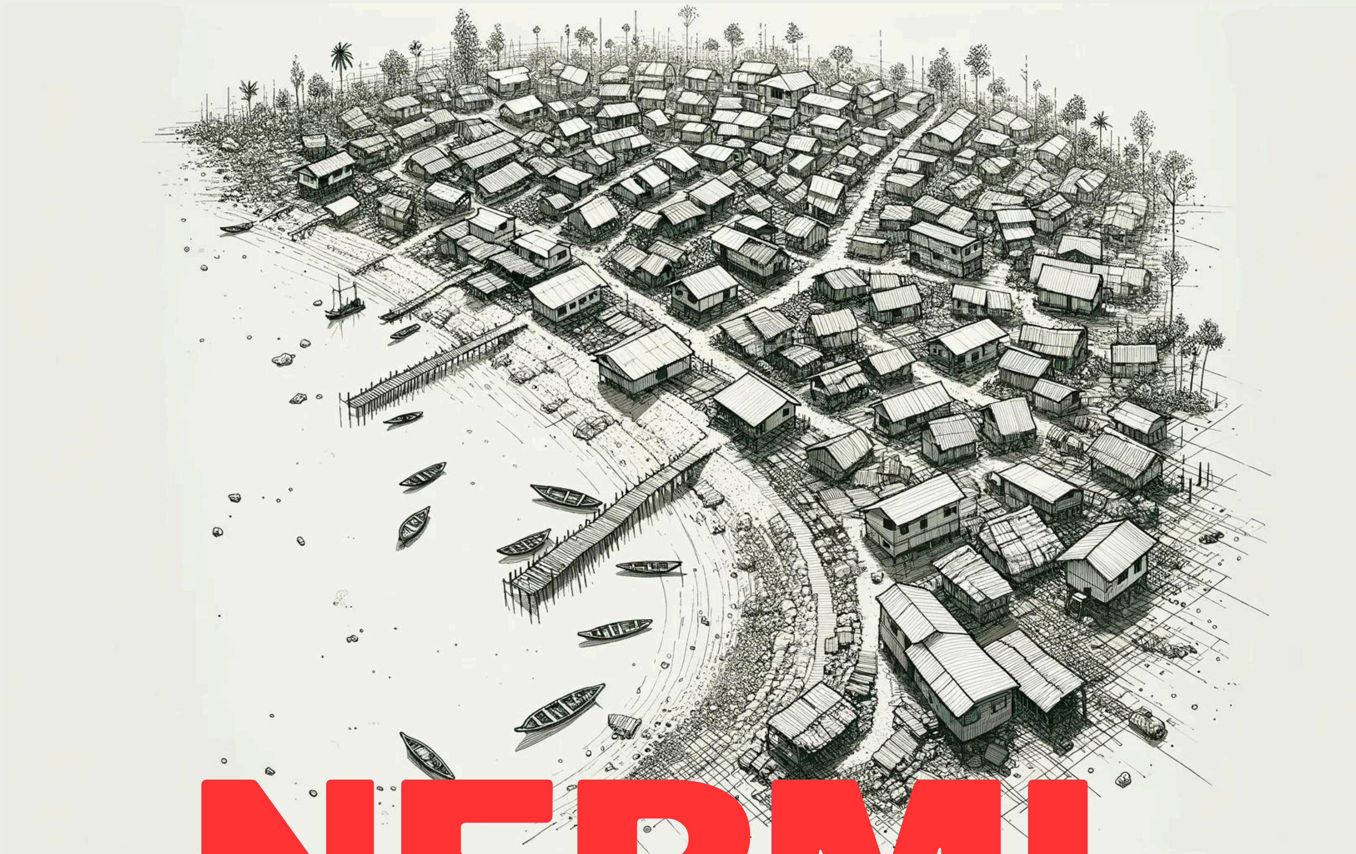
MASTER DISSERTATION



NERMI CCR

Enhancing Coastal Community Resilience Through an Indicator-Based Approach

"Context always counts, whether it's NERMI or not!"

Shayan Estifaei

TU Delft

DELFT UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL ENGINEERING AND GEOSCIENCES

CME5200 CME Master Thesis

Master Dissertation

Enhancing Coastal Community Resilience Through an Indicator-Based Approach

NERMI CCR Framework

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DELFT, SEPTEMBER 2024

Preface

In Kurdish history, there's a story of perseverance and courage passed down through generations. It's the tale of Kawa the Blacksmith, a legendary figure who represents the triumph of determination and bravery over tyranny. This story emphasizes the importance of strength, unity, and adaptation in challenging times. Kawa, a humble blacksmith, inspired his community to resist the oppression of the cruel tyrant Dehak. His courage led to the overthrow of the tyrant and the start of a new era of freedom and prosperity.

Coastal communities today face their own challenges, including environmental issues, economic pressures, and the looming threat of climate change. This thesis, inspired by Kawa's resilience, aims to create a framework to enhance the resilience of coastal communities.

