are often highly dependent on external funding sources. Frugal solutions, must then navigate these challenges by securing legitimacy across multiple, often competitive levels of decision-making. This requires proving their reliability within

technical frameworks, aligning with policy priorities, demonstrating cost-effectiveness to financial stakeholders and gaining public trust through participatory governance; which may seem monumental yet requires careful planning to capture the potential trade-offs necessary for its occurrence. Disaster events can sometimes provide a window of opportunity for revising or reforming existing imperatives and frameworks, as societal pressure mounts for change. However, this momentum for reform is often short-lived, and sustaining long-term progress can be challenging. Furthermore, one of the core challenges in achieving legitimacy convergence is the sequencing of legitimacy acquisition. In some cases, technical legitimacy precedes institutional legitimacy, as solutions must first prove their effectiveness before being recognized within policy frameworks. In other cases, financial legitimacy serves as the entry point, where external funding or cost-effectiveness studies push decision-makers to consider new approaches, also describing an actual variance in the legitimacy's importance over a period of time and given certain conditions. Given that, without social legitimacy, even the most technically and financially sound solutions risk rejection or poor implementation, finally needing institutional legitimacy across time for their sustainability. The interdependence of these factors means that legitimacy convergence is not a static process; it is a dynamic that requires continuous reinforcement and adaptability.

The following sections will explore how governance fragmentation poses a critical impediment to the successful integration of frugal innovation in flood resilience governance. By analyzing the structural inefficiencies, jurisdictional conflicts, and institutional gaps that hinder long-term resilience planning, this discussion will highlight how fragmentation disrupts the alignment of technical, institutional, financial, and social legitimacy, with a focus on the case study of Brazil. The examination will then transition to the Odisha Model, illustrating how legitimacy convergence can be achieved despite fragmented governance structures and exemplifying the convergence of these legitimacies.

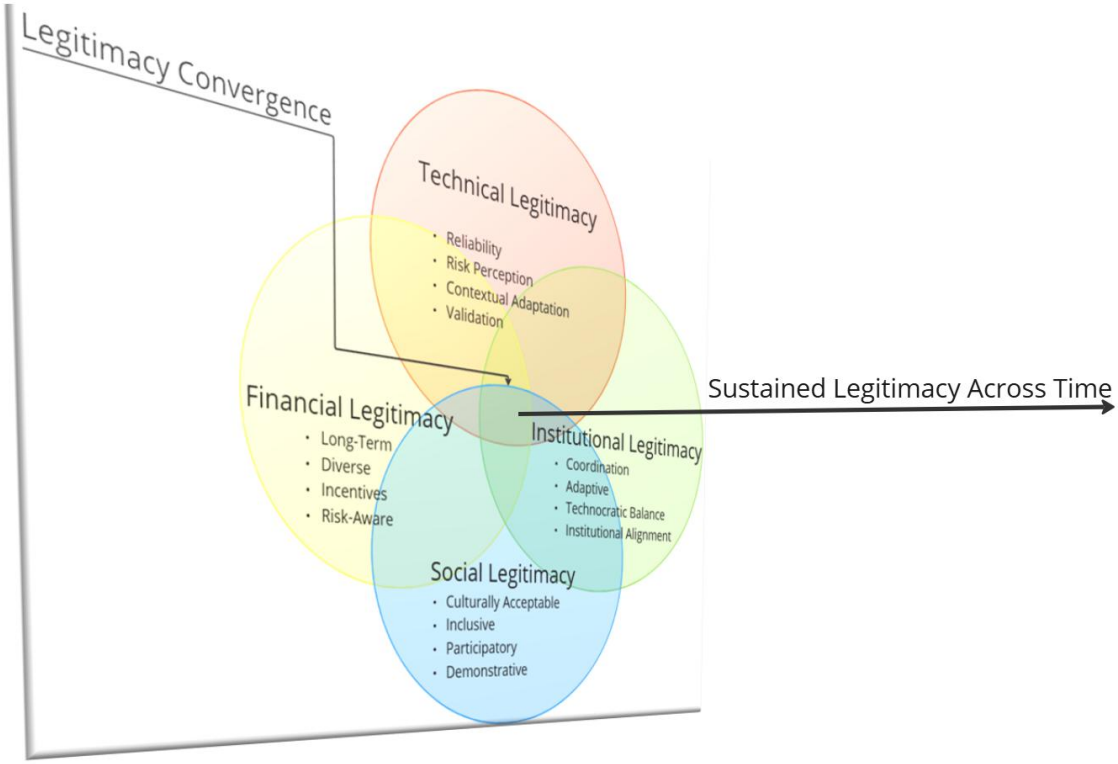
5.7 Establishing Institutions to Overcome Fragmentation

The May 2024 flood in Rio Grande do Sul, Brazil, serve as a stark case study of how institutional fragmentation can lead to governance failure within flood resilience planning. Despite the existence of flood protection infrastructure, the absence of a central coordinating body responsible for its maintenance and oversight resulted in widespread systematic failures when the infrastructure was needed. This fragmentation of governance, where floodplain and watershed responsibilities are divided or neglected among multiple municipal, state, and federal agencies, has led to a lack of long-term maintenance, conflicting jurisdictional priorities, and insufficient financial commitment to infrastructure upkeep. This case highlights the urgent need for a translating institutional framework to oversee flood resilience in Brazil connecting interfaces between levels of governance. Historically, the DNOS played a critical role in coordinating floodplain and watershed management, but its dissolution in 1990 left a governance void that has yet to be filled. As interviewee no. 1 noted: *"So, DNOS was dissolved, which was the only entity in Brazil responsible for addressing macro-drainage, and its responsibilities were transferred to municipalities. But this disrupted the physical logic, because the jurisdiction of, for example, Porto Alegre is the municipality , not the whole surrounding watershed."* This governance vacuum has resulted in municipalities managing flood infrastructure in isolation, with little coordination or financial support from state and even federal agencies. Without a central institution fomenting long-term planning, maintenance and inter-municipal collaboration, Brazil's flood resilience efforts remain reactive rather than proactive, perpetuating the short-termism paradox that prioritizes emergency response over sustained, long-term adaptation measures.

The failure to maintain flood control infrastructure in Rio Grande do Sul also reflects broader institutional deficiencies in Brazil's flood governance framework. The dissolution of DNOS was part of a larger trend of reducing direct government involvement in infrastructure management, transferring responsibilities to state and municipal authorities without a corresponding boost in financial or technical capabilities. Interviewee no. 9 highlighted how this transition led to severe governance inefficiencies: *"I would also like to mention, and that you also encounter in countries that are, let's say, less developed, is the challenge of sustainable asset management. So you can actually build a piece of infrastructure, but then you have to actively operate and maintain it. And I observed that many countries, such as Brazil, end up losing the adequate provisions for the operation and maintenance of their flood protection infrastructures."* This institutional gap created a fragmented governance landscape where municipalities struggle to maintain complex flood infrastructure without the technical and financial backing of a national coordinating body to oversee interfaces and have a holistic view of watershed management. The result is an ad-hoc system of infrastructure management, where maintenance is often deferred, and investments in long-term resilience are deprioritized in favor of short-term partisan and economic considerations.

Furthermore, the lack of a unified national flood resilience strategy has led to inconsistent planning and response approaches. As interviewee no. 5 noted: *"There was no long-term vision for flood protection after DNOS. There was no national planning to determine priorities. Investments were fragmented, distributed to states and municipalities without a cohesive federal strategy or vision."* This statement underscores the interplay between institutional legitimacy and governance efficiency. Without a centralized authority to set priorities, manage funding and oversee technical implementation, flood resilience measures remain disconnected and inconsistent, exacerbating the risks posed by extreme weather events. A crucial factor in addressing this fragmentation is ensuring that legitimacy is not merely acquired, but also maintained over time. Without mechanisms to maintain legitimacy beyond singular projects or political cycles, frugal solutions risk becoming segmented one-off interventions rather than embedded, enduring policy frameworks. The this is further emphasized by the time dimension presented in Figure 37 which describes that legitimacy is not static, instead it must be continuously sustained across political cycles, project lifespans and evolving governance contexts to avoid fragmentation and ensure long-term flood resilience. The failure to institutionalize long-term legitimacy in governance leads to recurrent cycles of ad-hoc responses rather than systematic resilience-building. Finally, it’s also worth mentioning that effective governance strategies must also be context-sensitive, ensuring that institutional frameworks align with local political, administrative and societal conditions to foster legitimacy and long-term resilience.

Figure 36 : Sustained Legitimacy Across Time



From Author (2024)

5.7.1 Context Sensitive Governance

The nature of governance structures, which can range from centralized to decentralized models, plays a significant role in shaping the implementation of flood resilience policies across different political and administrative contexts. Centralized governance systems concentrate decision-making authority at the national level, promoting uniform policy implementation but potentially constraining local adaptability. Conversely, decentralized governance frameworks empower municipalities and regional entities with substantial autonomy, thus enabling tailored solutions but often leading to fragmented coordination. The extent to which governance structures are centralized or decentralized shapes the feasibility of institutional interventions aimed at addressing flood resilience. Many countries facing governance fragmentation in flood management have implemented institutional models to ensure inter-municipal and cross-government coordination. A notable example revolves around the Special Purpose Vehicles (SPVs) in India: India has addressed governance fragmentation by creating SPVs, government-backed entities designed to oversee specific infrastructure and resilience projects from design to implementation and maintenance, per description from Interviewee no. 7: *Special Purpose Vehicles are dedicated agencies carved out within the government to manage projects end to end. They have full authority to cut across bureaucratic hierarchies, ensuring efficient planning, funding, and maintenance of infrastructure projects."* A national flood resilience SPV could serve as a promising model for Brazil. Such an entity, designed to oversee watershed management and flood infrastructure maintenance across multiple municipalities, may help address the challenges of localized mismanagement and ensure long-term financial and technical continuity in flood resilience efforts.

Another example revolves around the American Society of Civil Engineers in the United States, where federal leadership in flood resilience has often fluctuated under pressure from partisan politics. In this context, professional societies like ASCE have played a central role in maintaining technical and institutional continuity in flood resilience efforts. Interviewee no. 17 has highlighted ASCE's role in bridging such governance gaps: *"Professional societies, like ASCE, act as neutral entities that provide flood management standards and technical guidelines. They ensure that even if federal leadership changes, there remains a consistent knowledge base for states and cities to follow."* Characteristics of this apolitical, technical guidance model could also be adapted towards Brazil, where a federal independent technical body could provide standardized resilience planning and maintenance protocols for municipalities and states, thus aligning a national vision.

Given the repeated failures in flood infrastructure maintenance and governance coordination, Brazil must consider re-establishing a national flood management agency or an institutional equivalent, inspired by insights of its past and abroad alike, yet not forgetting to account for the unique national context. While replicating DNOS exactly may not be feasible, a modernized version could play a critical role in ensuring more effective and integrated resilience planning for the country. One of the key priorities for such an institution should be watershed-based flood management, ensuring that resilience planning accounts for entire watersheds rather than being restricted by municipal boundaries and interfaces. A fragmented approach that limits management to individual municipalities risks exacerbating downstream flooding due to localized mismanagement, or even strategic acts from local level politicians. In addition to watershed-focused planning, coordinated infrastructure maintenance is essential. A national oversight body would also be responsible for monitoring, funding and managing flood protection infrastructure, potentially with assistance from the market in the form of public-private partnerships as described in the previous sections, thus preventing the kind of neglect that contributed to the 2024 Rio Grande do Sul disaster. This failure to maintain critical flood defenses in the absence of a centralized authority has repeatedly demonstrated the need for a coordinated maintenance strategy to ensure long-term infrastructure resilience. A crucial component of such an agency would be apolitical and apolitical power separation, technical governance and community consulting or participation, ensuring that decision-making is driven by expertise rather than political considerations.

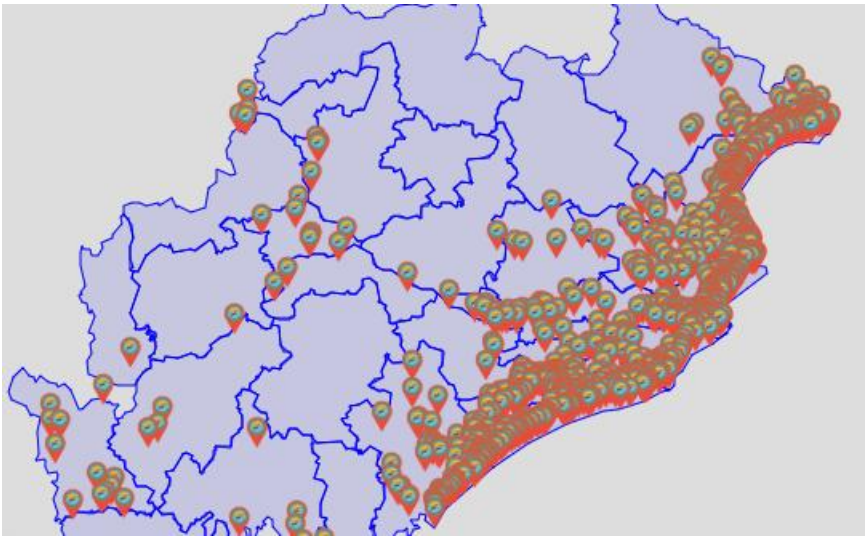
Drawing from the model used by the ASCE, the agency should be structured as a professional, evidence-based institution that is insulated from the influence of shifting political priorities. Building on that, interviewee no. 9 emphasized the need for a non-partisan entity to oversee flood resilience: *"I think in general terms, not limited to any specific country, you see that the electoral cycle is very adverse in this respect as well. Elected officials, they have like four years or sometimes five to show their worth and make sure they are re-elected. Well, would you like to focus on a very technical issue like flood protection, something that might never happen in the time that you are in office?"* This highlights how short-term political incentives often deprioritize long-term flood resilience planning, reinforcing the need for an agency that operates independently of electoral cycles. By ensuring political neutrality, a flood management agency could provide continuity in policy implementation, avoiding the disruptions caused by shifting political priorities every couple of years. Furthermore, the institution must incorporate flexible, multilevel coordination mechanisms that enable collaboration across national, state, and municipal levels. This will ensure the alignment of funding, planning, and implementation processes over time. Entrenched bureaucratic barriers have long hobbled Brazil's flood resilience endeavors, and without frameworks to facilitate seamless collaboration across government tiers, future flood protection initiatives risk being impeded by the same obstacles.

The Rio Grande do Sul floods of 2024 exemplify how institutional fragmentation leads to governance paralysis, allowing critical flood infrastructure to deteriorate due to poor coordination, inadequate funding, and unclear jurisdictional responsibilities. The dissolution of DNOS left Brazil without a central flood resilience authority, forcing municipalities to manage complex flood infrastructure without national oversight or long-term strategic planning. To prevent future disasters, Brazil must re-establish an institutional framework that enables legitimacy convergence through a sustained timespan, by addressing technical, institutional, financial and social legitimacy gaps in a manner that respects the nuances and oscillations that its developing society has. Brazil can then hope to develop a modernized flood resilience agency which combines technical expertise, long-term financial sustainability and cross-municipal coordination along with community involvement. However, as shows by the examples in India and US, these solutions must be context-sensitive, ensuring that governance structures align with Brazil's political, institutional and socio-economic realities rather than being imported wholesale from other models. Without such reforms, the cycle of infrastructure neglect and reactive governance, previously seen in the Deadlock of Flood Resilience will continue, leaving communities vulnerable to increasingly frequent and severe flooding events.