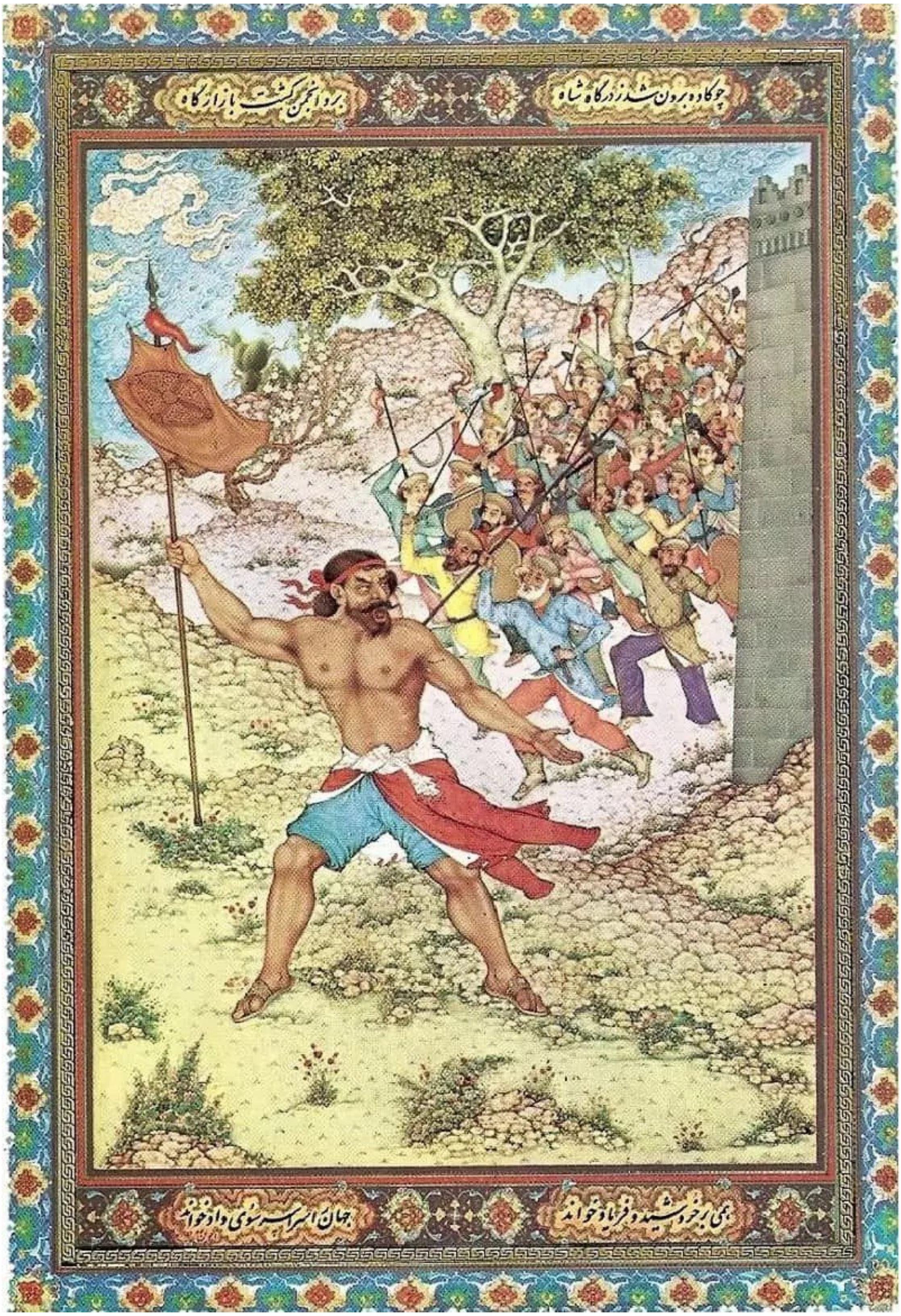
I want to express my deepest thanks to my committee members. Your guidance and support have been crucial in shaping this work. Your insights and encouragement have been very valuable to me, and I am truly grateful for your belief in this project.

I want to express my gratitude to Prof. Tina Comes, who has supported and guided me throughout this journey as my Chair. I also want to thank Dr. Omar Kammouh, my first supervisor, and Dr. Abdi Mehvar, my second supervisor, for their valuable input and encouragement. Additionally, I am thankful to Dr. Alexander Bakker, my company supervisor, for his insightful feedback and support.

Additionally, I want to express my sincere thanks to Menno Nagelhout from Rijkswaterstaat for his significant help, which greatly contributed to the success of this work. I am also grateful to Dr. Erik Jan Houwing for his support and mentorship. A special thanks to Hans (JPG) Ramler, Prof.dr.ir. S.N. Jonkman, Marcel Matthijsse, and Prof. Ayyoob Sharifi for their guidance and generosity in sharing their experiences with me. Lastly, I want to thank Dr. Zanyar Mirzaei for always being an inspiration to me and for encouraging me to reach this point in my academic journey. Most importantly, I dedicate this thesis to my father, my idol. His wisdom, strength, and unwavering support have been my guiding light, teaching me the importance of perseverance and courage. I also dedicate this work to my mother, who has shared with me the power of love. Her warmth, kindness, and constant care have been my source of comfort and strength. To my beloved family and dear friends, your love and support have carried me through this journey. Thank you for being my pillars of strength.

Thank you all for being part of this journey. May this work contribute to the resilience and climate adaptation of coastal communities, and may it remind us of the importance of peace. Let's strive for understanding, compassion, and unity and work towards a more peaceful and resilient world for all. Peace is not just the absence of war but the presence of justice, harmony, and mutual respect to our differences.

Shayan Estifaei
Summer 2024,
The Hague



Kawa The Blacksmith Source: Unknown

Abstract

The world is becoming more uncertain, with disasters happening more often due to climate change. This uncertainty puts many communities in danger. However, coastal communities are at greater risk from climate-related hazards such as floods, rising sea levels, and storms. Coastal communities face not only physical threats but also disruptions to their social, economic, organizational, environmental, and infrastructural systems. Any disruption to one of these dimensions can have cascading effects on the others.

This is where the concept of community resilience becomes critical. Community resilience is defined as a community's ability to withstand, adapt, and recover from disruptive events across all dimensions. To become more resilient, a community first needs to understand its current level of resilience. This can be achieved through various methods, including bottom-up approaches, where community members themselves identify their resilience, or top-down approaches that use a multidimensional assessment framework to provide a broader picture of resilience across various dimensions.

Despite the importance of assessment approaches, As identified in the literature, most resilience frameworks lack cross-sectoral integration, fail to address the interconnectedness of infrastructure systems, and do not effectively incorporate climate risks. Additionally, they often lack adaptability to specific cultural, social, and environmental contexts and fail to engage diverse perspectives during development. Therefore, this research addresses these gaps by developing an indicator-based framework designed to assess the resilience of coastal communities to climate-related hazards.

In this research, a combination of quantitative and qualitative methods is used to develop the NERMI CCR Coastal Community Resilience Framework. Quantitative methods, such as Principal Component Analysis (PCA) and expert consultations, provided qualitative insights. The framework, though not applied to a specific case study, has undergone two rounds of calibration to refine 134 key indicators across five dimensions: Social, Infrastructure, Environmental, Organizational, and Economic. The main research question of this study is:

> *"How can a new framework for coastal community resilience assessments be designed to effectively integrate the needs and expectations of decision-makers, include essential indicators and dimensions, be flexible to context, and shift the focus from isolated system evaluation to overall community resilience in its architecture?"*

The findings introduce the NERMI CCR framework, which integrates decision-makers' needs through a practical and adaptable tool. It includes 110 fixed indicators across Social, Economic, Organizational, Infrastructure, and Environmental dimensions. Furthermore, it includes 24 context-specific indicators with flexibility for different settings. It shifts from isolated system evaluations to a system-of-systems approach. This enables decision-makers to address interdependencies and enhance community resilience.

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CHAPTER

1

Introduction

The Great Wave off Kanagawa By Katsushika Hokusai

Source: arthive.com

1 Introduction

This chapter begins by explaining the relevant background information on the topic, followed by an illustration of the problem statement and then the research gap. The research gap leads to the research objective and questions. Finally, the theoretical and practical relevance will be demonstrated.

1.1 Background

Disaster is an abrupt, catastrophic occurrence that seriously challenges the ability of a community or civilization to operate and results in extensive losses of people, property, money, and/or the environment that exceed the capacity of the impacted community or society to recover using its level of resources (Khorram-Manesh, 2017). Among different types of disasters, Natural disasters can have a devastating impact on people's lives and communities. These events, such as floods or hurricanes, can result in widespread damage, loss of life, and disruption to infrastructure and the community that is relying on them. One of the main characteristics of natural disasters is their unpredictability. These life-threatening events cannot be prevented. However, by understanding the risks and taking appropriate measures, individuals, communities, and governments can reduce the impacts of natural disasters (Hallegatte & Dumas, 2009; Khorram-Manesh, 2017; Tselios & Tompkins, 2020).

Flooding is consistently identified as the most frequent natural disaster globally, causing significant human and economic impacts (Few et al., 2013; Guha-Sapir et al., 2013; Jonkman et al., 2024; Kunreuther et al., 2019). Between 1950 and 2008, floods and storms accounted for 70% of natural disasters (Guha-Sapir et al., 2013). From 1993 to 2002, floods affected an average of 140 million people annually, surpassing all other natural or technological disasters combined (Few et al., 2013). Flood disasters come in various forms, each characterized by specific causes and impacts. Major types include regional, flash, ice-jam, storm-surge, dam/levee-failure, and debris/landslide/mudflow floods (Perry, 2000). The further classification provided by FEMA (2020) suggests four broad categories: flash flooding, coastal flooding, river and stream flooding, and closed-basin flooding. These classifications highlight the diversity of flood hazards and their potential consequences in different geographic and environmental contexts.

Climate change is a significant driver of coastal flood disasters, with sea-level rise projected to become the primary factor in population exposure growth by 2100 (Lincke et al., 2022). However, socio-economic development has been the main cause of increased flood exposure historically and remains crucial for asset exposure (Lincke et al., 2022). Coastal flooding is influenced by complex interactions between multiple drivers, including sea-level rise, river discharge, and extreme water levels (Bermúdez et al., 2021). According to Kirezci et al. (2020), at the end of the century, 68% of the global coastal area flooded will be caused by tide and storm events, with 32% due to projected regional sea level rise. The impacts of coastal flooding on society, economy, and the environment are substantial, necessitating further research on climate change adaptation, multi-hazard risk assessment, and resilience-building in coastal areas (Fang & Shi, 2021).

The Netherlands has a long history of battling coastal flooding. Throughout history, floods in the southwestern Netherlands and coastal Belgium have been caused by both natural mechanisms, such as storm surges, and human activities, including warfare (De Kraker, 2006). The North Sea flood of 1953 was a crucial event that caused widespread damage and over 2,400 fatalities (Woods, 2013). This catastrophe led to significant improvements in coastal defenses, warning systems, and flood management policies in both the Netherlands and the UK (Woods, 2013). The Dutch response included the development of the Delta Works, a series of dams, locks, and barriers to protect against future flooding (Meijerink, 2005).

According to Haasnoot et al. (2020), the Netherlands remains vulnerable to flooding, similar to the situation in 1953. Situated in the low-lying Rhine-Meuse delta, with 26% of its land below sea level, nearly two-thirds of the country is at risk of flooding from rivers and the sea (See Figure 1.2). This puts its population of 17 million and its €800 billion GDP in a critical and risk-exposed position. According to UNDP (2024), the Netherlands' population flood exposure, which refers to the number of people or communities at risk of experiencing floods due to their proximity to flood-prone areas, was 0% from 1995 to 2014 but is projected to increase to 0.4% by 2039, double the global average, and reach 1.4% by the century's end (See Figure 1.1). Despite reduced flood probabilities, Agency (2024) note that the Netherlands' densely populated delta faces a larger scale of exposure than 60 years ago, increasing the risk of casualties and widespread impacts.

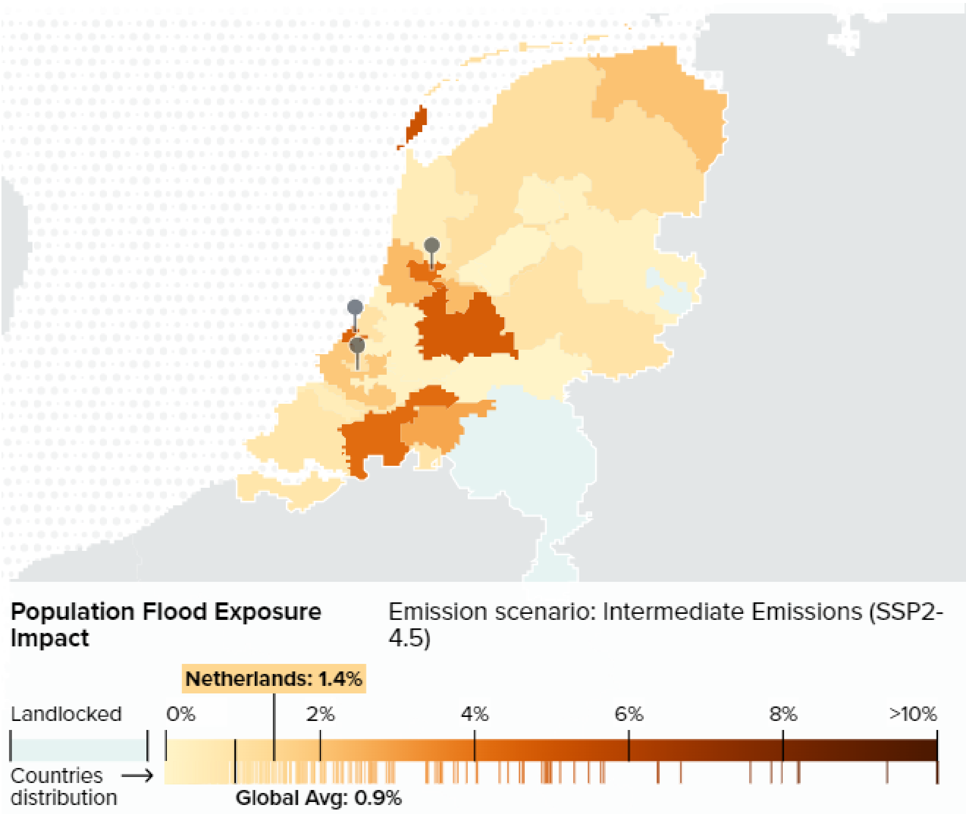


Figure 1.1: Flood Exposure Impact Prediction for the Netherlands (UNDP, 2024)