5.8 The Odisha Model: A Case of Legitimacy Convergence

Flood resilience governance in the Global South is often characterized by institutional fragmentation, financial constraints, and governance misalignment, creating systemic barriers to the adoption of frugal innovations. While conventional, large-scale flood protection measures dominate policymaking due to their technical, institutional, and financial backing, decentralized and low-cost solutions often struggle to gain legitimacy. However, the Odisha Model stands as a interesting example of legitimacy convergence; where technical, institutional, financial and social legitimacy align to create a sustainable and community-involving approach to flood resilience. This chapter examines how the Odisha Model has successfully navigated governance fragmentation by securing legitimacy across multiple dimensions. It highlights how a decentralized, participatory flood resilience strategy has been integrated into formal governance structures, securing both financial and institutional backing while maintaining strong community participation. By analyzing this example, this study hopes to display insight into how legitimacy convergence can enable frugal innovation to transition from marginal interventions to mainstream flood resilience policies.

Figure 37 : Emergency Shelters in Odisha, India



Source: https://www.iied.org/building-resilience-climate-change-through-slum-upgrading-case-jaga-mission-odisha-india

Odisha, a coastal state in Northeast India, has historically faced severe flooding and extreme weather events. The state's approach to flood risk has progressed through a multi-tiered governance framework that integrates disaster preparedness with decentralized, community-driven resilience initiatives. Unlike conventional flood resilience policies that rely primarily on large-scale structural interventions, Odisha has leveraged nature-based solutions, community participation and adaptive governance mechanisms to strengthen long-term flood resilience, in an area marked by staunch inequality and vulnerability. One of the key successes of the Odisha Model lies in its ability to bridge governance fragmentation by aligning institutions under a cohesive flood management imperative also in touch with realities of the locality. As interviewee no. 7 noted: *"Schools and other community buildings are designed in a way that whenever there is a cyclone warning, these buildings also serve as shelter houses. This ensures that communities are not only aware of emergency procedures but also have access to some sort of resilient infrastructure."* This statement highlights a critical component of institutional legitimacy; the ability to facilitate cross-sectoral collaboration rather than relying on rigid, bureaucratic structures that often hinder resilience efforts. Odisha's governance approach contrasts with many Global South contexts, where flood management is highly centralized and disconnected from local implementation mechanisms.

Figure 38 : Building Community Resilience In Odisha

Source: https://www.iied.org/building-resilience-climate-change-through-slum-upgrading-case-jaga-mission-odisha-india

The model integrates grassroots, decentralized early warning systems and community-led evacuation planning, which have demonstrated effectiveness in reducing disaster impact and with results presented on the following section. Unlike traditional grey infrastructure approaches, Odisha's strategy emphasizes scalability, adaptability and integration with existing localized systems. Interviewee no. 10's position emphasized the role of technical adaptability in ensuring long-term feasibility: *"Cyclone shelter programs in places like Bangladesh and Odisha have reduced fatalities from hundreds of thousands to nearly zero. These models work because they are technically designed to withstand extreme events and provide immediate, localized resilience while involving society."* This underscores that technical legitimacy is not static but an evolving process, and one that requires empirical validation, iterative learning and integration within broader governance frameworks. In Odisha, pilot programs and field-tested interventions have played a crucial role in strengthening confidence in frugal flood resilience approaches since the early 2000s while involving other areas of the public domain such as education and health. This model has also found usage in other places of similar socio-geographic context such as neighboring Bangladesh, displaying scalability.

5.8.1 A Compromise Solution

One of the most striking successes of the Odisha Model has been its sharp reduction in flood-related fatalities. The implementation of decentralized, community-based shelters in highly vulnerable areas has allowed thousands of people to evacuate safely before extreme weather events, significantly lowering the number of deaths. This approach represents a compromise solution, as it has prioritized preserving human life over minimizing financial losses. While it has allowed for a significant reduction in flood-related fatalities, it has not prevented substantial financial damages, as seen in the data presented in Figure 40.

Figure 39 : Tropical cyclone induced damage in Odisha Province in the past Century

Years	Frequency	Total deaths	Total affected	Total damage ('000 US$)
1916-50	11	108,544	1,042,010	NA
1950-60	4	2,400	2,375,000	NA
1960-70	7	2,437	425,000	12,530
1970-80	10	24,736	23,010,672	541,335
1980-90	21	3,749	21,363,793	2,325,163
1990-2000	18	15,802	28,216,101	5,126,700
2000-10	15	709	5,827,550	328,416
2010-20	13	1,315	16,742,174	12,876,096

Source: EM-DAT Disaster Database available at https://www.emdat.be/emdat_db/

While the decentralized shelter model has been effective in saving lives, it has not had the same direct impact on financial damage, as many communities still suffer from housing and infrastructure losses after flood events. This ties into the previously mentioned Short-Term vs. Long-Term Resilience Paradox, where policymakers must balance immediate disaster response efforts with long-term flood mitigation investments. As interviewee no. 13 noted: *" Of course, frugal solutions should not be taken as a solution for everything. I mean, you can have this as an intermediate strategy, while economic resources in the future might provide for more involved infrastructure and protection."* This paradox reflects the broader governance dilemma faced in many Global South contexts like India or Brazil. While large-scale grey infrastructure projects such as dams and embankments could offer more robust long-term solutions, these projects require substantial financial investment, economic development, and policy continuity, all of which remain uncertain in highly fragmented governance environments. Frugal innovation has the potential to remediate this paradox by providing intermediate, scalable and also cost-effective solutions that can be readily deployed while gradually transitioning toward more robust long-term investments.

The Odisha Model's notable success can be attributed to its pragmatic effectiveness, particularly in its utilization of cost-effective, community-focused flood resilience strategies. The model incorporates nature-based solutions, decentralized early warning systems, and community-led evacuation planning, ensuring that flood resilience efforts are both scalable and adaptable to local circumstances. Interviewee no. 8 also echoed the transformative impact of cyclone shelter programs in reducing disaster-related fatalities: *" And if you look at cyclones that hit Bangladesh in the 1970s, for instance, you know, you could have cases where hundreds of thousands of people died in flooding and cyclones. I mean, just let that number sink. Hundreds of thousands of people would die in cyclone events. But now, in these same countries, these levels have been reduced to one or*

0.1% of those numbers. So the cyclone shelter program, largely responsible for that impact, is tremendously successful." This underscores how well-designed, locally integrated shelters can serve as life-saving infrastructure, ensuring communities have accessible, immediate protection from extreme weather events. Odisha's experience demonstrates that effective flood resilience does not always require large-scale, costly infrastructure, but rather strategic, communityoriented solutions that are tested and institutionalized over time, at least and most importantly to save lives.

Figure 40 : Select tropical cyclones in Odisha and its impact during last two decades

Name of Tropical Cyclone	Year	No. of Deaths	No. Affected (million)	Damages (million USD)	Fatality per million affected
Super Cyclone	1999	9843	12.63	2500	779.33
Phailin	2013	47	13.23	633.5	3.55
Fani*	2019	64	16.5	2352	3.82

Source: EM-DAT Disaster Database available at https://www.emdat.be/emdat_db/&*Govt of Odisha, Fani Report (May 2019)

Moreover, by enabling people to return home quickly once floodwaters recede, the Odisha Model allows communities to recover faster, minimizing displacement and the long-term socioeconomic costs associated with evacuation events, indirectly fomenting coping capacity to thrive. This approach reduces the psychological and economic toll of floods while also strengthening community resilience by preserving social cohesion and local livelihoods. Decentralized shelters play a critical role in that, by ensuring that emergency response efforts remain accessible and well-coordinated. Thus, a key factor in the social legitimacy of Odisha's flood resilience model is its integration of local communities in disaster preparedness and response. Interviewee no. 7 highlighted how Odisha's resilience approach has been institutionalized at multiple levels, reinforcing social legitimacy through collective engagement and preparedness:*" would also like to draw certain examples where this has been seen as a collective problem. So for example, if you look into many states in eastern part of India for example Odisha or West Bengal which all get lot of cyclones induced flooding, their resilience has now been seen as a collective effort of public-private partnerships. Even village level communities identify their evacuation zones a priori."* This emphasizes how community-driven efforts in Odisha have strengthened public trust and institutional adaptability by ensuring that preparedness strategies are inclusive and participatory. The Odisha Model thus presents a viable compromise, demonstrating that locally adaptable, socially embedded and economically viable measures can enhance flood resilience in vulnerable regions of the Global South.

Moreover, a major challenge for frugal innovation in flood resilience is the financial misalignment between short-term emergency response funding and long-term investment in preventative measures. Odisha has overcome this challenge by securing multi-level funding sources, combining government allocations, international aid and community-driven financial participation to supplant traditional funding sources withing governance structure. This has ensured that the applied measures remain sustainable, continuing to serve vulnerable communities beyond initial investment cycles. Interviewee no. 16 emphasized the importance of this financial viability, particularly in areas where large-scale infrastructure investments are not feasible, or stuck within policy inertia: *" And, you know, particularly for areas that do not allow for very high investment levels. Some areas are too large or simply also technically unfit for building dikes or alike. And then*

solutions like this, like these shelters and warning systems. Yeah, I agree. They can be effective in protecting the community." This highlights a critical aspect of financial legitimacy; it is not simply about obtaining funds but about ensuring that frugal resilience solutions remain viable in resource-constrained settings. Odisha has tackled this challenge by developing sustainable funding models, allowing for incremental investments to be targeted a priori, rather than relying on "one-off", capital-intensive projects. This financial adaptability has been essential in maintaining the program's scalability and long-term viability, ensuring that cyclone shelters and other resilience infrastructure remain effective, accessible and ultimately financially sustainable over time.

The Odisha Model provides a valuable case study of legitimacy convergence, demonstrating how the legitimacies must align to enable the successful adoption of frugal solutions. Unlike many Global South contexts where governance fragmentation hinders resilience efforts, Odisha has successfully navigated these challenges by ensuring that community-led approaches are formally recognized, financially supported and further technically validated. This example illustrates that frugal innovation in flood resilience is not inherently limited by governance fragmentation; it rather requires mechanisms that facilitate legitimacy convergence. The insights from Odisha suggest that strengthening governance coordination, securing multi-level financial backing and embedding resilience strategies within local communities are essential for ensuring the long-term success of flood resilience approaches.

6 Discussion

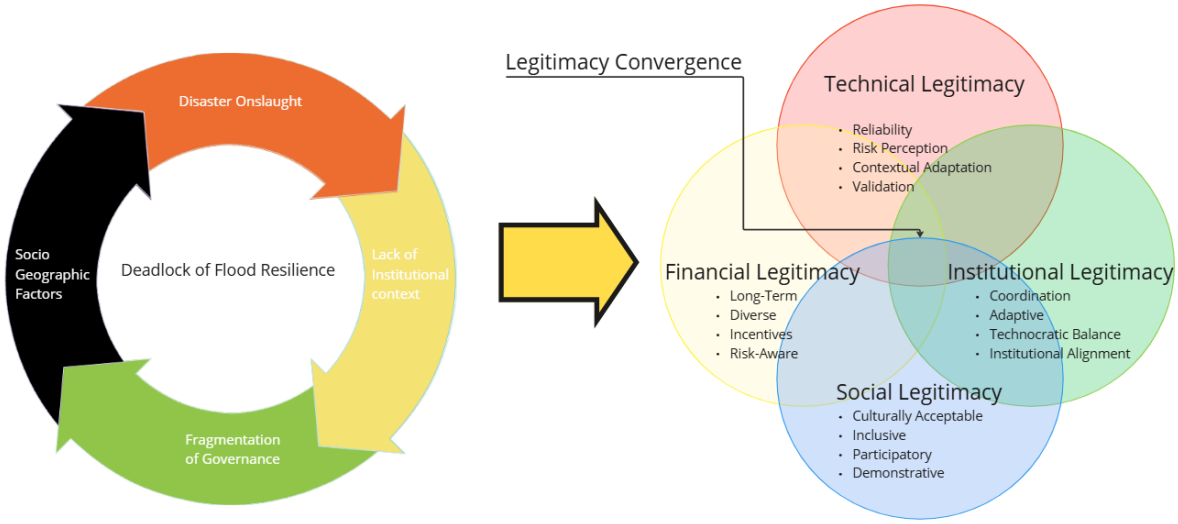
6.1 Reframing Flood Resilience: From Deadlock to Legitimacy Convergence

The analysis of flood resilience in the Global South has been historically characterized by a paradoxical and cyclical deadlock, wherein short-term emergency responses continuously undermine long-term adaptive strategies. This conceptualization, developed through the literature review, underscores how the cyclic nature of disaster events, institutional fragmentation, socio-geographic limitations, and the lack of locally-tailored governance structures perpetuate a self-reinforcing cycle of flood vulnerability. As illustrated in Figure 42**,** this Deadlock of Flood Resilience has thus emphasized this cyclicality, advocating for a sequential understanding of resilience barriers, where each component triggers the next in a self-reinforcing loop, effectively preventing a transformative shift in governance and adaptation. Expanding upon this foundational understanding, the Four Legitimacies Framework, also depicted in figure 42, introduces a reconceptualization of resilience strategies by transitioning from a sequential dependency to a perspective of mutual interdependence. This framework challenges the previous assumption of a linear progression of barriers and instead argues instead that legitimacy, must be achieved concurrently for an effective and sustainable flood resilience solution to be applied. The Four Legitimacies Framework contrasts with the deadlock model, which suggests that governance failures and socio-geographic limitations naturally lead to institutional gaps and short-term reactive measures. Instead, the Four Legitimacies Framework posits that these dimensions are not merely steps within a cycle, but rather dynamic and co-dependent components of resilience-building.

The conceptual shift to mutual dependency is critical because it redefines how legitimacy is established in flood resilience governance. Rather than attempting to resolve individual constraints in isolation, the framework emphasizes the need for convergence across all four legitimacy domains. For instance, technical legitimacy cannot be fully realized without institutional coordination, just as

financial sustainability is contingent upon social inclusivity and participatory governance. This interwoven structure suggests that resilience is not a function of progressive problem-solving but rather an emergent property of a system in which all legitimacy dimensions reinforce one another.

Figure 41 : From deadlock to Legitimacy

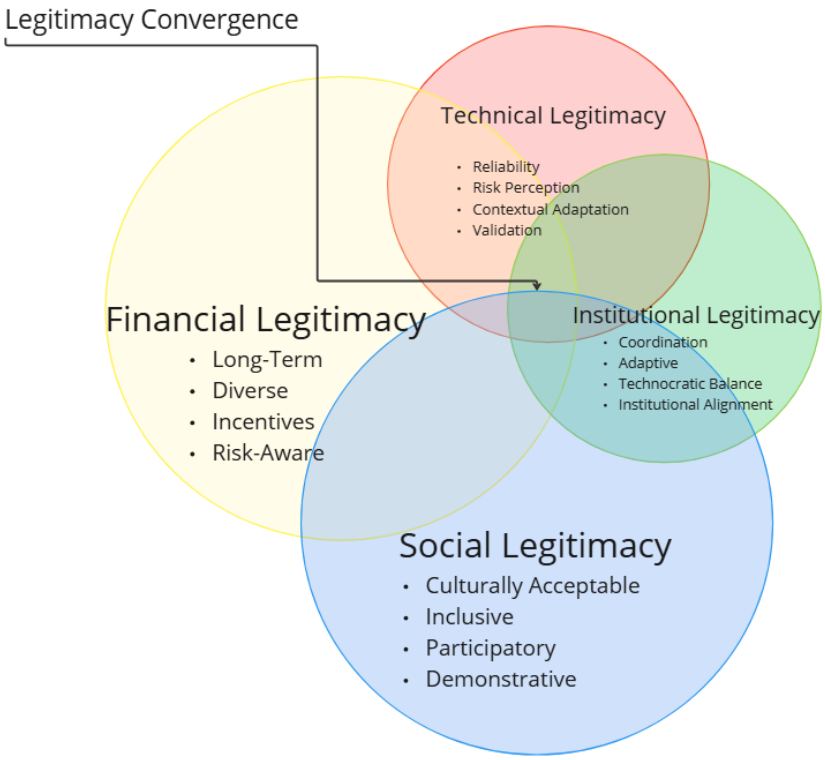


From Author (2024)

6.2 Legitimacies in the Immediate Aftermath of a Disaster Onslaught

In the immediate wake of a disaster, the governance of flood resilience is marked by an urgent need to restore stability and mitigate damage while providing relief to affected communities. At this stage, the interaction between different legitimacy dimensions defines the effectiveness of the response. However, financial and social legitimacy appear to take precedence as the most dominant forces, shaping immediate recovery efforts. This dynamic is visually represented in Figure 43, where Financial and Social Legitimacy are emphasized as leading contributors in the post-disaster response phase. Their overlapping areas reflect the interdependence required for inclusive and well-resourced emergency efforts.