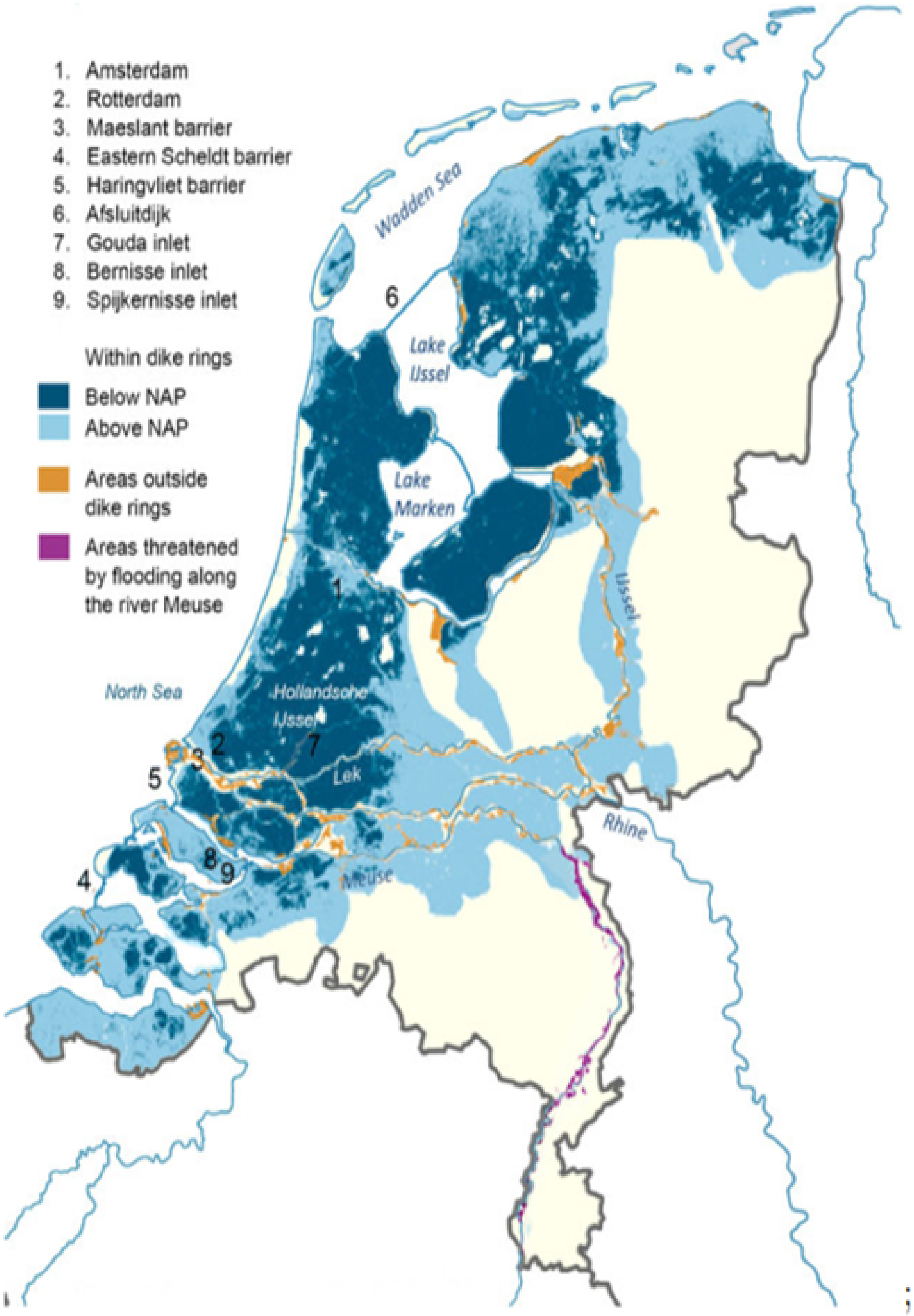


Figure 1.2: Flood Prone Zones in the Netherlands (Haasnoot et al., 2020)

As previously mentioned, in the aftermath of 1953 flood, the Dutch government implemented the Delta Works, a comprehensive flood protection program including dams, sluices, and storm surge barriers (Gerritsen, 2005; Woods, 2013). Despite high levels of flood protection, absolute safety is not guaranteed (Terpstra, 2011; Wesselink et al., 2007). Potential coastal flooding might pose a significant threat to Dutch communities as the impact of flooding on Dutch coastal areas can be socio-economic. Jonkman et al. (2008), indicates that a flood event in South Holland could potentially expose large, densely populated areas and result in hundreds to thousands of fatalities. Despite these risks, Dutch residents generally perceive low or no flood risk, leading to increased high-value development in vulnerable coastal zones (Filatova et al., 2011). This skewed risk perception may create economically significant risks under current flood protection policies.

While the threat of natural disasters such as flooding continues to challenge communities worldwide, the capacity of these communities to recover and adapt has become increasingly critical. Community resilience—the ability to anticipate, withstand, and recover from disasters—is now recognized as an essential component of disaster risk management. As seen in the case of the Netherlands, the implementation of robust flood defenses like the Delta Works highlights how proactive measures can enhance resilience. However, resilience goes beyond infrastructure; it includes social, economic, and environmental systems that enable communities to bounce back and even thrive after disasters. Understanding community resilience is, therefore, crucial for mitigating the long-term impacts of natural disasters and ensuring sustainable recovery.

1.2 Community Resilience

According to the Cambridge Dictionary, ”community” refers to a group of people living in a specific area or who share common interests, social groups, or nationalities. If a community is viewed as a system—meaning a set of connected parts working together for a common purpose—it can be seen as more than just a group of people. It includes all the social elements of society. With the rise in natural disasters, it is crucial that these communities are protected and made resilient against potential dangers. On the other hand, According to United Nations Office for Disaster Risk Reduction (2024), Resilience is The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Different scholars have proposed various methods for using the definitions of community and resilience to introduce the new concept of community resilience. B. Pfefferbaum et al. (2014) emphasizes the importance of collective action by all subsystems within a community to function as a whole, highlighting learning as a crucial phase in the resilience process. Cutter et al. (2014) focus on the time factor, stressing the importance of restoration measures to recover the functionality of basic structures during and after a disruption. Similarly, Kammouh et al. (2019) consider the time factor, defining resilience as the ability to quickly recover from the impacts of a disaster, with expertise in managing the situation being just as important as the recovery itself. ARUP International Development (2011) offers a systematic definition of community resilience, identifying several key characteristics that a resilient community system must have to effectively respond to disasters, also incorporating the learning stage within their definition.

While the concept of community resilience provides a comprehensive framework for understanding how communities can prepare for, withstand, and recover from disasters, putting these ideas into practice often uncovers critical challenges and problems.