Figure 42 : 4 Legitimacies- Aftermath of a Disaster



From Author (2024)

Financial legitimacy is a critical factor in the immediate response phase, as the rapid mobilization of resources is essential for funding emergency relief, restoring critical infrastructure, and supporting displaced populations. Unlike structured long-term financial mechanisms, post-disaster financing relies on emergency aid, humanitarian assistance, and swift government interventions to address the urgent needs arising from the disaster. The ability to quickly allocate and distribute funds, often having to bypass bureaucratic hurdles, directly influences how effectively immediate needs such as shelter, medical aid and food security are met, displaying also how emergency logistics tend to in their own nature be interdisciplinary. If financial legitimacy falters, due to inefficiencies of mismanagement or simply due to the load applied by the disaster, recovery can stall, exacerbating this crisis. Moreover, social legitimacy plays a defining role in fostering public trust along with ensuring inclusive and participatory recovery efforts. Disaster-affected populations must feel represented in decision-making, and community-led responses often help to fill governance gaps in this phase. Moreover, the presence of culturally acceptable and locally embedded recovery strategies strengthens cooperation and prevents unrest. Grassroots mobilization, mutual aid networks and local leadership also become crucial components of legitimacy, as centralized governance may struggle to reach all affected areas promptly. Failure to engage communities can lead to resistance, breakdowns in compliance and inefficiencies in response coordination.

As highlighted in figure 43, Technical and Institutional Legitimacy do not disappear but take on supporting roles. Although technical and institutional legitimacy maintain significance in the immediate aftermath of a disaster, they assume a subordinate role rather than taking the lead in the response efforts. Technical legitimacy is primarily reactive, focusing on quick adaptations rather than long-term resilience planning. Emergency flood barriers, debris clearance and temporary infrastructure repairs must be rapidly deployable and reliable, thus ensuring that immediate post-

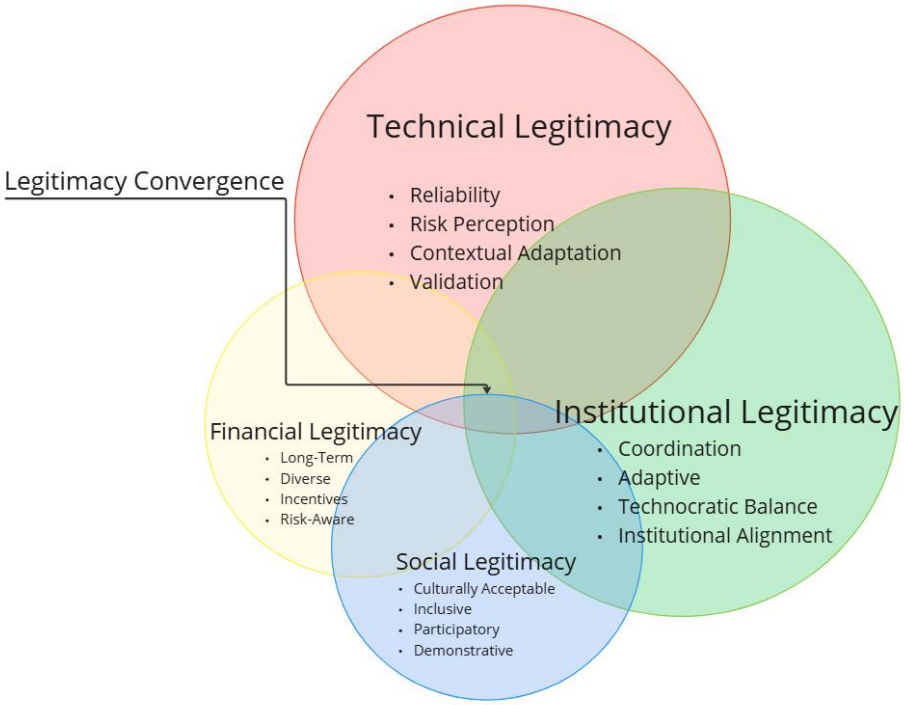
disaster risks are mitigated. However, the long-term sustainability of these solutions is not necessarily the primary concern at this stage. Although coordination remains crucial, traditional bureaucratic processes can hamper or slow down immediate disaster response efforts, necessitating more adaptive and flexible governance approaches rather than rigid institutional enforcement, particularly if the disaster event surpasses historical precedents and demands the learning of new lessons. In this phase, the effectiveness of institutions is measured by their ability to facilitate rapid decision-making and inter-agency collaboration, rather than their adherence to formalized procedures in order for the logistics to be restored and for society to return to normalcy with the utmost speed.

As financial and social legitimacy bridge the gap between immediate needs and structured recovery, institutional and technical legitimacy must gradually reassert their roles to ensure long-term resilience. Figure 43 anticipates this transition, showing how all four forms of legitimacy eventually need to converge again to support sustained flood resilience. The transition from emergency response to structured governance necessitates a coordinated convergence of the four legitimacy dimensions, whereby rapid relief measures are integrated with durable policy and infrastructure solutions. This interplay between legitimacy dimensions illustrates why multi-dimensional legitimacy is essential for effective resilience governance. Without financial and social legitimacy at the forefront, institutional and technical interventions struggle to gain traction in the immediate chaos following disaster onslaughts.

6.3 Legitimacies in the Transition to Long-Term Resilience Planning

As the immediate emergency response stabilizes and the focus transitions towards long-term resilience planning, the relative prominence of the different legitimacy dimensions shifts. Technical and institutional legitimacy now take precedence, guiding the transition from reactive emergency measures to more structured and forward-looking flood governance. Per Figure 44, Institutional legitimacy becomes increasingly critical as governments and key stakeholders work towards establishing a long-term resilience framework, most likely also compounding lessons learnt from the disaster. Unlike the emergency phase, where decision-making tends to be centralized and time-sensitive, this stage requires coordinated and adaptable governance mechanisms that ensure stability, accountability, and sustained policy alignment across institutional levels and stakeholders. Legitimacy is further reinforced when flood resilience strategies are embedded within comprehensive regulatory frameworks, which help to ensure continuity beyond political cycles and short-term funding priorities. The role of institutions is no longer limited to managing immediate disaster relief, but has expanded to safeguarding the long-term sustainability of flood resilience efforts.

Figure 43 : 4 Legitimacies - Long-Term Resilience



From Author (2024)

With the shift towards long-term resilience, technical legitimacy assumes a dominant role, ensuring that flood mitigation strategies are robust, sustainable and well-integrated into local environmental and urban planning contexts. Unlike the immediate aftermath, where temporary solutions were deployed in response to urgent needs, the focus now shifts towards long-term planning for the adoption of more integrated flood resilience methods. As shown in Figure 44, the overlapping areas between Technical and Institutional Legitimacy emphasize the necessity for risk-informed, coordinated governance that is both scientifically grounded and still contextually appropriate. Interestingly, the somewhat diminished role of technical legitimacy in the immediate aftermath of the disaster, compared to the prominence of social legitimacy, might also support solutions that incorporate a degree of community involvement, giving way for frugal innovation to pierce through the barriers impeding it from taking place. The effectiveness of these measures hinges on their contextual adaptation, ensuring that they align with regional hydrological conditions, climate projections, and naturally the socio-economic realities of the locality. Technical legitimacy also requires risk perception and validation, where scientific assessments, engineering studies and data-driven insights inform resilience strategies. Such elements bolster public trust in resilience solutions, ensuring that flood risk mitigation approaches are technically robust while also being widely embraced by policymakers and the broader population in general. Moreover, institutional legitimacy strengthens as governance frameworks become more structured and integrated across multiple levels along with becoming accustomed with the new post disaster realities. Coordination between levels of governance is here essential to ensure that resilience strategies doing reverse back into fragmentation, instead developing within a cohesive system. In contrast to the immediate disaster phase, where institutional structures may have been temporarily overridden or sidelined, long-term resilience planning necessitates the institutional alignment of policies, imperatives and funding mechanisms. Institutional legitimacy is reinforced when governance structures are adaptive and responsive, enabling flood resilience strategies to evolve with ever more changing climate risks,

technological advancements and socio-economic shifts inherent to developing societies. Achieving a technocratic balance is also essential, ensuring that expert-driven, data-informed decision-making does not overshadow local knowledge and community needs, but rather integrates these perspectives into a well-rounded governance framework.

While financial and social legitimacy remain vital, their influence shifts compared to the post-disaster phase. Financial legitimacy transitions from short-term emergency aid to structured, and more diversified funding mechanisms which seek to sustain long-term resilience investments. Instead of reactive funding through disaster relief programs, resilience financing now should involve multi-stakeholder investment models, insurance-supported risk management and economic incentives for sustainable urban development. The emphasis here is on ensuring that financial mechanisms support flood resilience in a long-term, risk-aware and incentive driven manner. Similarly, social legitimacy, while still relevant, assumes a more supportive role as immediate community mobilization gives way to institutionalized participation in policy-making. Rather than relying solely on grassroots-driven recovery efforts, social legitimacy in long-term resilience planning is established through public consultations, participatory governance structures, and transparent decision-making processes that foster public trust and acceptance of long-term mitigation strategies. Figure 44 captures this strategic rebalancing, showing how legitimacy convergence requires a new configuration of priorities, while still supported by financial incentives and societal trust.

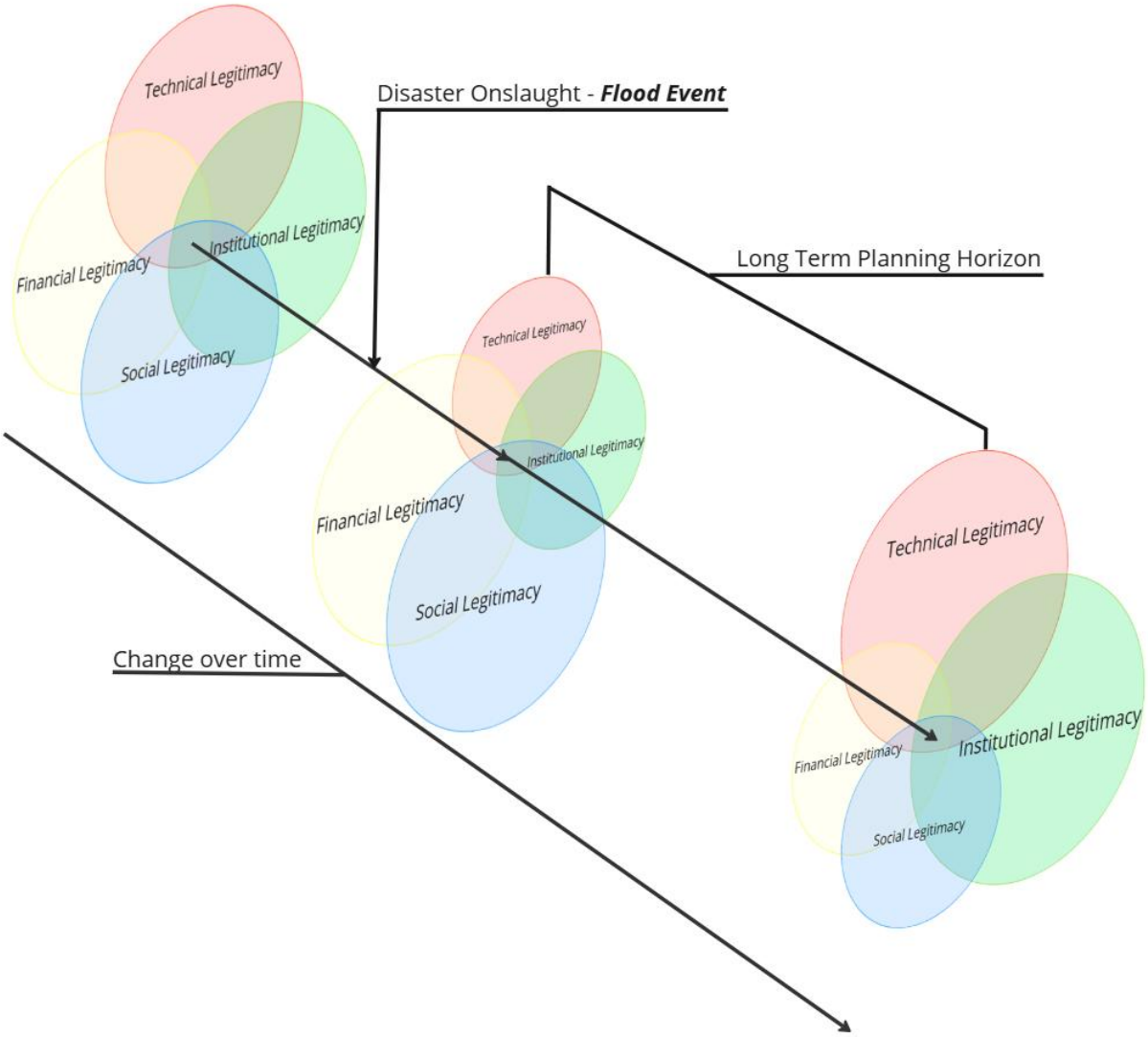
As the governance of flood resilience transitions from emergency response to structured long-term adaptation, legitimacy convergence becomes the mechanism through which competing priorities are reconciled. While financial and social legitimacy were the dominant forces immediately after the disaster, long-term resilience depends on the integration of institutional governance and technical reliability to ensure sustainability. The interplay between these shifting priorities highlights the fact that different facets of governance and institutionalization gain or lose prominence over time but must nevertheless, always interact to maintain a provisional balance. This reinforces the understanding that flood resilience is not achieved through isolated interventions but through a dynamic and evolving governance process that adapts to both immediate shocks and long-term vulnerabilities. Yet, the impacts of social legitimacy cannot be completely overridden, risking to a reversion towards previously applied frameworks where a distance between the solution and society at large remained immense.

6.4 Highlighting the Dynamic Nature of Legitimacy

The conceptualization of legitimacy in flood resilience governance is not static; rather, it is a dynamic and evolving process that reflects shifting needs, competing priorities, and the inherent tensions of balancing short-term crisis response with long-term planning. Such dynamic interaction is illustrated by Figure 45, which visually traces how the prominence and relative influence of each legitimacy domain evolves from the pre-disaster stage, through the immediate aftermath and onto the long-term planning horizon. This interdependent nature of the Four Legitimacies Framework over time, is also closely aligned with the paradoxical resolution, here applied towards governance, and taken from the aforementioned Dynamic Equilibrium Model (Smith & Lewis, 2011). This model provides a theoretical background for understanding how contradictory yet interdependent forces, such as the shifting dominance of different legitimacies over time, must be continuously managed rather than fully resolved in order to sustain effective resilience strategies. Moreover, the variation in the relevance of different legitimacy dimensions over time, aligns closely with the paradoxical nature of resilience governance as previously discussed. In the immediate aftermath of a flood, financial and social legitimacy take precedence, as urgent funding mobilization and community engagement are

critical for short-term recovery. However, as the response stabilizes and shifts toward long-term planning, technical and institutional legitimacy become dominant, emphasizing engineered solutions, regulatory structures, and institutional coordination. As seen in Figure 45, this dynamic is not a linear or clearly defined transition, but rather an iterative process in which legitimacy convergence takes on different meanings and shapes at different points in time, also influenced by political oscillations and societal changes.

Figure 44 : Dynamic Nature of Flood Resilience



From Author (2024)

This transition reflects the paradoxical tensions outlined in the Dynamic Equilibrium Model. In accordance with Smith and Lewis (2011), paradoxes arise from the persistent and contradictory demands within complex systems over time, thus necessitating iterative cycles of tension, acceptance and further compromise. In the context of flood resilience governance, the interplay between legitimacy dimensions represents such a paradox, where different elements of legitimacy pull in opposing directions but must ultimately be negotiated rather than eliminated altogether. For instance, if financial legitimacy dominates in the short term, there is a risk that long-term technical and institutional measures will be underfunded, leading to a cycle of recurring vulnerability, exemplified by monumental initiatives that negotiate political capital in jeopardy of long-term planning. Conversely, if resilience strategies focus exclusively on technical and institutional

legitimacy without maintaining financial and social legitimacy, they risk becoming disconnected from community needs and political realities of their place of application, potentially resulting in inert or contested policy measures. Therefor, the Dynamic Equilibrium Model provides a lens through which to understand legitimacy convergence as a potential paradoxical resolution. Rather than viewing legitimacy dimensions as competing forces that require a definitive trade-off, resilience governance must embrace a strategy of acceptance, recognizing that legitimacy dimensions are interdependent and must be managed dynamically over time. This necessitates flexible governance approaches that can navigate the evolving dynamics of legitimacies, ensuring financial and social legitimacy do not compromise long-term sustainability while also preventing technical and institutional legitimacy from becoming disconnected from pressing context sensitive requirements. Ultimately, by integrating the paradox perspective, resilience governance transcends a rigid or sequential problem-solving approach, instead adopting an iterative process of balancing competing priorities. Per Figure 45, legitimacy dimensions expand and contract over time, reshaping the nature of convergence as the governance process unfolds over time. This dynamic reflects a cornerstone of paradox perspective: rather than resolving tensions outright, governance strategies must continuously oscillate between competing imperatives, adjusting as conditions evolve with time.

7 Validation

This section aimed to validate the proposed framework by assessing its applicability, coherence, and effectiveness in addressing the identified challenges. To accomplish this, two validation interviews with domain experts were conducted, as presented table 9. These experts provided insights into the framework's conceptual clarity, practical relevance and finally on the potential for real-world application. The primary objective of these interviews was to ensure that the framework adequately captures the complexity of flood resilience governance, particularly in the context of governance fragmentation, the legitimacy convergence framework and the overall interactions of paradoxes with frugal innovation. The validation process followed a semi-structured format, enabling a open-ended discussion while maintaining a structured focus on key aspects of the framework. Each interview lasted around 45 minutes. The interviews began with an overview of the framework, followed by a detailed exploration of each component, were the experts were encouraged to provide critical feedback on the framework's strengths, weaknesses and potential areas for refinement.

Table 9 : Validation Interviewees List

Interview Number	Role	Affiliation	Geographic Context
20	Dean of the Hydrological Research Institute	Federal University, Porto Alegre, Brazil	Global South
21	Climate Resilience Professor	Private University, Boston, USA	Global North

7.1 Validation Discussion

The validation interviews provided critical insights into the applicability and robustness of the proposed framework, reinforcing its conceptual soundness while offering constructive refinements

and room for potential further research topics to build upon. Such discussions served to validate the developed models' relevance in addressing governance fragmentation and the paradoxes surrounding frugal innovation in flood resilience. While the overall feedback was highly positive, the interviews also generated valuable recommendations for refinement, particularly concerning the framework's treatment of temporal dynamics, political legitimacy, and institutional sustainability which were further taken into account.

One of the key elements of the study is the paradox framework, particularly the short-term vs. long-term resilience paradox and its relationship with governance dynamics. The validation interviews confirmed the accuracy of this paradox but also emphasized the need to reinforce the framework's temporal dynamics, as in reality these problems manifest over long periods of time. As observed by Interviewee 20, resilience strategies must move beyond short-term crisis response and instead focus on fostering long-term institutional sustainability, as per the excerpt: *"The sustainable legitimacy, it is long-term, it is not short. In the short term, the mission is to save lives... but for a real solution, it is a long-term process. And in this long-term walk, things change."* This comment reinforces the necessity of embedding flexibility within the framework, recognizing that different forms of legitimacy fluctuate in prominence depending on the developments pertaining to flood governance implementation and outside factors (i.e., disasters, political stability, socio-economic conditions). Echoing this perspective, Interviewee 21 provided complementary perspectives, emphasizing the importance of institutional structures capable of sustaining resilience strategies beyond short-term political cycles, by stating: *"The political class makes the decision, but the institutional environment must exist beyond that. Otherwise, the project dies with political transitions."* This insight confirms the framework's relevance in diagnosing one of the primary governance barriers to flood resilience. However, the interviews also emphasized the need to more explicitly incorporate the importance of autonomous institutional structures capable of sustaining resilience strategies beyond shifting political cycles.

The validation process also examined the Four Legitimacies Framework, inspecting how it defines the factors that determine the applicability and sustainability of frugal flood resilience solutions. The feedback from the 2 interviewees on this component was largely positive, affirming its comprehensiveness and conceptual clarity. Nevertheless, an important recommendation emerged regarding political interference within legitimacy. Interviewee 20 cautioned against an overemphasis on political variations within the framework, warning that some unrelated political actors often engage with flood resilience projects opportunistically, without meaningful long-term commitment nor added value. He stated: *"Be careful with too much usage of this political legitimacy concept, because politicians don't always understand and may just interfere or take credit without adding real value to it."* This critique highlights the need to differentiate between institutional legitimacy and transient political interests, ensuring that decision-making remains anchored in governance structures rather than shifting political agendas. This insight invertedly comes from his personal experience working in Brazilian resilience, which is often compromised by personal interested politics. Another central discussion from the validation interviews was about the dynamic and interrelated nature of legitimacy factors and how they should be represented within the framework. Interviewee 21 noted that legitimacy is not static and that different dimensions gain or lose relevance over time depending on specific flood events, political climates and further societal needs, thus being in agreement with the proposed model: *"At different times, different factors matter more, sometimes technical legitimacy is central, other times financial support is the biggest challenge. Your framework needs to in a way reflect this fluidity."* The validation interviews suggested that the proposed model should explicitly recognize the dynamic and evolving nature of legitimacy

dimensions over time. This would reinforce the need for adaptability in flood resilience strategies, as the relative importance of various legitimacy factors can shift depending on the specific governance context. The interviewee recommended that this temporal fluidity of legitimacy be reflected visually within the framework, rather than viewing the legitimacy factors as fixed categories. This would emphasize that the different dimensions of legitimacy are interacting and shifting elements, which must be considered in relation to the unique political, institutional, and social conditions of each case.

7.2 The Odisha Model as a Case of Legitimacy Convergence?

The validation interviews next examined The Odisha Model as an example of legitimacy convergence, which has created an effective flood resilience strategy for the Global South. The 2 interviewees confirmed the relevance of the Odisha case, particularly in demonstrating how decentralized, community-driven flood resilience initiatives can achieve formal institutional recognition and financial sustainability. However, while the model was validated as a strong example, Interviewee 20 cautioned against direct transplantation of the Odisha experience into other governance contexts. He noted: *"Engineering is universal, but societies, institutions, and financing capacities are different. Odisha offers a good reference, but applying it directly elsewhere without adaptation could be problematic."* This feedback reinforces the framework's applicability as a potential guideline or positive example rather than a prescriptive solution, which would need adaptation to local contexts for its overall validity. Therefore, the Odisha case serves to provide valuable insights into how legitimacy convergence can facilitate the adoption of frugal flood resilience solutions, but the validation process confirmed that its application must be still adapted to the specific political, financial, and institutional conditions of other regions. The framework should emphasize that successful cases like Odisha serve as learning models rather than direct blueprints for other flood-prone regions.

Furthermore, a critical dimension of the framework is its response to governance fragmentation and the institutional voids that hinder flood resilience strategies. The validation interviews confirmed that the framework successfully diagnoses governance fragmentation as a major barrier, particularly in the presence multi-level actors and structures. However, Interviewee 21 also noted that the framework does not inherently prescribe solutions, as governance fragmentation is deeply tied to legal and institutional structures. He remarked that: *"The framework indicates the problem. But governance fragmentation is deeply tied to legal structures, creating new institutions or restoring old ones is a political and legal challenge, beyond just an analytical framework. "* This insight highlights a key limitation of the study: while the framework successfully captures the structural barriers posed by governance fragmentation, it does not aim to dictate institutional reforms, which are highly context-dependent also requiring a more in-depth analysis. The validation process confirmed that this limitation is not a flaw, but rather an indication of the model's appropriate scope. Instead of prescribing rigid institutional solutions, the framework should be positioned as a diagnostic tool that helps identify governance barriers and inform discussions on potential solutions tailored to specific contexts.

7.3 Reflection Validation

The overall feedback on the framework was highly positive, with strong validation of its structural logic, conceptual rigor and potential applicability. The validation process reinforced that the framework successfully captures the complexities of flood resilience governance, particularly given the challenges posed by governance fragmentation and the paradoxes surrounding frugal

innovation. However, key refinements were also suggested to enhance the framework's clarity and sharpness. One major recommendation was to explicitly incorporate a temporal dimension to reflect the evolving nature of legitimacy factors over time. Additionally, the validation process confirmed the need to differentiate between institutional legitimacy and a phenomena that approaches transient political practices, thus ensuring that political engagement and oscillations does not undermine the long-term sustainability of flood resilience strategies. Furthermore, while the Odisha Model was validated as a strong case of legitimacy convergence, the feedback reinforced that it should be framed as a reference model rather than a direct template for application in other regions. The expert validation interviews affirmed that the proposed framework offers a robust conceptual foundation for examining the paradoxes inherent in flood resilience governance. The suggested refinements enhanced the framework's applicability, ensuring it maintains academic rigor while remaining practically relevant in informing more effective flood resilience strategies. Although governance fragmentation persists as a significant challenge in multi-level flood governance, the framework successfully illuminates its systemic drivers, providing a basis for further institutional and policy deliberations.

8 Conclusion

This study has systematically investigated the relationship between frugal innovation and flood resilience in the Global South, analyzing the paradoxes that emerge when incorporating low-cost, adaptable solutions into flood risk management. Through a comprehensive examination of these paradoxes, their impact on flood resilience outcomes, and the role of governance fragmentation, the research has demonstrated the dynamic interplay among various legitimacy dimensions; being them technical, institutional, financial and social, along with how they shape the long-term sustainability of resilience measures. The following discussion revolves around how the text attempted to answer the research question, by answering its sub-questions and the proceeding to have a discussion on the overarching research question.

SQ1: What paradoxes emerge when applying frugal innovation to flood resilience in the Global South?

The paradoxes revealed through this study reflect a complex network of governance tensions that directly shape the viability of frugal innovation in flood resilience efforts. Chief among these is the Short-Term vs. Long-Term Resilience paradox, which emerged as the most dominant in both frequency and thematic relevance across the interview dataset. It encapsulates the tension between urgent, short-cycle interventions, often politically motivated or disaster-driven, and the slow, sustained investment required to institutionalize resilient, adaptive strategies. While frugal innovation offers rapid, cost-effective solutions that can support immediate needs, their long-term potential is often stunted by institutional structures that are reactive, fragmented, and driven by political immediacy. Complementing this core finding, two other highly recurrent paradoxes—Fragmentation vs. Centralization and Centralization vs. Autonomy—further complicate the governance environment within which frugal solutions must operate. The former highlights how institutional silos and governance dispersion across municipal, regional, and national levels create inconsistent and often conflicting approaches to resilience. The latter points to the tension between empowering local actors to innovate and adapt, versus the dominance of top-down, centralized mandates that often lack the contextual understanding necessary for successful implementation.

These paradoxes reinforce the structural misalignment between the grassroots nature of frugal innovation and the institutional reality of flood governance.

Additionally, paradoxes such as Technocratic Dominance vs. Local Knowledge, Cost-Efficiency vs. Long-Term Resilience, and Universality vs. Local Adaptation highlight epistemic and operational tensions. Frugal innovation often relies on local, context-driven knowledge and adaptive techniques, yet these are frequently undervalued within highly technocratic planning regimes that prioritize standardized, large-scale infrastructure solutions. Similarly, the adaptability and affordability of frugal strategies may raise concerns over long-term robustness, especially in institutional cultures that associate resilience with visibility, permanence, and engineering legitimacy. The distribution of these paradoxes across different domains, ranging from infrastructure and water policy to nature-based solutions, demonstrates that they are not isolated phenomena but systemic characteristics of resilience planning. This reinforces the conceptual value of the paradox framework for analyzing governance blockages in flood resilience. As such, these tensions do not merely hinder the application of frugal innovation; they illuminate the deeper institutional logics and governance cultures that must be addressed to enable adaptive, scalable, and socially embedded flood resilience strategies in the Global South.

SQ2: What is the relationship between these paradoxes and flood resilience outcomes?

The study finds that paradoxes such as Short-Term vs. Long-Term Resilience fundamentally shape the effectiveness and trajectory of flood resilience efforts. When short-term emergency responses dominate flood governance, strategies become inherently reactive. This reinforces dependence on crisis-driven interventions, undermining sustained efforts toward mitigation and adaptive planning. Governance structures that allocate resources based on immediate threats, rather than long-term systemic vulnerabilities, further exacerbate this paradox. Consequently, efforts to institutionalize innovation, whether frugal or not, often falter in environments where the urgency of the present overrides future-oriented resilience. Nevertheless, the findings show that actively managing and embracing these paradoxes ,rather than attempting to eliminate them, can help unlock transformative potential. Frugal innovation, particularly through nature-based and community-driven solutions, can serve as a middle ground that bridges short-term needs and long-term adaptation goals. For instance, hybrid approaches that combine cost-effective, flexible interventions with robust infrastructural measures can help to resolve tensions between cost-efficiency and robustness. Moreover, adaptive governance mechanisms that facilitate local experimentation while promoting cross-scalar learning can allow context sensitive practices to eventually acquire institutional validity, further allowing for them to gain traction, as observed with the Odisha Model

Finally, this study attempts to underscores that flood resilience is not a singular technical fix but a multifaceted and dynamic challenge requiring alignment across social, institutional, environmental and financial domains on top of in the technical axis. In this regard, an overarching and integrative framework, such as the Dynamic Equilibrium Model employed in the study, becomes a very helpful guiding tool to navigate such intricacies. The study suggests that how paradoxes are acknowledged, managed and further integrated into governance systems will shape whether frugal innovation enhances or hinders flood resilience outcomes in the long term.

SQ3: How does governance fragmentation reflect paradoxes in flood resilience?

Governance fragmentation reinforces and amplifies the Short-Term vs. Long-Term Resilience paradox by creating institutional barriers that impede sustained resilience planning across the areas. The study highlights how the absence of coordination across governance levels leads to inconsistent flood resilience measures, with national, state, and municipal actors operating within fragmented, and often conflicting, policy frameworks. Short-term political incentives further exacerbate this misalignment, as decision-makers tend to prioritize visible, high-cost interventions yielding immediate electoral benefits rather than those of long-term, adaptation strategies. For instance, in Brazil, the dissolution of DNOS created a governance vacuum that left flood resilience responsibilities dispersed among multiple self isolating agencies, thus weakening long-term infrastructure maintenance and investment in adaptive strategies. Furthermore, this research finds that governance fragmentation hinders the institutionalization of frugal innovation, as decentralized governance structures often lack capacity or will to support alternative, low-cost solutions especially at scale. Moreover, the lack of a central coordinating mechanism constrains policymakers' capacity to harmonize short-term disaster response with long-term resilience planning, leaving communities susceptible to recurring flood events. Consequently, addressing governance fragmentation necessitates institutional reforms that integrate short-term emergency measures within a comprehensive, multi-level resilience strategy.