1.3 Problem Definition and Research Gap

Identifying the problem in resilience is crucial for developing effective solutions. While challenges often carry a negative connotation, they can also present opportunities. Resilience issues may exist in both the problem and opportunity spaces, offering not only obstacles but also potential for growth and improvement.

Infrastructure systems have been viewed and managed in isolation (Alizadeh & Sharifi, 2020; Index, 2014; Osman, 2021; Perera et al., 2024; Terblanche et al., 2022; Zhou et al., 2010), with each sector optimized independently (French, 2014; Hall et al., 2016). However, this approach is becoming inadequate in areas where infrastructure systems become increasingly interconnected (French, 2014). Furthermore, this approach fails to account for the interconnected nature of our world, where systems and communities are interdependent. According to Shah and Babiceanu (2015), Interdependent infrastructures are susceptible to cascading failures, where disruptions in one system can propagate to others. A "system-of-systems" perspective is crucial for understanding the implications of these interdependencies and developing more resilient and adaptable infrastructure (Fu et al., 2013).

Several scholars have addressed the issue of infrastructure systems being viewed in isolation. French (2014) argues that understanding interactions among urban infrastructure systems is key to creating more sustainable cities. Markolf et al. (2018) introduce the concept of infrastructure as linked social, ecological, and technological systems (SETSs), suggesting that this framework can help identify and prevent maladaptive issues like lock-in. Anderies et al. (2016) emphasize the importance of institutions in shaping infrastructure systems, proposing a research trajectory that views institutions as one class of infrastructure among many that interact dynamically. These perspectives collectively advocate for a more holistic, interdisciplinary approach to infrastructure planning and management.

Despite these contributions, **there is a lack of a cross-sectoral, system-based approach that recognizes the interconnected nature of infrastructure systems** (Ahern, 2011). This is also in line with the fact that achieving true community resilience requires integrating multiple actions across social, economic, and environmental realms and disciplines and systems (Colker, 2020).

In addition, Community resilience framework development has recently received a lot of attention (Cimellaro et al., 2016; Courtney et al., 2008; Cutter et al., 2014; Dasgupta & Shaw, 2015; Peacock et al., 2010), mostly focused on enhancing the ability of systems to adapt, recover, and remain functional during disruptions. Researchers have identified multiple domains for assessing community resilience, including social, economic, institutional, physical, and natural aspects (Ostadtaghizadeh et al., 2015). Some frameworks emphasize the importance of a ”Whole Community” approach, considering factors such as economic diversity, critical infrastructure, and emergency services capabilities (Collins et al., 2011; Plodinec, 2020). Despite the growing interest in community resilience, **there is a lack of consensus on how to operationalize and measure the concept of community resilience effectively** (Ostadtaghizadeh et al., 2015).

To address this gap, Various scholars have attempted to create assessment tools, some referred to as benchmarks, frameworks, indexes, etc. However, Resilience frameworks often lack operational effectiveness due to several challenges. These include the complexity and interdependencies of critical infrastructure systems, which create uncertainties in risk assessment and decision-making (Lichte et al., 2022). The proliferation of resilience definitions and conceptual frameworks, along with data availability, variability, and compatibility issues, further complicate the development of operational measurement frameworks (Oladokun & Montz, 2019).

Additionally, The importance of context in resilience science cannot be underestimated. Resilience frameworks that work well in one setting may not be as effective in another due to differences in social structures, economic conditions, and environmental challenges. For instance, a framework designed for developed countries might emphasize technological solutions and infrastructure robustness, while a framework for rural areas in developing countries might prioritize community engagement and local knowledge (Adger, 2000). Therefore, globalized frameworks must include context-specific indicators to allow communities to tailor their strategies to their unique circumstances (Cutter et al., 2014). However, **there is a lack of community resilience frameworks that could adapt to specific cultural, societal, or economic contexts** (Ran et al., 2020). Furthermore, although localized frameworks provide valuable insights (Almutairi et al., 2020; Meerow et al., 2016; Walpole et al., 2021; Xue et al., 2017), their effectiveness in larger, more complex systems is less understood as they see the localization of the framework as a matter of limited scale. This highlights the need for research that examines how resilience principles can be scaled and adapted for broader applications while maintaining relevance across different contexts. Developing a global framework with context-specific indicators is crucial to ensure that resilience strategies are adaptable and effective in various environments (Adger, 2000; Cutter et al., 2014).

With regards to coastal communities, While several coastal community resilience frameworks have been developed, there are significant gaps in addressing future risks, and climate change impacts (Almutairi et al., 2020). **Many frameworks focus on governance, infrastructure, and socioeconomic factors but often neglect environmental impacts and climate change risks and are not addressing resilience in a multi-dimensional manner** (Almutairi et al., 2020; Hoque et al., 2019). Additionally, **most frameworks fail to consult during development with a diverse range of individuals to obtain different perspectives. This potentially compromises their applicability and effectiveness** (Almutairi et al., 2020).

From a methodological perspective, two prominent approaches to assessing the resilience of infrastructure systems have been identified: simulation-based and indicator-based methods. Simulation-based approaches (Arrighi et al., 2021; Ebrahimi et al., 2022; Kammouh et al., 2020; Mustafa et al., 2023; Sen et al., 2021; Zhang et al., 2023) are popular among researchers for modeling the behavior of infrastructure systems (Mottahedi et al., 2021). However, these methods are resource-intensive, require extensive data, and often rely on assumptions that may not accurately reflect real-world scenarios (Kammouh & Chahrour, 2023; Leal et al., 2023). Moreover, simulation approaches are complex, costly, and time-consuming, making them inaccessible to many organizations (Mottahedi et al., 2021).

In contrast, indicator-based frameworks offer a practical alternative. By using a set of adaptable indicators, decision-makers can avoid the complexities and limitations of simulation methods (Dasgupta & Shaw, 2015). An indicator-based approach allows communities to use a global framework as a blueprint, focusing on context-specific indicators without wasting time and resources (Birkmann et al., 2013; Keating et al., 2017).

Various studies utilized indicator-based approach. Jovanović et al. (2018) examined smart infrastructure through multiple dimensions, including system/physical, information/data, organizational/business, societal/political, and cognitive/decision-making, using indicator-based methods such as ANL, REWI, and scenario planning. Valizadeh et al. (2023) concentrated on the acyclic stormwater network structure, specifically in the Auckland Region, New Zealand, analyzing its physical dimensions and employing node analysis as their method. Ranjbar and Naderpour (2020) investigated building resilience against earthquakes, particularly at the Olive View Hospital in the USA, utilizing case studies and fragility curves. Barreiro et al. (2021) addressed urban flooding in Lisbon, Portugal, focusing on the physical dimension of multiple infrastructures and incorporating stakeholder involvement in their case study approach.