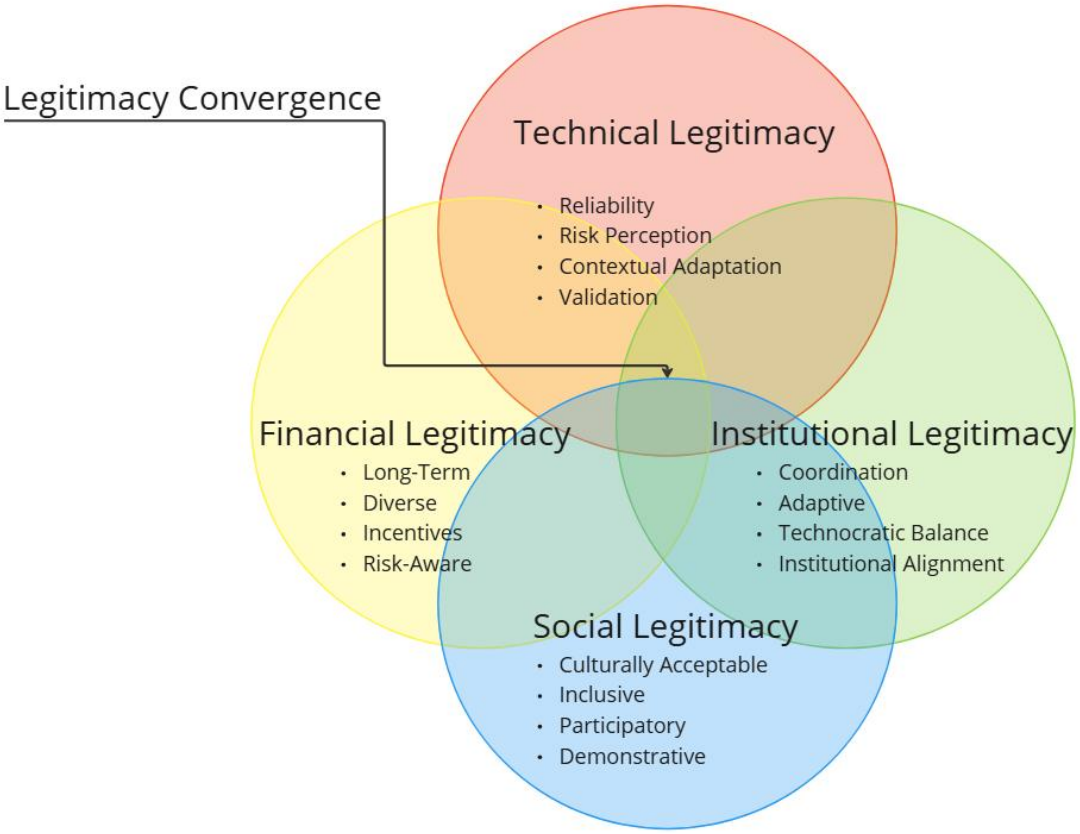
What becomes evident is that addressing governance fragmentation requires more than improving coordination or redefining mandates; necessitating instead the simultaneous alignment of multiple forms of legitimacy underpinning flood resilience. This indicates that resilience is not built sequentially, but rather through the concurrent reinforcement of all these legitimacies. In fragmented systems, however, this interdependence is precisely what becomes disrupted: technical solutions remain isolated, institutional mandates are unclear, funding is reactive and communities are left disengaged or uninformed. Without a structure that allows these elements to interact dynamically, flood resilience efforts remain partial and prone to collapse under the pressures of political cycles, disaster response urgency, and bureaucratic inertia. Thus, governance fragmentation certainly perpetuates the paradoxes that hinder the adoption of flood resilience strategies across the Global South.

“In what ways do and can the paradoxes of frugal innovation influence flood resilience in the Global South?”

The findings of this study illustrate that the paradoxes of frugal innovation both constrain and enable flood resilience, depending on how they are managed within governance structures. The Short-Term vs. Long-Term Resilience paradox is central to this tension, as it encapsulates the competing demands of crisis-driven flood management and the long-term institutionalization of adaptive resilience strategies. When paradoxes remain unaddressed, they end up perpetuating a governance cycle in which flood resilience efforts remain reactive, fragmented and ultimately dependent on emergency response mechanisms rather than proactive and preventive adaptation. The dominance of short-term financial imperatives, coupled with governance misalignment, prevents frugal innovation from being systematically integrated into resilience planning. However, when governance

structures actively acknowledges and adapt to these paradoxes, rather than attempting to eliminate them outright, frugal innovation can serve as a strategic intermediary. It can provide context-sensitive solutions that can align immediate disaster response with sustained, long-term resilience objectives, breaking the cycle of reactive and fragmented flood management.

Figure 45 : 4 Legitimacies



From Author (2024)

The study reveals that the aforementioned convergence of legitimacy is not a fixed or static concept. Rather, it evolves through ongoing negotiations among governance actors, influenced by external disruptions, institutional changes, and political dynamics. Moreover, this research finds that different dimensions of legitimacy take precedence at different phases of the flood resilience process: social and financial legitimacy are most critical during the emergency response phase, while technical and institutional legitimacy become vital as long-term strategies are developed and embedded. This dynamic alignment is essential to defining what allows for a solution to potentially be applicable while also allowing for frugal innovations to transition from isolated alternatives to institutionalized, mainstream approaches. This temporal interplay aligns with the "Paradoxical Resolution" of the Dynamic Equilibrium Model proposed by Smith & Lewis, 2011, which emphasizes the need to continuously balance and recalibrate tensions rather than resolve them conclusively. By applying this logic to flood resilience governance, the study highlights how legitimacy convergence enables systems to accommodate paradoxes over time, thus allowing for learning, coordination and strategic flexibility rather than rigid governance. This has the potential to spiral vicious cycles where resilience might finally be achieved within the context of Global South economies, something of much importance given potentially more inclement weather of the upcoming decades.

Ultimately, this research argues that the influence of paradoxes on frugal innovation is not inherently negative. On the contrary, when paradoxes are used as entry points for systemic reflection and innovation, they can also help to catalyse governance reform and transformation.

The findings suggest that frugal innovation holds significant potential to enhance flood resilience in the Global South; but only if governance systems are capable of negotiating paradoxes dynamically, and by doing so, supporting legitimacy alignment across different moments in time. Moving forward, flood resilience governance must adopt an iterative, integrative approach that bridges short-term crisis response with long-term planning. This would entail the development of institutional frameworks that embed flexibility, cross-sectoral engagement, and the dynamic alignment of legitimacy across multiple levels into the core of resilience efforts.

9 Limitations

This study offers valuable insights into the paradoxes of frugal innovation in flood resilience governance, but it is crucial to also acknowledge its limitations. These constraints stem from the research design, methodological choices and large scope, which inevitably shape the findings and their generalizability. The key limitations of this study are outlined below:

- **Deductive Nature of the Interview Questions**: One of the primary limitations of this research is the deductive structure of the interview questions, which may have influenced how participants engaged with the subject matter. The study aimed to explore the impact of paradoxes on flood resilience and along with the effects of fragmentation on the former. However, the interview design introduced certain conceptual elements, such as paradoxes and institutional gaps, as part of the question framing, rather than allowing them to emerge organically from the interviewees own accounts. While efforts were made to maintain an open-ended, exploratory tone, this deductive approach may have shaped the breadth of the interviewee's responses, guiding them towards discussing resilience challenges within this predefined theoretical lens. This could have constrained the emergence of alternative perspectives or previously unconsidered themes that might have surfaced in a more inductive interview process.

- **Potential Bias Among Interviewees**: Another limitation relates to potential bias among interviewees, particularly concerning their institutional affiliations and professional backgrounds. Many participants currently hold positions within governmental agencies, research institutions, or organizations directly involved in flood resilience governance. As a result, there may have been a reluctance to critically assess or openly critique the institutions they work with, leading to potential response bias. While some interviewees provided candid assessments of governance inefficiencies, institutional loyalty and personal experience may have influenced how certain issues were framed, particularly regarding the role of current governance structures in exacerbating or mitigating resilience challenges, along with prejudices regarding other institutions and structures. This limitation suggests that further research incorporating more independent or external perspectives, such as affected communities and NGOs, could perhaps provide a more nuanced understanding of these governance dynamics. Furthermore, the emotional state of the participants while answering the questions was not considered, which could have provided insights into the presence of such bias in their responses.

- **Absence of a Mixed-Methods Approach**: This study utilized a qualitative research methodology, without incorporating a mixed-methods approach. This design choice limits the ability to generalize the findings or validate them quantitatively. While the qualitative methods were well-suited for exploring the complex dynamics of governance paradoxes and legitimacy, the absence of quantitative data means that the prevalence and statistical

significance of certain patterns remain unverified. The integration of a mixed-methods approach, incorporating survey data, network analysis or some type of quantitative modelling, could have provided additional layers of insight, particularly regarding the institutional adoption of frugal innovations, the effectiveness of governance coordination, and the financial viability of alternative resilience strategies. Yet, this becomes challenging given the difficulty in measuring the success of frugal innovation in practice. Future research could build upon the current findings by triangulating qualitative insights with quantitative assessments to develop a more comprehensive analysis of flood resilience governance.

- **Scope Constraints of a Master's Thesis**: The study originally set out with a much broader research scope, which had to be refined due it acquiring dimensions much larger that what the constraints of a master's thesis allow for. The complexity of flood resilience governance spans multiple scales, institutions, and socio-political contexts, making it a highly intricate and multidisciplinary are of study. While the research attempted to successfully capture key governance paradoxes and tensions, a more in-depth, longitudinal study, such as a PhD dissertation, could eventually provide a deeper and more extensive exploration of these dynamics. The time constraints of this study also meant that certain aspects, such as historical institutional developments, comparative case studies and longitudinal policy shifts, could not be fully addressed nor included within the scope of this thesis. As a result, this research serves as a foundational step toward a more extensive investigation of governance paradoxes and fragmentation within flood resilience, highlighting areas that merit further empirical and theoretical exploration.
- **Challenges in Capturing Informal Governance Dynamics**: Another important limitation is the challenge in capturing informal governance dynamics. This study primarily focuses on formal governance structures, institutional structures and policy frameworks, meaning that the role of informal governance, in which community-led initiatives and non-state actors are often confined to may not have been explored. In many Global South contexts, informal governance structures end up playing a crucial role in shaping flood adaptation strategies, particularly in areas where state-led interventions are completely absent or even insufficient.

Overall, while this study hoped to provide significant contributions to the understanding of governance paradoxes in flood resilience, it is thus important to recognize its methodological and scope-related limitations. Consequently, the above mentioned points could have further strengthened the depth and applicability of the findings. Additionally, incorporating informal governance structures and historical institutional analysis would provide further nuance to the discussion. Future research can build upon these limitations by expanding on the following recommendations while conducting comparative analyses across different governance contexts to refine and validate the conclusions drawn in this study.

10 Recommendations

While this study has provided valuable insights into the role of frugal innovation in flood resilience governance, several areas do warrant further investigation to refine and expand upon its findings. Future research could deepen the understanding of governance structures, explore institutional interdependencies and assess the applicability of these findings beyond the Global South. Key recommendations for the future research identified during the body of this study are outlined below:

- **Investigating the Detailed Intricacies of Governance and Bureaucratic Rites**: One critical approach for future research is an in-depth exploration of the bureaucratic structures, along with internal conflicts within governance institutions. While this study has highlighted governance fragmentation as a key barrier, a more granular analysis of how specific institutions interact, could provide a richer understanding of the institutional dynamics that shape flood resilience. Bureaucratic processes, create overlaps and political rivalries that end up impacting decision-making. Investigating these internal power structures and inter-agency coordination mechanisms could help to unravel the systemic challenges that can end up influencing resilience policy. Future research, thus should aim to map out institutional relationships while conducting ethnographic studies of decision-making processes and analyzing bureaucratic rites.
- **Bringing These Insights Back to the Global North**: Another important direction for future research involves applying the findings of this study to flood resilience governance in the Global North, hoping to foment cross country collaboration. While this research has primarily focused on the Global South, the paradoxes of frugal innovation a are not exclusive to developing regions, showing themselves throughout the world. Many high-income countries also face challenges of bureaucratic fragmentation and have a the need to balance short-term disaster response with long-term adaptation practices. Investigating how legitimacy dimensions fluctuate in different contexts could offer comparative insights into resilience governance as a whole. Additionally, understanding how frugal innovation principles might be adapted to developed-world flood resilience strategies could challenge reliance on infrastructure-heavy solutions.
- **Evaluating the Role of International Aid and Policy Transfer**: Another critical area for future research is the influence of international aid and policy transfer on flood resilience strategies within the Global South. Institutions such as the World Bank, the International Monetary Fund, along with various United Nations agencies have played a significant role in financing and shaping flood resilience policies of the 20th century through funding mechanisms, development loans and technical assistance. It would be interesting to see if these can keep up with challenging conditions fomented by more inclement weather and resource scarcity. However, the effectiveness of these interventions remains contested, as they often introduce tensions between externally imposed strategies and local realities. Future research should thus explore the extent to which international funding aligns with the priorities and constraints of local institutions and respective communities.

In conclusion, future research should aim to delve deeper into institutional structures and their intricacies, along with governance mechanisms to assess the broader applicability of legitimacy convergence and paradox resolution within resilience. Additionally, a more extensive review of frugal innovation examples across different contexts could provide a richer understanding of how these solutions evolve, scale, and further integrate themselves into formal governance frameworks. Addressing these areas will provide a more comprehensive understanding towards governance dynamics and hopefully strengthen the practical implications of resilience strategies across diverse policy environments.

References

Aerts, J. (2018). A Review of Cost Estimates for Flood Adaptation. *Multidisciplinary Digital Publishing Institute*, *10*(11), 1646–1646. https://doi.org/10.3390/w10111646

Agency, and E. E., Ferreira, A., Kolaszewska, D., Adriaenssens, V., Rademaekers, K., Eichler, L., Dige, G., & Vermeulen, J. (2017). *Green infrastructure and flood management – Promoting cost-efficient flood risk reduction via green infrastructure solutions*. Publications Office. https://doi.org/doi/10.2800/324289

Ahmed, T., El-Zein, A., Tonmoy, F., Maggi, F., & Chung, K. S. K. (2018). Flood Exposure and Social Vulnerability for Prioritizing Local Adaptation of Urban Storm Water Systems. *Springer Nature*, 41–49. https://doi.org/10.1007/978-3-319-95711-1_5

Alexander, M., Doorn, N., & Priest, S. (2017). Bridging the legitimacy gap—Translating theory into practical signposts for legitimate flood risk governance. *Springer Science+Business Media*, *18*(2), 397–408. https://doi.org/10.1007/s10113-017-1195-4

Ali, R. A., Mannakkara, S., & Wilkinson, S. (2020). *Factors affecting successful transition between post-disaster recovery phases: A case study of 2010 floods in Sindh, Pakistan*.

Almeida, J., & Engel, C. (2020). Guidelines for Climate Change Adaptation in Brazilian Cities Through Urban Green Infrastructure. *IOP Publishing*, *503*(1), 012036–012036. https://doi.org/10.1088/1755-1315/503/1/012036

Almutairi, A., Mourshed, M., & Ameen, R. F. M. (2020). Coastal community resilience frameworks for disaster risk management. *Springer Science+Business Media*, *101*(2), 595–630. https://doi.org/10.1007/s11069-020-03875-3

ANA. (1997, January). *Agência nacional de águas e saneamento básico (ANA)*. https://www.gov.br/ana/en

Astrini, M., & Garcia, R. T. (2024, May). *Unveiling the climate crisis in brazil's rio grande do sul*. https://revolve.media/interviews/unveiling-the-climate-crisis-in-brazils-rio-grande-do-sul

Baccarini, D. (1996). *The concept of project complexity a review*. https://doi.org/10.1016/0263-7863(95)00093-3

Bajracharya, S. R., Khanal, N. R., Nepal, P., Kumar, S., Ghimire, P. K., & Pradhan, N. S. (2021). Community Assessment of Flood Risks and Early Warning System in Ratu Watershed, Koshi Basin, Nepal. *Multidisciplinary Digital Publishing Institute*, *13*(6), 3577–3577. https://doi.org/10.3390/su13063577

Bala, H., Ghosh, A. K., Kazal, M. M. H., Rahman, M. S., Sultana, M. S., & Sujan, M. H. K. (2020). Floating gardening in Bangladesh: A sustainable income generating activity in wetland areas. *IJARIT Research Foundation*, *10*(1), 87–93. https://doi.org/10.3329/ijarit.v10i1.48098

Beech, N., Burns, H., Caestecker, L. de, MacIntosh, R., & MacLean, D. (2004). Paradox as invitation to act in problematic change situations. *SAGE Publishing*, *57*(10), 1313–1332. https://doi.org/10.1177/0018726704048357

Bhat, G., Karanth, A., Dashora, L., & Rajasekar, U. (2013). Addressing flooding in the city of Surat beyond its boundaries. *SAGE Publishing*, *25*(2), 429–441. https://doi.org/10.1177/0956247813495002

Bhatti, Y., & Ventresca, M. J. (2013). How Can 'Frugal Innovation' Be Conceptualized? *RELX Group (Netherlands)*. https://doi.org/10.2139/ssrn.2203552

Bloodgood, J. M., & Chae, B. (2010). Organizational paradoxes: Dynamic shifting and integrative management. *Emerald Publishing Limited*, *48*(1), 85–104. https://doi.org/10.1108/00251741011014472

Bolderston, A. (2008). Writing an Effective Literature Review. *Elsevier BV*, *39*(2), 86–92. https://doi.org/10.1016/j.jmir.2008.04.009

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Taylor & Francis*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brem, A., Wimschneider, C., Dutra, A. R. de A., Cubas, A. L. V., & Ribeiro, R. D. (2020). How to design and construct an innovative frugal product? An empirical examination of a frugal new product development process. *Elsevier BV*, *275*, 122232–122232. https://doi.org/10.1016/j.jclepro.2020.122232

Brooks, J. W., Ravishankar, M. N., & Oshri, I. (2020). Paradox and the negotiation of tensions in globally distributed work. *SAGE Publishing*, *35*(3), 232–250. https://doi.org/10.1177/0268396220936697

Busch, H. C., Dauth, T., Fischer, L., & Souza, M. L. de. (2018). Frugal innovation approaches to sustainable domestic energy: Two cases of solar water heating from Brazil. *Inderscience Publishers*, *10*(3/4), 231–231. https://doi.org/10.1504/ijtlid.2018.093725

Buschschlüter, V. (2024, January). *Brazil floods: Hundreds of Rio Grande do Sul towns under water*. https://www.bbc.com/news/world-latin-america-68968987

Bwambale, B., Nyeko, M., Muhumuza, M., & Kervyn, M. (2020). Questioning knowledge foundation: What is the best way to integrate knowledge to achieve substantial disaster risk reduction? *Elsevier BV*, *51*, 101850–101850. https://doi.org/10.1016/j.ijdrr.2020.101850

Chigbu, U. E., Atiku, S. O., & Plessis, C. C. D. (2023). The Science of Literature Reviews: Searching, Identifying, Selecting, and Synthesising. *Multidisciplinary Digital Publishing Institute*, *11*(1), 2–2. https://doi.org/10.3390/publications11010002

Chitadze, N. (2023). *The Global North-Global South Relations and their reflection on the World Politics and International Economy*. *8*(1), 42–51. https://doi.org/10.31578/jss.v8i1.131

Clarke, B., Barnes, C., Rodrigues, R., Zachariah, M., Alves, L. M., Haarsma, R., Pinto, I., Yang, W., Vahlberg, M., Vecchi, G., Izquierdo, K., Kimutai, J., & Otto, F. E. L. (2024). *Scientific report—Brazil RS floods: Climate change, el niño and infrastructure failures behind massive floods in southern brazil*. https://noticias.paginas.ufsc.br/files/2024/06/Scientific-report-Brazil-RS-floods.pdf

Clarke, M., & Parris, B. (2019). Understanding disasters: Managing and accommodating different worldviews in humanitarian response. *Springer Nature*, *4*(1). https://doi.org/10.1186/s41018-019-0066-7

Cohen-Shacham, E., Andrade, Á., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C. R., Renaud, F. G., Welling, R., & Walters, G. (2019). *Core principles for successfully implementing and upscaling Nature-based Solutions*. *98*, 20–29.

Cooper, A., & Pile, J. (2014). The adaptation-resistance spectrum: A classification of contemporary adaptation approaches to climate-related coastal change. *Elsevier BV*, *94*, 90–98. https://doi.org/10.1016/j.ocecoaman.2013.09.006

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BioMed Central*, *11*(1). https://doi.org/10.1186/1471-2288-11-100

Dados, N., & Connell, R. (2012). *The Global South*.

Deen, S. (2015). *Pakistan 2010 floods: Policy gaps in disaster preparedness and response*. https://www.sciencedirect.com/science/article/pii/S2212420915000308

Derickson, K., Klein, M., & Keeler, B. L. (2021). *Reflections on crafting a policy toolkit for equitable green infrastructure*.

Dewulf, A., Karpouzoglou, T., Warner, J., Wesselink, A. J., Mao, F., Vos, J., Tamás, P. A., Groot, A., Heijmans, A., Ahmed, F., Hoang, L. P., Vij, S., & Buytaert, W. (2019). The power to define resilience in social–hydrological systems: Toward a power-sensitive resilience framework. *Wiley*, *6*(6). https://doi.org/10.1002/wat2.1377

Dhyani, S., Karki, M., & Gupta, A. K. (2020). Opportunities and Advances to Mainstream Nature-Based Solutions in Disaster Risk Management and Climate Strategy. *Springer Nature*, 1–26. https://doi.org/10.1007/978-981-15-4712-6_1

Diplomat, T. W. (2024, May). *Historic floods in the brazilian state of rio grande do sul*. https://www.waterdiplomat.org/story/2024/05/historic-floods-brazilian-state-rio-grande-do-sul

Driessen, P., Hegger, D. L. T., Bakker, M. H. N., Rijswick, H. F. M. W. van, & Kundzewicz, Z. W. (2016). Toward more resilient flood risk governance. *Resilience Alliance*, *21*(4). https://doi.org/10.5751/es-08921-210453

Ensor, J., Park, S. E., Attwood, S., Kaminski, A. M., & Johnson, J. L. (2016). Can community-based adaptation increase resilience? *Taylor & Francis*, *10*(2), 134–151. https://doi.org/10.1080/17565529.2016.1223595

Fang, X., Li, J., & Ma, Q. (2023). Integrating green infrastructure, ecosystem services and nature-based solutions for urban sustainability: A comprehensive literature review. *Elsevier BV*, *98*, 104843–104843. https://doi.org/10.1016/j.scs.2023.104843

Farahmand, H., Dong, S., Mostafavi, A., Berke, P., Woodruff, S., Hannibal, B., & Vedlitz, A. (2020). Institutional congruence for resilience management in interdependent infrastructure systems. *Elsevier BV*, *46*, 101515–101515. https://doi.org/10.1016/j.ijdrr.2020.101515

Fernandes, G. A. de A. L., Teixeira, M. A. C., Fernandes, I. F. de A. L., & Angélico, F. (2020). The failures of horizontal accountability at the subnational level: A perspective from the Global South. *Taylor & Francis*, *30*(5), 687–693. https://doi.org/10.1080/09614524.2020.1773764

Frantzeskaki, N., Loorbach, D., & Meadowcroft, J. (2012). Governing societal transitions to sustainability. *Inderscience Publishers*, *15*(1/2), 19–19. https://doi.org/10.1504/ijsd.2012.044032

Galloway, G. E., Reilly, A., Ryoo, S., Riley, A., Haslam, M., Brody, S., Highfield, W., Gunn, J., Rainey, J. on, & Parker, S. (2018). *The growing threat of urban flooding: A national challenge*. https://cdr.umd.edu/urban-flooding-report

Gandenberger, C., Kroll, H., & Walz, R. (2020). The role of frugal innovation in the global diffusion of green technologies. *Inderscience Publishers*, *83*(1/2/3), 97–97. https://doi.org/10.1504/ijtm.2020.109218

Gersonius, B., Buuren, A. van, Zethof, M., & Kelder, E. (2016). Resilient flood risk strategies: Institutional preconditions for implementation. *Resilience Alliance*, *21*(4). https://doi.org/10.5751/es-08752-210428

Gilissen, H. K., Hoole, A. M., Matczak, P., Pettersson, M., & Bruzzone, S. (2016). A framework for evaluating the effectiveness of flood emergency management systems in Europe. *Resilience Alliance*, *21*(4). https://doi.org/10.5751/es-08723-210427

Gim, C., Miller, C. A., & Hirt, P. W. (2019). The resilience work of institutions. *Elsevier BV*, *97*, 36–43. https://doi.org/10.1016/j.envsci.2019.03.004

Goossen, W. J. (2018, August). *Interview—The Dutch make room for the river*. https://www.eea.europa.eu/signals-archived/signals-2018-content-list/articles/interview-2014-the-dutch-make

Greco, A., Long, T. B., & Jong, G. de. (2021). Identity reflexivity: A framework of heuristics for strategy change in hybrid organizations. *Emerald Publishing Limited*, *59*(7), 1684–1705. https://doi.org/10.1108/md-10-2019-1369

Groeskamp, S., & Kjellsson, J. (2020). *Engineering a solution to sea level rise: The northern european enclosure dam*. *101*(7), E1997–E2005.

Guerriero, R., & Penning-Rowsell, E. C. (2020). Innovation in flood risk management: An 'Avenues of Innovation' analysis. *Wiley*, *14*(1). https://doi.org/10.1111/jfr3.12677

Guimaraens, R. (2024). A enchente de 41. *Libretos*. https://books.google.com.br/books?hl=nl&lr=&id=0XMMEQAAQBAJ&oi=fnd&pg=PT104&dq=enchente+porto+alegre&ots=Hb1H3EC4Zm&sig=CliPej6mwU2sGsRW9hX4lvW_Y5A&redir_esc=y#v=onepage&q=enchente%20porto%20alegre&f=false

Gupta, J., & Bavinck, M. (2017). Reprint of "Inclusive development and coastal adaptiveness." *Elsevier BV*, *150*, 73–81. https://doi.org/10.1016/j.ocecoaman.2017.10.020

Hartog, H. den. (2021). Engineering an Ecological Civilization Along Shanghai's Main Waterfront and Coastline: Evaluating Ongoing Efforts to Construct an Urban Eco-Network. *Frontiers Media*, *9*. https://doi.org/10.3389/fenvs.2021.639739

Hegger, D. L. T., Driessen, P., Wiering, M., Rijswick, H. F. M. W. van, Kundzewicz, Z. W., Matczak, P., Crabbé, A., Raadgever, G. T., Bakker, M. H. N., Priest, S., Larrue, C., & Ek, K. (2016). Toward more flood resilience: Is a diversification of flood risk management strategies the way forward? *Resilience Alliance*, *21*(4). https://doi.org/10.5751/es-08854-210452

Herath, H. M. M., & Wijesekera, N. T. S. (2020). Transformation of flood risk management with evolutionary resilience. *EDP Sciences*, *158*, 06005–06005. https://doi.org/10.1051/e3sconf/202015806005

Herk, S. van, Zevenbergen, C., Gersonius, B., Waals, H., & Kelder, E. (2013). Process design and management for integrated flood risk management: Exploring the multi-layer safety approach for Dordrecht, The Netherlands. *IWA Publishing*, *5*(1), 100–115. https://doi.org/10.2166/wcc.2013.171

Herreros-Cantis, P., Olivotto, V., Grabowski, Z. R., & McPhearson, T. (2020). Shifting landscapes of coastal flood risk: Environmental (in)justice of urban change, sea level rise, and differential vulnerability in New York City. *BioMed Central*, *2*(1). https://doi.org/10.1186/s42854-020-00014-w

Hill, B., Liang, Q., Bosher, L., Chen, H., & Nicholson, A. (2023). A systematic review of natural flood management modelling: Approaches, limitations, and potential solutions. *Wiley*, *16*(3). https://doi.org/10.1111/jfr3.12899

Hindocha, C. N., Antonacci, G., Barlow, J., & Harris, M. (2021). Defining frugal innovation: A critical review. *BMJ*, *7*(4), 647–656. https://doi.org/10.1136/bmjinnov-2021-000830

Hopkins, J. (2022, January). *'Emerald tutu' of floating wetlands*. https://news.northeastern.edu/2023/04/28/magazine/professor-develops-emerald-tutu/

Horning, J. J., & Neumann, P. G. (2008). Risks of neglecting infrastructure. *Association for Computing Machinery*, *51*(6), 112–112. https://doi.org/10.1145/1349026.1349047

Hossain, F., & Kalyanapu, A. (2012). Cities, Dams, and Extreme Weather. *American Society of Civil Engineers*, *82*(11), 68–71. https://doi.org/10.1061/ciegag.0000428

Hossain, M. (2021a). Frugal innovation: Unveiling the uncomfortable reality. *Elsevier BV*, *67*, 101759–101759. https://doi.org/10.1016/j.techsoc.2021.101759

Hossain, M. (2021b). Frugal innovation: Unveiling the uncomfortable reality. *Elsevier BV*, *67*, 101759–101759.

Hossain, M., Simula, H., & Halme, M. (2016). Can frugal go global? Diffusion patterns of frugal innovations. *Elsevier BV*, *46*, 132–139. https://doi.org/10.1016/j.techsoc.2016.04.005

Hughes, S., Dobie, S., Schwarz, K., LeMee, G. L., Lane, M., & González, A. E. R. (2021). Centering Racial Justice in Urban Flood Resilience Policy and Planning: Tools for Practitioners. *Mary Ann Liebert, Inc.* https://doi.org/10.1089/env.2021.0045

Ingram, A., Lewis, M. W., Andriopoulos, C., & Gotsi, M. (2008). Innovation Tensions and Organizational Ambidexterity: Toward a Collective Paradox Frame. *Academy of Management*, *2008*(1), 1–6. https://doi.org/10.5465/ambpp.2008.33649824

Jackson, R. L., Drummond, D. K., & Camara, S. K. (2007). What Is Qualitative Research? *Taylor & Francis*, *8*(1), 21–28. https://doi.org/10.1080/17459430701617879

Janda, S. von, Kuester, S., Schuhmacher, M. C., & Shainesh, G. (2020). What frugal products are and why they matter: A cross-national multi-method study. *Elsevier BV*, *246*, 118977–118977. https://doi.org/10.1016/j.jclepro.2019.118977

Johannessen, Å., & Mostert, E. (2020). Urban Water Governance and Learning—Time for More Systemic Approaches? *Multidisciplinary Digital Publishing Institute*, *12*(17), 6916–6916. https://doi.org/10.3390/su12176916

Jonga, A., Meilianda, E., & Nizamuddin, N. (2021). Community-based intervention in reducing flood impacts in Gambia. *IOP Publishing*, *711*(1), 012020–012020. https://doi.org/10.1088/1755-1315/711/1/012020

Jonkman, S. N., Voortman, H. G., Klerk, W. J., & Vuren, S. van. (2018). Developments in the management of flood defences and hydraulic infrastructure in the Netherlands. *Taylor & Francis*, *14*(7), 895–910. https://doi.org/10.1080/15732479.2018.1441317

Kahle, H. N., Dubiel, A., Ernst, H., & Prabhu, J. (2013). The democratizing effects of frugal innovation. *Emerald Publishing Limited*, *5*(4), 220–234. https://doi.org/10.1108/jibr-01-2013-0008

Kahn, M. E., McComas, M., & Ravi, V. (2021). *The local economic impact of flood-resilient infrastructure projects*. https://21cc.jhu.edu

Karyono, T. H., Melyan, N. H., Salsa, S. Y., & Fariz, E. (2017). *Flood responsive design of the low-income settlements in kampung melayu, jakarta, indonesia*. 235–250.