However, It is important to recognize that when discussing resilience, the focus is on the community, system, or individual that is at risk from an unforeseen high-impact event. Therefore, it is essential to focus not only on measurement tools. **While these tools cannot, on their own, create a resilient community, they can offer guidance to other communities looking to become safer, stronger, and more vibrant in the face of unexpected events** (Cutter, 2015).

1.4 Research Objectives and Question

Given these gaps, there is a need for a more practical and adaptable framework that integrates multiple dimensions of resilience—social, economic, infrastructure, organizational, and environmental—while also considering the community as a whole rather than focusing on isolated systems. This research aims to create a framework for enhancing the resilience of coastal communities against coastal hazards.

1.4.1 Main Research Question

"How can a new framework for coastal community resilience assessments be designed to effectively integrate the needs and expectations of decision-makers, include essential indicators and dimensions, be flexible to context, and shift the focus from isolated system evaluation to overall community resilience in its architecture?"

1.4.1.1 Sub-Questions

- **RQ1:** What are the specific needs and expectations of decision-makers regarding coastal community resilience assessments that can be effectively integrated into the design of the new framework?
- **RQ2:** What essential dimensions and indicators contribute to coastal community resilience against coastal hazards?
- **RQ3:** What essential indicators ensure a multi-dimensional approach to assessing coastal community resilience to hazards, with universal applicability or flexibility for specific contexts?
- **RQ4:** How can the collected indicators be operationalized to ensure practicality and effectiveness in decision-making processes?

1.5 Research Relevance

In the scientific field, this research is a step forward to fulfilling the previously identified gaps both in the literature and decision-making space.

1.5.1 Theoretical Relevance

1. This research tackles the gaps identified in literature with an indicator-based approach. We aim to prevent the drawbacks of the other approaches. We aim to prevent the drawbacks of the simulation-based approaches due to their resource-intensive nature and limitations in accurately representing real-world scenarios.
2. While most recent research focuses on developing a resilience framework, this research also investigates the potential context-specificity of indicators that can contribute to the framework's operationality, practicality, and adaptability.
3. This research can make a valuable contribution to the existing knowledge about the resilience of coastal communities. It is particularly unique in its combination of system theory and resilience.

Currently, most resilience approaches focus on analyzing infrastructure systems in isolation. This research, however, aims to assess the resilience of the communities that these systems protect.

1.5.2 Practical Relevance

1. This research holds great practical significance as there is a major issue in the operationalization factor of the existing frameworks. By involving experts from the very beginning of the framework development, this research can ensure that the indicator collection is validated in a feedback loop.
2. Moreover, the findings of this research can be adapted to various situations by making necessary adjustments to the measures. Users can customize the measures according to their specific requirements and utilize this framework efficiently. This can aid decision-makers in making more effective and efficient decisions.

1.6 Transition to research design

With a clear understanding of the gaps in current coastal community resilience assessments and the need for a more adaptable, indicator-based framework, the next step is to systematically develop this framework. To achieve this, a structured research design is essential. Chapter 2 will outline the research design used in this study, including the methodologies for indicator mining, expert consultation, and calibration.

CHAPTER

2

Research Design

Methodological Framework

The Ninth Wave By Ivan Aivazovsky

Source: arthive.com

2 Research Design

In Chapter 2, the research design for this study will be presented. The chapter is organized to enable us to address the research questions. It will begin with an explanation of the research scope, followed by a description of the research methodology, and conclude with an outline of the research.

2.1 Research Scope

The scope of this study is inspired by the mangrove ecosystem, where various elements work together to ensure its sustainability (See Figure 2.1). Similarly, The study primarily targets coastal communities as the population of interest. The study views community resilience as essential to the overall resilience of coastal areas. It considers the community as a system made up of several interconnected parts—infrastructure, social, economic, organizational, and environmental—that must work together for the community to be resilient. Taking a top-down approach, this research looks at the community as a whole, recognizing its interdependence with broader systems.

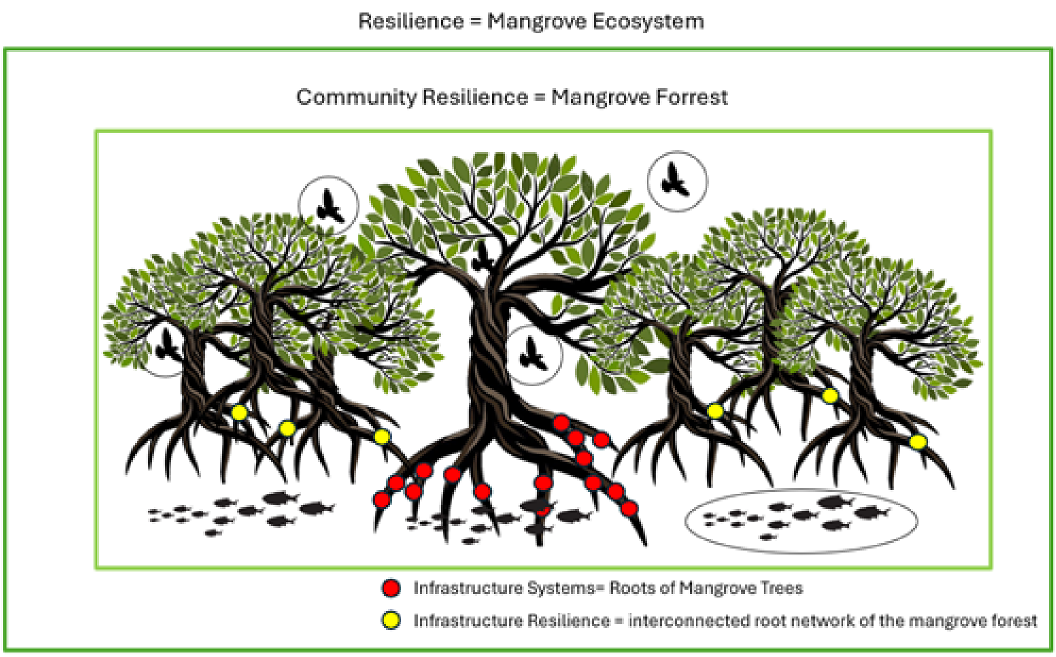


Figure 2.1: Research Scope

Furthermore, By focusing on a multi-dimensional approach, the study integrates social, economic, infrastructure, environmental, and organizational dimensions of resilience. Also, The study follows a systematic methodology, including both quantitative and qualitative approaches. The following section will provide a detailed elaboration of the research methodology.