Khan, R. (2016). How Frugal Innovation Promotes Social Sustainability. *Multidisciplinary Digital Publishing Institute*, *8*(10), 1034–1034. https://doi.org/10.3390/su8101034

Khokhar, S., Pathan, H., Raheem, A., & Abbasi, A. M. (2020). *Theory development in thematic analysis: Procedure and practice*. *3*(3), 423–433.

Kim, J. H., & Jurey, N. (2013). Local and Regional Governance Structures. *SAGE Publishing*, *28*(2), 111–123. https://doi.org/10.1177/0885412213477135

Klijn, F., Marchand, M., Meijer, K., Most, H. van der, & Stuparu, D. (2021). Tailored flood risk management: Accounting for socio-economic and cultural differences when designing strategies. *Elsevier BV*, *12*, 100084–100084. https://doi.org/10.1016/j.wasec.2021.100084

Kroll, H., & Gabriel, M. (2020). Frugal innovation in, by and for Europe. *Inderscience Publishers*, *83*(1/2/3), 34–34. https://doi.org/10.1504/ijtm.2020.109230

Laeni, N., Brink, M. van den, & Arts, J. (2021). Institutional Conditions for Inclusive, Flood Resilient Urban Deltas: A Comparative Institutional Analysis of Two International Resilience Programs in Southeast Asia. *Multidisciplinary Digital Publishing Institute*, *13*(18), 2478–2478. https://doi.org/10.3390/w13182478

Lam, D. P. M., Hinz, E., Lang, D. J., Tengö, M., Wehrden, H. von, & Martín-López, B. (2020). Indigenous and local knowledge in sustainability transformations research: A literature review. *Resilience Alliance*, *25*(1). https://doi.org/10.5751/es-11305-250103

Lamoree, B., Verwey, A., Glerum, P., & Bacellar, D. (2024). *Dutch Disaster Risk Reduction & Surge Support (DRRS) Programme*. https://prefeitura.poa.br/sites/default/files/usu_doc/sites/dmae/DRRS%20Porto%20Alegre%20-%20final%20report%2025%20August%202024%20PT_0.pdf

Larson, A. M., & Soto, F. (2008). Decentralization of Natural Resource Governance Regimes. *Annual Reviews*, *33*(1), 213–239. https://doi.org/10.1146/annurev.environ.33.020607.095522

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. *Medknow*, *4*(3), 324–324. https://doi.org/10.4103/2249-4863.161306

Lewis, M. W. (2000). Exploring Paradox: Toward a More Comprehensive Guide. *Academy of Management*, *25*(4), 760–776. https://doi.org/10.5465/amr.2000.3707712

Lewis, M. W., & Smith, W. K. (2014). *Paradox as a Metatheoretical Perspective: Sharpening the Focus and Widening the Scope*.

Loggia, G. L., Puleo, V., & Freni, G. (2020). Floodability: A New Paradigm for Designing Urban Drainage and Achieving Sustainable Urban Growth. *Springer Science+Business Media*, *34*(10), 3411–3424. https://doi.org/10.1007/s11269-020-02620-6

Longhurst, R. (2009). Interviews: In-Depth, Semi-Structured. *Elsevier BV*, 580–584. https://doi.org/10.1016/b978-008044910-4.00458-2

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Elsevier BV*, *42*(3), 237–246. https://doi.org/10.1016/j.futures.2009.11.009

Marks, D., & Lebel, L. (2016). Disaster governance and the scalar politics of incomplete decentralization: Fragmented and contested responses to the 2011 floods in Central Thailand. *Elsevier BV*, *52*, 57–66. https://doi.org/10.1016/j.habitatint.2015.08.024

Matczak, P., & Hegger, D. (2020). Flood Risk Governance for More Resilience—Reviewing the Special Issue's Contribution to Existing Insights. *Multidisciplinary Digital Publishing Institute*, *12*(8), 2122–2122. https://doi.org/10.3390/w12082122

Matczak, P., & Hegger, D. (2021). Improving flood resilience through governance strategies: Gauging the state of the art. *Wiley-Blackwell*, *8*(4). https://doi.org/10.1002/wat2.1532

Mateo, J. R. S. C., Carral, L., Díaz-Ruiz-Navamuel, E., Formoso, J. Á. F., & Iglesias, G. (2018). Complexity and Project Management: A General Overview. *Hindawi Publishing Corporation*, *2018*, 1–10. https://doi.org/10.1155/2018/4891286

Mazó, E. G. (2024, May). *An 8 million Passenger Hub Under Water: Porto Alegre Airport Today in Pictures*. https://aviacionline.com/2024/05/under-water-porto-alegre/

McDermott, T. K. J. (2022). Global exposure to flood risk and poverty. *Nature Portfolio*, *13*(1). https://doi.org/10.1038/s41467-022-30725-6

McNabb, D. E. (2017). How to Write a Research Proposal. *Informa*, 100–108. https://doi.org/10.4324/9781315181158-9

Mendoza, G., & Khero, Z. (2016). Building Pakistan's Resilience to Flood Disasters in the Indus River Basin. *Springer Nature*, 81–110. https://doi.org/10.1007/978-981-10-1914-2_5

Meng, M., Dąbrowski, M., & Stead, D. (2020). Enhancing Flood Resilience and Climate Adaptation: The State of the Art and New Directions for Spatial Planning. *Multidisciplinary Digital Publishing Institute*, *12*(19), 7864–7864. https://doi.org/10.3390/su12197864

Mian, S. (2014). Pakistan's Flood Challenges: An assessment through the lens of learning and adaptive governance. *Wiley*, *24*(6), 423–438. https://doi.org/10.1002/eet.1659

Mosavi, A., Öztürk, P., & Chau, K. (2018). Flood Prediction Using Machine Learning Models: Literature Review. *Multidisciplinary Digital Publishing Institute*, *10*(11), 1536–1536. https://doi.org/10.3390/w10111536

Muhonda, P., Mabiza, C., Makurira, H., Kujinga, K., Nhapi, I., Goldin, J., & Mashauri, D. A. (2014). *Analysis Of Institutional Mechanisms That Support Community Response to Impacts of Floods and Drought in the Middle-Zambezi River Basin*. https://www.sciencedirect.com/science/article/pii/S1474706514000989

Munawar, H. S., Khan, S. I., Anum, N., Qadir, Z., Kouzani, A. Z., & Mahmud, M. A. P. (2021). Post-Flood Risk Management and Resilience Building Practices: A Case Study. *Multidisciplinary Digital Publishing Institute*, *11*(11), 4823–4823. https://doi.org/10.3390/app11114823

Mwendwa, P., & Giliba, R. A. (2012). Benefits and Challenges of Urban Green Spaces. *Taylor & Francis*, *10*(1), 73–79. https://doi.org/10.1080/10042857.2012.10685062

Naz, N., Gulab, F., & Aslam, M. (2022). *Development of qualitative semi-structured interview guide for case study research*. https://cssrjournal.com/index.php/cssrjournal/article/view/170

Niemcryk, S., & Glascoff, D. W. (1997). *Considerations in presenting, interpreting, and reviewing research findings*. *7*(1), 41–47. https://doi.org/10.7182/prtr.1.7.1.u12r17v746268n66

Niroumand, M., Shahin, A., Naghsh, A., & Peikari, H. R. (2020). Frugal innovation enablers: A comprehensive framework. *Emerald Publishing Limited*, *12*(1), 1–20. https://doi.org/10.1108/ijis-10-2019-0099

Nkwunonwo, U. C. (2020). Flood Risk Analysis for Critical Infrastructure Protection: Issues and Opportunities in Less Developed Societies. *IntechOpen*. https://doi.org/10.5772/intechopen.95364

Nur, I., & Shrestha, K. K. (2017a). An Integrative Perspective on Community Vulnerability to Flooding in Cities of Developing Countries. *Elsevier BV*, *198*, 958–967. https://doi.org/10.1016/j.proeng.2017.07.141

Nur, I., & Shrestha, K. K. (2017b). An Integrative Perspective on Community Vulnerability to Flooding in Cities of Developing Countries. *Elsevier BV*, *198*, 958–967. https://doi.org/10.1016/j.proeng.2017.07.141

O'Brien, K., Pelling, M., Patwardhan, A., Hallegatte, S., Maskrey, A., Oki, T., Oswald-Spring, Ú., Wilbanks, T. J., & Yanda, P. Z. (2012). Toward a Sustainable and Resilient Future. *Cambridge University Press*, 437–486. https://doi.org/10.1017/cbo9781139177245.011

Odeh, L. E. (2010). *A Comparative Analysis of Global North and Global South Economies*. *12*(3), 338–348.

Ogie, R., Adam, C., & Perez, P. (2019). A review of structural approach to flood management in coastal megacities of developing nations: Current research and future directions. *Taylor & Francis*, *63*(2), 127–147. https://doi.org/10.1080/09640568.2018.1547693

Ogrean, C. (2016). Solving Strategic Paradoxes through Organizational Ambidexterity—A Foray into the Literature -. *DeGruyter Open*, *11*(2), 97–103. https://doi.org/10.1515/sbe-2016-0024

Opperman, J. J., & Galloway, G. E. (2022). Nature-based solutions for managing rising flood risk and delivering multiple benefits. *Elsevier BV*, *5*(5), 461–465. https://doi.org/10.1016/j.oneear.2022.04.012

Papachroni, A., Heracleous, L., & Paroutis, S. (2014). Organizational Ambidexterity Through the Lens of Paradox Theory. *SAGE Publishing*, *51*(1), 71–93. https://doi.org/10.1177/0021886314553101

Pearson, J., Punzo, G., Mayfield, M., Brighty, G. C., Parsons, A., Collins, P., Jeavons, S., & Tagg, A. (2018). Flood resilience: Consolidating knowledge between and within critical infrastructure sectors. *Springer Science+Business Media*, *38*(3), 318–329. https://doi.org/10.1007/s10669-018-9709-2

Perricone, V., Mutalipassi, M., Mele, A., Buono, M. P. di, Vicinanza, D., & Contestabile, P. (2023). Nature-based and bioinspired solutions for coastal protection: An overview among key ecosystems and a promising pathway for new functional and sustainable designs. *Oxford University Press*, *80*(5), 1218–1239. https://doi.org/10.1093/icesjms/fsad080

Rasmussen, D. J., Kopp, R. E., & Oppenheimer, M. (2023). Coastal Defense Megaprojects in an Era of Sea-Level Rise: Politically Feasible Strategies or Army Corps Fantasies? *American Society of Civil Engineers*, *149*(2). https://doi.org/10.1061/(asce)wr.1943-5452.0001613

Raub, K. B., Flynn, S. E., Stepenuck, K. F., & Hedderman, C. (2024). *Integrating resilience and nexus approaches in managing flood risk*. *6*, 1306044.

Reidpath, D. D., & Allotey, P. (2019). The problem of 'trickle-down science' from the Global North to the Global South. *BMJ*, *4*(4), e001719–e001719. https://doi.org/10.1136/bmjgh-2019-001719

Rijke, J., Herk, S. van, Zevenbergen, C., Ashley, R., Hertogh, M., & Heuvelhof, E. ten. (2014). Adaptive programme management through a balanced performance/strategy oriented focus. *Elsevier BV*, *32*(7), 1197–1209. https://doi.org/10.1016/j.ijproman.2014.01.003

Rocha, A. P. (2024, January). *"Minimal State Allowed the Mud to Reach My House," says a victim of the floods in rio grande do sul*. https://www.brasildefato.com.br/2024/06/05/minimal-state-allowed-the-mud-to-reach-my-house-says-a-victim-of-the-floods-in-rio-grande-do-sul

Rosca, E., Reedy, J., & Arlinghaus, J. C. (2017). Does Frugal Innovation Enable Sustainable Development? A Systematic Literature Review. *Palgrave Macmillan*, *30*(1), 136–157. https://doi.org/10.1057/s41287-017-0106-3

Rosenzweig, C., & Solecki, W. (2014). Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city. *Elsevier BV*, *28*, 395–408. https://doi.org/10.1016/j.gloenvcha.2014.05.003

Schoon, M., & Cox, M. (2018). Collaboration, Adaptation, and Scaling: Perspectives on Environmental Governance for Sustainability. *Multidisciplinary Digital Publishing Institute*, *10*(3), 679–679.

Sediri, S., Trommetter, M., Frascaria-Lacoste, N., & Fernández-Manjarrés, J. (2020). Transformability as a Wicked Problem: A Cautionary Tale? *Multidisciplinary Digital Publishing Institute*, *12*(15), 5895–5895. https://doi.org/10.3390/su12155895

SEMA. (1999, May). *Secretaria do meio ambiente e infraestrutura do rio grande do sul (SEMA-RS)*. https://sema.rs.gov.br/quem-somos

Shah, M. A. R., Rahman, A., & Chowdhury, S. H. (2015). Challenges for achieving sustainable flood risk management. *Wiley*, *11*(S1). https://doi.org/10.1111/jfr3.12211

Sheikh, F. A., Pugh, R., Wu, X., & Sarkar, S. (2023). Regional studies and frugal innovation: A missing link? *Routledge*, *58*(4), 893–905. https://doi.org/10.1080/00343404.2023.2222136

Smamus. (2024, January). *Impacts of the may 2024 floods in porto alegre*. https://storymaps.arcgis.com/stories/315f1495891343c5b2491e8ea63d9c67

Smith, W. K., & Lewis, M. W. (2011). Toward a Theory of Paradox: A Dynamic Equilibrium Model of Organizing. *Academy of Management*, *36*(2), 381–403. https://doi.org/10.5465/amr.2011.59330958

Snel, K. A. W., Priest, S., Hartmann, T., Witte, P., & Geertman, S. (2021). 'Do the resilient things.' Residents' perspectives on responsibilities for flood risk adaptation in England. *Wiley*, *14*(3). https://doi.org/10.1111/jfr3.12727

Soffiati, A. (2005). *Vista do DNOS: Uma instituição mítica da república brasileira*. http://dx.doi.org/10.22296/2317-1529.2005v7n2p61

Sörensen, J., Persson, A., Sternudd, C., Aspegren, H., Nilsson, J., Nordström, J., Jönsson, K., Mottaghi, M., Becker, P., Pilesjö, P., Larsson, R., Berndtsson, R., & Mobini, S. (2016). Re-Thinking Urban Flood Management—Time for a Regime Shift. *Multidisciplinary Digital Publishing Institute*, *8*(8), 332–332. https://doi.org/10.3390/w8080332

Sousa, A. (2024, January). *Floods advance and security and transportation collapse in rio grande do sul*. https://www1.folha.uol.com.br/internacional/en/brazil/2024/05/floods-advance-and-security-and-transportation-collapse-in-rio-grande-do-sul.shtml

Stohl, C., & Cheney, G. (2001). Participatory Processes/Paradoxical Practices. *SAGE Publishing*, *14*(3), 349–407. https://doi.org/10.1177/0893318901143001

Stokkom, H. T. C. van, & Smits, A. J. M. (2005). *Flood defense in The Netherlands: A new era, a new approach*. https://repository.ubn.ru.nl/bitstream/handle/2066/32509/32509.pdf;sequence=1

Sul21. (2024, May). *Daiana santos aciona MP-RS contra condomínio de luxo em pelotas por racismo ambiental*. https://sul21.com.br/noticias/geral/2024/05/daiana-santos-aciona-mp-rs-contra-condominio-de-luxo-em-pelotas-por-racismo-ambiental/

Takin, M. E. J., Cilliers, & Ghosh, S. (2023). *Advancing flood resilience: The nexus between flood risk management, green infrastructure, and resilience*.