2.2 Research Methodology

The research methodology has four stages (See Figure 2.2): Indicator Mining, Expert Consultation, Calibration (Part A), and Calibration (Part B). **Indicator Mining** identifies relevant indicators for community resilience through a systematic literature review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. **Expert Consultation** evaluates the importance of these indicators through a 5-point Likert scale survey and interviews, further gathering insights on operationalization and decision-maker needs and expectations. **Calibration (Part A)** stage utilizes insights from the Indicator Mining and Expert Consultation, along with PCA (Principal Component Analysis), to further refine the identified and consulted indicators from the literature and experts. Finally, **Calibration (Part B)** further refines the developed framework to a specific context related to the Province of Zeeland.

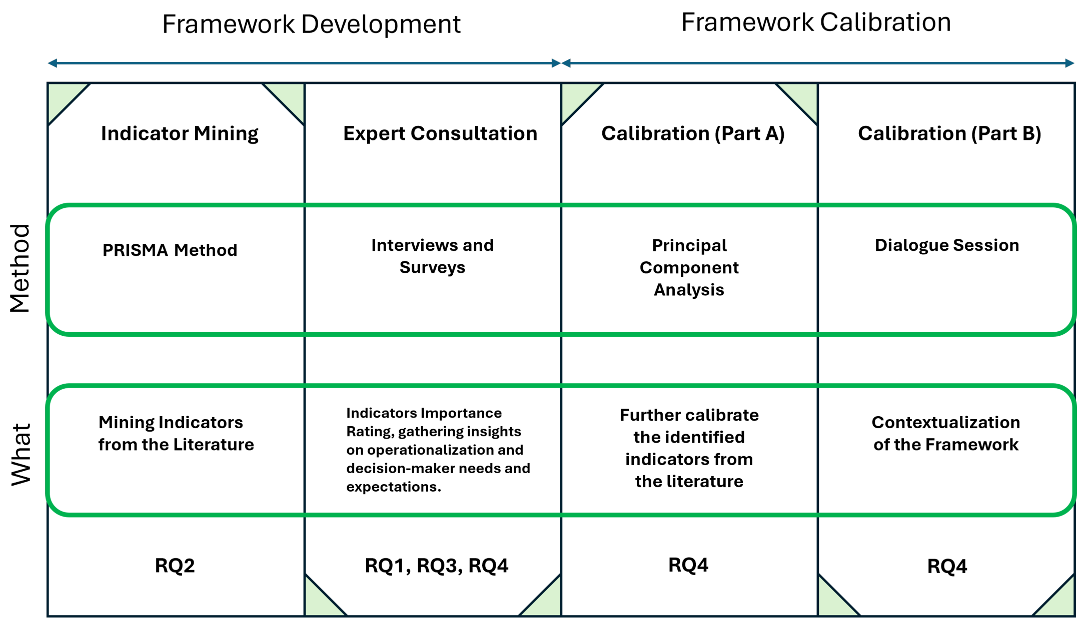


Figure 2.2: Research Methodology

2.3 Framework Development

2.3.1 Indicator Mining

The purpose of conducting indicator mining is to extract relevant community resilience indicators from the literature through a systematic collection and analysis of various resilience frameworks and indicators, creating a database for further research. To achieve this, the PRISMA method was utilized, a standardized approach initially developed for medical studies but applicable to a wide range of research fields (Copeland et al., 2023; Estevão & Costa, 2020; Sharma & Laishram, 2024; Wiguna et al., 2024).

This systematic approach ensured the inclusion of relevant studies by applying specific inclusion and exclusion criteria. Multiple databases, including Google Scholar, TU Delft Repository, and Science Direct, were accessed, and automation tools like Zotero and ATLAS.ti were employed for efficient document management and data extraction. The review identified essential indicators and dimensions for contributing to coastal community resilience, aligning with the research question (RQ2).

2.3.2 Expert Consultation

The expert consultation had two main objectives: first, to evaluate the importance of the indicators identified from the literature, and second, to understand the factors related to the operationalization of these indicators and the specific needs and expectations of decision-makers. This dual focus aimed to ensure that the developed framework for assessing community resilience is both theoretically sound and practically applicable. By engaging experts from various fields and regions, the study included diverse perspectives and experiences to enhance the relevance of the developed resilience framework. To achieve these objectives, a Likert scale questionnaire was developed, and extensive interviews were conducted.

1. Survey: A questionnaire was developed based on the indicators collected from the literature (See Appendix C). Experts were asked to rate the importance of these indicators using a 5-point Likert scale. The main questionnaire was divided into four sub-questionnaires, each covering five dimensions: social, economic, infrastructure, environmental, and organizational, and was given to the experts. The output of the survey served as an input for the next stage in which principal component analysis was conducted.

2. Interviews: In-depth interviews were conducted with the experts to discuss the operationalization of the collected indicators and the specific needs and expectations of decision-makers. The interviews were scheduled in two sessions per expert, conducted via Microsoft Teams. The first session introduced the topic and research project, while the main session focused on exploring the research questions in detail. The interview protocol included questions on operationalization and decision-maker needs, alongside profile-related questions (See Appendix A) to shape the discussions effectively. The output of interviews were stored in a manual transcript and content analysis using Atlas.ti was conducted on it.

2.4 Framework Calibration

2.4.1 Calibration (Part A)

For the Calibration (Part A), the goal was to refine the indicators and reduce the amount of the data gathered from the expert consultation phase while ensuring the essential data loss is kept to a minimum. Principal Component Analysis was used to achieve this. Principal Component Analysis (PCA) is a statistical technique widely used for dimensionality reduction in data analysis. It transforms a large set of variables into a smaller one that still contains most information in the large set (Beccari, 2016; Casali et al., 2021; Jolliffe & Cadima, 2016; Kherif & Latypova, 2020; Shirali et al., 2016; Valinejad et al., 2022). For further details regarding the mathematical foundation of this approach, readers may refer to Jolliffe and Cadima (2016).

2.4.2 Calibration (Part B)

For Calibration (Part B), An exploratory scan was conducted. Experts from two key organizations, Rijkswaterstaat and the Safety District of Zeeland, were chosen to be involved due to their critical roles in regional disaster response and their deep understanding of the Zeeland Province and its flood protection system. The exploratory scan is guided by the following:

How can the previously identified context-specific potential indicators be refined to address the context of Zeeland?

Furthermore, a dialogue session had to be organized in which participants could rate context-specific potential indicators on a Likert scale ranging from 1 to 5, with one denoting least applicable and five most applicable. During this step, participants were put in different virtual rooms to analyze the indicators separately and prepare notes for open discussion.