Taquette, S. R., & Souza, L. M. B. da M. (2022). Ethical Dilemmas in Qualitative Research: A Critical Literature Review. *SAGE Publishing*, *21*, 160940692210787–160940692210787. https://doi.org/10.1177/16094069221078731

Tariq, M. A. U. R., & Giesen, N. van de. (2012). Floods and flood management in Pakistan. *Elsevier BV*, *47–48*, 11–20. https://doi.org/10.1016/j.pce.2011.08.014

Thorne, S. (2000). Data analysis in qualitative research. *BMJ*, *3*(3), 68–70. https://doi.org/10.1136/ebn.3.3.68

Tsekleves, E., Darby, A., Ahorlu, C., Pickup, R. W., Souza, D. de, & Boakye, D. (2020). *Challenges and Opportunities in Conducting and Applying Design Research beyond Global North to the Global South*. https://doi.org/10.21606/drs.2020.145

Vangen, S. (2016). Developing Practice-Oriented Theory on Collaboration: A Paradox Lens. *Wiley*, *77*(2), 263–272. https://doi.org/10.1111/puar.12683

Vidal, L.-A., & Marle, F. (2008). Understanding project complexity: Implications on project management. *Emerald Publishing Limited*, *37*(8), 1094–1110. https://doi.org/10.1108/03684920810884928

Villela, C. (2024, January). *With heavy rain, water rises through drains and floods porto alegre again*. https://www1.folha.uol.com.br/internacional/en/brazil/2024/05/with-heavy-rain-water-rises-through-drains-and-floods-porto-alegre-again.shtml

Weiser, A.-K., & Laamanen, T. (2022). Extending the Dynamic Equilibrium Model of Paradox: Unveiling the dissipative dynamics in organizations. *SAGE Publishing*, *3*(3), 263178772210903–263178772210903. https://doi.org/10.1177/26317877221090317

Weyrauch, T., & Herstatt, C. (2016). What is frugal innovation? Three defining criteria. *Springer Nature*, *2*(1). https://doi.org/10.1186/s40669-016-0005-y

Yasmin, T., Farrelly, M., & Rogers, B. C. (2019). Adaptive governance: A catalyst for advancing sustainable urban transformation in the global South. *Taylor & Francis*, *36*(5), 818–838. https://doi.org/10.1080/07900627.2019.1611548

Yen, B. C. (2000). *100-Year Return Period: Of What?* https://doi.org/10.1061/40517(2000)60

Yuan, F., Fan, C., Farahmand, H., Coleman, N., Esmalian, A., Lee, C.-C., Patrascu, F. I., Zhang, C., Dong, S., & Mostafavi, A. (2022). Smart flood resilience: Harnessing community-scale big data for predictive flood risk monitoring, rapid impact assessment, and situational awareness. *IOP Publishing*, *2*(2), 025006–025006. https://doi.org/10.1088/2634-4505/ac7251

Zevenbergen, C., Gersonius, B., & Radhakrishan, M. (2020). *Flood resilience*. https://royalsocietypublishing.org/doi/10.1098/rsta.2019.0212

Zevenbergen, C., Herk, S. van, & Rijke, J. (2016). Future-Proofing Flood Risk Management. *SAGE Publishing*, *22*(1), 49–54. https://doi.org/10.1177/1087724x16674473

Zylberkan, M. (2024, January). *Porto alegre city hall was warned six years ago about the risk of failure in flood control system*. https://www1.folha.uol.com.br/internacional/en/brazil/2024/05/porto-alegre-city-hall-was-warned-six-years-ago-about-the-risk-of-failure-in-flood-control-system.shtml

Appendix A : Interview Protocol (Data Analysis)

List of interview questions

The interview questions were designed to elicit insights from all participants regarding their experiences and perspectives on flood resilience strategies across various governance levels. These questions aimed to explore the strengths and weaknesses of current structures, the balance between innovative and traditional practices, and the integration of technocratic and community-driven solutions. By addressing these topics, the study seeks to understand how stakeholders navigate the complexities and paradoxes inherent in flood resilience planning and implementation. The findings from these interviews will be interpreted through the lens of the Dynamic Equilibrium Model (Smith & Lewis, 2011) and the overarching paradox perspective, providing a theoretical foundation for analysing and managing the tensions that arise in the context of flood resilience.

Opening Questions

1. Could you briefly describe your experience in implementing flood resilience strategies in your region?

2. What are the main strengths and weaknesses you observe in the current flood resilience structures or strategies implemented in your region?

3. How do flood resilience frameworks align or fail to align with the different levels of governance in your region (macro, meso, local)?

Core Questions

4. How do you balance the need to introduce innovative flood resilience measures (change) with maintaining and strengthening traditional and locally established practices (stability)?

5. How do you navigate the tension between technocratic solutions, which often come from centralized authorities, and the sociogeographic need for locally adapted and community-driven solutions?

6. How do you address the paradox of aligning regional flood resilience goals with the diverse needs and values of local communities?

7. When confronted with the paradox of immediate flood protection versus long-term sustainability, how do you navigate this conflicting flood resilience deadlock?

8. How do you perceive and navigate the inherent tensions or contradictions in implementing flood resilience strategies?

9. What challenges and opportunities have you encountered when trying to integrate frugal innovations with traditional flood resilience methods in your region?

10. How do you balance the incorporation of local knowledge and practices with the adoption of transnational frameworks and external expertise? Are there cases where this balance has led to more effective outcomes?

11. How do local power dynamics and governance complexities impact your ability to effectively manage these paradoxes?

12. How can lessons learned in the Global South be applied to developed countries, such as in the case of the 2024 floods in Valencia?

13. How can fragmentation and governance gaps across levels be addressed to improve flood resilience?

Closing Question

14. Based on your experiences, what recommendations would you give to other decision-makers in similar contexts to navigate flood resilience paradoxes and develop more context-sensitive and sustainable strategies?

Appendix B : Validation Interview

Introduction

- Name of the researcher
- Educational Qualification
- Current academic endeavour
- Research objective
- Research Results and Proposed Framework
- Purpose of validation interview
- Introduction of the Interviewee
- Informed consent/ confidentiality clause

Validation Interview Questions

1. How complete do you find the discussion on the paradoxes present in applying frugal innovation to flood resilience?
2. How well does the 4 Legitimacies Framework define what makes a frugal solution applicable?
3. Do you think that the ODISHA model exemplifies well a case of Legitimacy Convergence per the analysis of this thesis?
4. How effectively does the framework capture and propose solutions for governance fragmentation, particularly in multi-level flood resilience coordination?
5. Do you think something should be added or removed or restructured in the framework?

Appendix C : Informed Consent Form

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: Video recorded interviews that will be automatically transcribed as text. Both the recording and the transcript will be destroyed right after the conclusion of this study;	☐	☐
4. I understand that I won't be compensated for my participation.	☐	☐
5. I understand that the study will end by APRIL/2025. The exact date will be decided during the green light meeting		
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves collecting specific personally identifiable information (PII), such as name, e-mail address, designation, and location. It also involves the collection of personally identifiable research data (PIRD), with the potential risk of my identity being revealed public. I understand that I can ask for the interview to stop at any point if I feel the need to do so.	☐	☐
7. I understand that some of this PIRD is considered as sensitive data within GDPR legislation, specifically data related to my specific role and responsibilities.	☐	☐
8. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: all the data will be safely stored on TU Delft One Drive, and the access to this data will be limited. I am also aware that this data will be destroyed once the study is completed.	☐	☐
9. I understand that personal information collected about me that can identify me, such as e-mail address, name, job designation and location, will not be shared beyond the study team.	☐	☐
10. I understand that the (identifiable) personal data I provide will be destroyed right after the conclusion of this study.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		

11. I understand that after the research study the de-identified information I provide will be used for the Master's thesis report developed by the researcher and that it will be publicly available in TU Delft's repository.	☐	☐
12. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
13. I agree that my real name can be used for quotes in research outputs.	☐	☐
PLEASE TICK THE APPROPRIATE BOXES	Yes	No
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
14. I give permission for the de-identified video recording that I provide to be archived in TU Delft repository so it can be used for future research and learning.	☐	☐
15. I understand that access to this repository is open, but it can be restricted on my request.	☐	☐

Signatures

_____ _____ _____

Name of participant [printed] Signature

Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____ _____ _____

Researcher name [printed] Signature Date

Study contact details for further information:
FRANCISCO FRANCO BULHOES MENDES

Appendix D : Open Codes

Code

- Academia Involvment
- Act of God
- Adaptability
- Adaptive Designs
- Aging Assets
- Apolitical Institutions
- Axial Codes
- Bipartisan Recovery
- Blue-Green Infrastructure
- Bottom-Up Governance
- Brazilian Sanitation Framework
- Bureaucracy
- Centralization vs. Autonomy
- Climate Change
- Climate Finance and Risk Transfer
- Climate Messaging
- Climate Skepticism
- Co-Production of Solution
- Community Education
- Community Governance
- Community Initiative
- Community Involvement
- Community-Led vs. Technocratic Solutions
- Competing Priorities in Public Investment
- Context Sensitive Governance
- Coping Capacity
- Cost Efficiency vs. Long Term Resilience
- Crisis-Induced Learning
- Cross-Border Learning
- Cross-Subsidization Tensions
- Data-Driven Governance
- Decentralization Overload
- Decentralization vs. Coordination
- Decentralized Recovery Effectiveness
- Decision Making Burden
- Delayed Response
- Delayed Risk Recognition
- Democratic Maturity
- Disaster Memory Decay
- Disaster Memory Instituionalization
- DNOS
- Early Warning Systems
- Economic Disparities
- Economic Loss
- Efficiency Paradigm
- Environmental Concerns
- Equity Gaps in Climate Resilience
- External Validation
- Factors Affecting Frugal Innovation
- Failure in Monitoring
- Fast Recovery

Code

- Lack of Asset Maintenance
- Lack of Infrastructure
- Lack of Institutional Motivation
- Lack of Resilience Coverage
- Legacy Infrastructure Risk
- Local Governace Factors
- Local Knowlegde
- Local Level Collaboration
- Local Level Lack of Capability
- Local Level Measures
- Local Level Protectionism
- Local vs. Global Knowlegde
- Long Term Focus
- Low-Cost Adaptation
- Macro-Meso Alignment
- Macro-Meso Disalignment
- Market Adoption of Innovation
- Market Based Resilience Strategies
- Market Mechanisms
- Market-Based Solutions
- Meso-Level Alignment
- Meso-Level Asymmetry
- Military Governance
- Military Logistics
- Missing Data
- Mutual Aid Collaboration
- NIMTOF (Not in My Term of Office)
- Non-Stationarity in Climate Risk
- Outdated Systems
- Paradoxes in Frugal Innovation
- Parallel Structures of Power
- Parliamentary Amendments
- Participatory Systems
- Partisan Governance
- Police Mainstreaming
- Policy Continuity
- Policy Enforcement
- Policy Enforcement Failure
- Policy Evaluation Metrics
- Policy Flexibility
- Policy Inertia
- Policy Mediation Structures
- Policy Myopia
- Policy Reform
- Policy Toolbox
- Political Accountability Deficit
- Political and Policy Dynamics
- Political Blame Game
- Political Capital Through Resilience
- Political Decision Making
- Political One-up-Manship

- FESP
- Financial and Resource Constraints
- Financial Disincentives
- Financial Incentives
- Fragmentation of Governance
- Fragmentation vs. Centralization
- Frugal Innovation
- Frugal Innovation Challenges
- Frugal Policy
- Funding Gaps
- Geographic Uniqueness
- Geographic Variability
- Global Knowledge Flows
- Governance Across the Levels
- Governance Adaptability
- Governance Capacity
- Governance Centralization
- Governance Compromise
- Governance Fragmentation
- Governance Fragmentation and Integration
- Governance Mediation Failures
- Governance Resilience
- Governance Trust
- Governance Vacuum
- Governance Weakening
- Grassroots Solutions
- Green-Grey Infrastructure
- Historical Context
- Hybrid Infrastructure
- Implementation Challenges
- Incentive-Driven Compliance
- Inequality
- Informal Power (Influence)
- Informal Systems Resistance
- Innovation Resistance
- Innovation Stagnation
- Institutional Capacity
- Institutional Complacency
- Institutional Dynamics
- Institutional Gaps
- Institutional Infrastructure
- Institutional Knowledge Retention
- Institutional Legitimacy
- Institutional Legitimacy Overlaps
- Institutional Risk Aversion
- Institutional Risk Exposure
- Institutional Translation
- Integrated Monitoring
- Integrated Systems
- Integrative Policy
- Inter-Governmental Coordination
- Inter-Governmental Tensions
- Interdisciplinary Resilience
- International Financing
- Political Oscillations
- Political Polarization
- Pollution
- Post-Colonial Inferiority Perception
- Power Dynamics
- Power Separation
- Private Sector Involvment
- Private Sector Steering
- Public Perception
- Public vs. Private Steering
- Public-Private Partnerships
- Reactive Policies
- Regulatory vs. Advisory Governance
- Resilience Awareness
- Resilience Bonds
- Resilience Neglect Costs
- Resilience Ownership
- Resilience Unfeasibility
- Resilient Rebuilding
- Resource Prioritization
- Resource Scarcity
- Retrofitting Challenges
- Rigid Sustem Vulnerabilities
- Risk Governance
- Risk Perception Failure
- Risk-Aware Urban Planning
- Safe-to-Fail Infrastructure
- Scalability
- Scalability in Disaster Response
- Science vs. Political Narrative
- SETS (Sociological Technological Systems)
- Short Term vs. Long Term
- Social Acceptability
- Social Factors
- Social Resilience
- Societal Learning
- Societal Needs
- Socio-Economic Disruption
- Strategic Environmental Assessment (SEA)
- Sustainable Asset Management
- Systems Thinking Failure
- Systems Thinking in Resilience
- Technical Capacity
- Technocratic Balance
- Technocratic Dominance
- Technocratic Dominance vs. Local Knowledge
- Technology Transferibility
- Temporary Disaster Management
- Top-Down Governance
- Transferability Challenges
- Tropicalization of Innovation
- Types of Paradoxes
- Uncertain Conditions in Resilience
- Universality vs. Local Adaptation

- Investment Capacity
- Knowledge Fragmentation in Policy
- Knowledge Integration and Institutional Learning
- Knowledge Systems
- Unplanned Urbanization
- Urban Resilience
- Vicious Cycle
- Virtuous Cycle
- Vulnerability
- Watershed-Based Governance
- Weather Extremes

Appendix E: Axial Code-Document Table

	1:	2:	3:	4:	5:	6:	7:	8:	9:	10	11	12	13	14	15	16	17	18	19	Tot...
Community-Led vs. Technocratic Solutions	19	22	15	7	13	14	10	9	18	12	8	14	21	14	17	7	24	16	26	286
Financial and Resource Constraints	36	22	16	9	19	13	6	18	16	20	7	12	10	6	14	14	16	13	18	285
Governance Fragmentation and Integration	109	59	59	42	68	41	22	46	66	44	47	53	45	31	46	53	47	32	35	945
Knowledge Integration and Institutional Learning	35	14	27	12	31	25	4	24	34	7	16	30	14	8	21	23	24	12	15	376
Paradoxes in Frugal Innovation	100	61	43	34	49	31	11	33	56	34	26	40	45	18	41	31	31	31	25	740
Political and Policy Dynamics	56	42	18	15	47	26	10	33	28	25	27	20	13	13	23	35	10	18	16	475
Totals	355	220	178	119	227	150	63	163	218	142	131	169	148	90	162	163	152	122	135	3107

From Author (2024)

Appendix F : HREC Letter of Approval

Date 15-Apr-2025
Correspondence hrec@tudelft.nl

Human Research Ethics Committee TU Delft
(http://hrec.tudelft.nl)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Navigating Paradoxes for Flood Resilience with Frugal Innovation in the Global South
Applicant: Franco Bulhões Mendes, Francisco

Dear Francisco Franco Bulhões Mendes,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your submission to the HREC which has been approved.

In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:
• In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.
• Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor, and that ongoing covid risks and precautions are flagged in the informed consent - with particular attention to this where there are physically vulnerable (eg: elderly or with underlying conditions) participants involved.
• Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.
• Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent.

Good luck with your research!

Sincerely,

Dr. C. Shelley-Egan
Chair HREC
Faculty of Technology, Policy and Management