2.5 Research Outline

The outline of the report is represented in Figure 2.3. Chapters 1 and 2 provide the background and necessary information about the research design. Chapter 3 covers Indicator Mining, including the collection of frameworks and indicators. Furthermore, Chapter 4 elaborates on the expert consultation stage of the research. Chapter 5 focuses on the first part of Framework Calibration with the application of PCA. Chapter 6 presents the second part of Framework Calibration through the exploratory scan. Chapter 7 presents the developed framework. Limitations, Conclusion, and Recommendation are elaborated on in Chapter 8. The research questions are answered throughout the report, and each chapter serves as a prerequisite for the next.

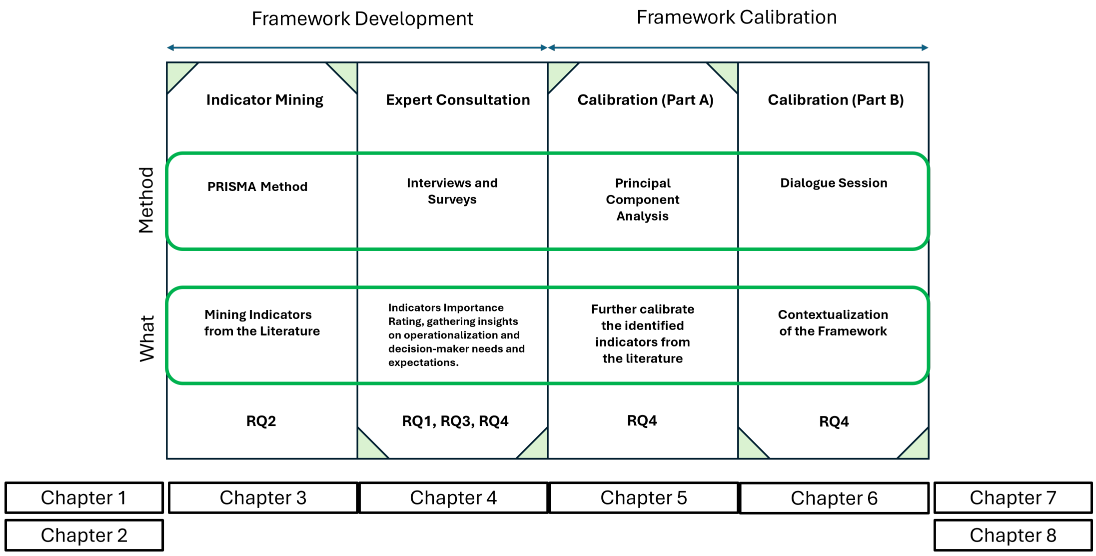


Figure 2.3: Research Outline

2.6 Transition to indicator mining

As depicted, The research design set the stage for the next critical step: identifying the essential indicators and resilience dimensions from the literature. In the following chapter, a systematic Indicator Mining process will extract key factors to build a solid foundation for the framework's development.

Chapter
3

Indicator Mining

Indicator Identification Process Through Systematic Review

After the Hurricane, Bahamas By Winslow Homer

Source: arthive.com

3 Indicator Mining

In this chapter, the indicator mining process will be presented to identify various community resilience frameworks and their associated indicators. First, the review and mining strategy will be explained. In addition, the selected frameworks and extracted indicators will be presented. In conclusion, the answer to RQ2 will be provided.

3.1 Review Strategy

The literature review utilized the PRISMA method, a reporting method for systematic reviews and meta-analyses. PRISMA is a modified version of the previous QUOROM method and consists of a 27-item checklist. Although initially developed for medical studies, this method is also applicable in other fields of research (Copeland et al., 2023; Ha-Mim et al., 2024; How et al., 2022; Moher et al., 2009; Saeedi et al., 2019).

To carry out a complete search of the literature, various keywords were employed (See Table 3.1), including ”infrastructure resilience frameworks,” ”coastal resilience frameworks,” ”coastal risk assessment,” ”community resilience frameworks,” and ”coastal community resilience frameworks.” These keywords were selected based on their relevance to the subject and their ability to uncover the most valuable information. Having said that, several databases were accessed (See Table 3.1), including Google Scholar, TU Delft Repository, and Science Direct (SCOPUS). These databases were chosen due to their extensive collections of scholarly literature, including articles, digital reports, books, master dissertations, and online publications. The gathered materials were carefully reviewed and analyzed to identify relevant information that could be used to support the research objectives. Additionally, a filter was applied to refine search results based on the publication period between 2005 and 2024, as research on community resilience has shown a significant increase since 2005 (Introduction of Hyogo Framework), with exponential growth observed from 2010 to 2019 (Hu et al., 2024).

Table 3.1: Databases and Keywords Used in Review

Database	**Keywords Used**
Google Scholar, TU Delft Repository, Science Direct (SCOPUS)	• ”coastal resilience frameworks” • ”community resilience indicators” • ”infrastructure resilience frameworks” • ”coastal risk assessment” • ”resilience frameworks” • ”coastal community resilience”
Search Period	2005–2024

3.1.1 Inclusion and Exclusion Criteria

During the review, specific inclusion and exclusion criteria were applied to ensure that the studies selected for analysis were of high quality and relevant to the research question. The criteria applied are summarized in Table 3.2.

Table 3.2: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Published by reputable scientific bodies	Studies not focused on resilience indicators
Cited at least once in academic literature	Non-peer-reviewed or grey literature
Conducted by scientific professionals or verified institutions	Studies outside the scope of research
	Irrelevant resilience aspects (e.g., psychological)

3.2 PRISMA Process Applied to Indicator Mining

The selection process followed the three main stages of PRISMA: Identification, Screening, and Selection (See Figure 3.1). During the identification stage, frameworks were evaluated for compliance with inclusion criteria, such as relevance to community resilience. Duplicates were removed using automation tools like Zotero and ATLAS.ti. Following identification, 33 frameworks were moved to the screening stage, where they were further evaluated based on their approach to resilience and the types of indicators they utilized.

After identifying 33 frameworks from the literature, frameworks went through the screening process. The documents were screened during this process to identify if they aligned with this research. Based on the scope of the research, the selection was restricted to those frameworks that included the community and the infrastructure system together. Therefore, the studies with isolated approaches were excluded (e.g.,Index (2014), Osman (2021), Perera et al. (2024), and Zhou et al. (2010)). Subsequently, 29 frameworks were subjected to an eligibility assessment. For eligibility assessment, Three main criteria were used. The first criterion was scope. The aim was to find frameworks that could be applicable within the same scope as the research. Since the research follows a top-down approach, bottom-up frameworks were excluded.

The top-down approach, also known as Nomothetic, aims for comparisons across different units of analysis, utilizing state, national, or international sources of data and quantitative methods in the construction of the index (Cutter, 2015).

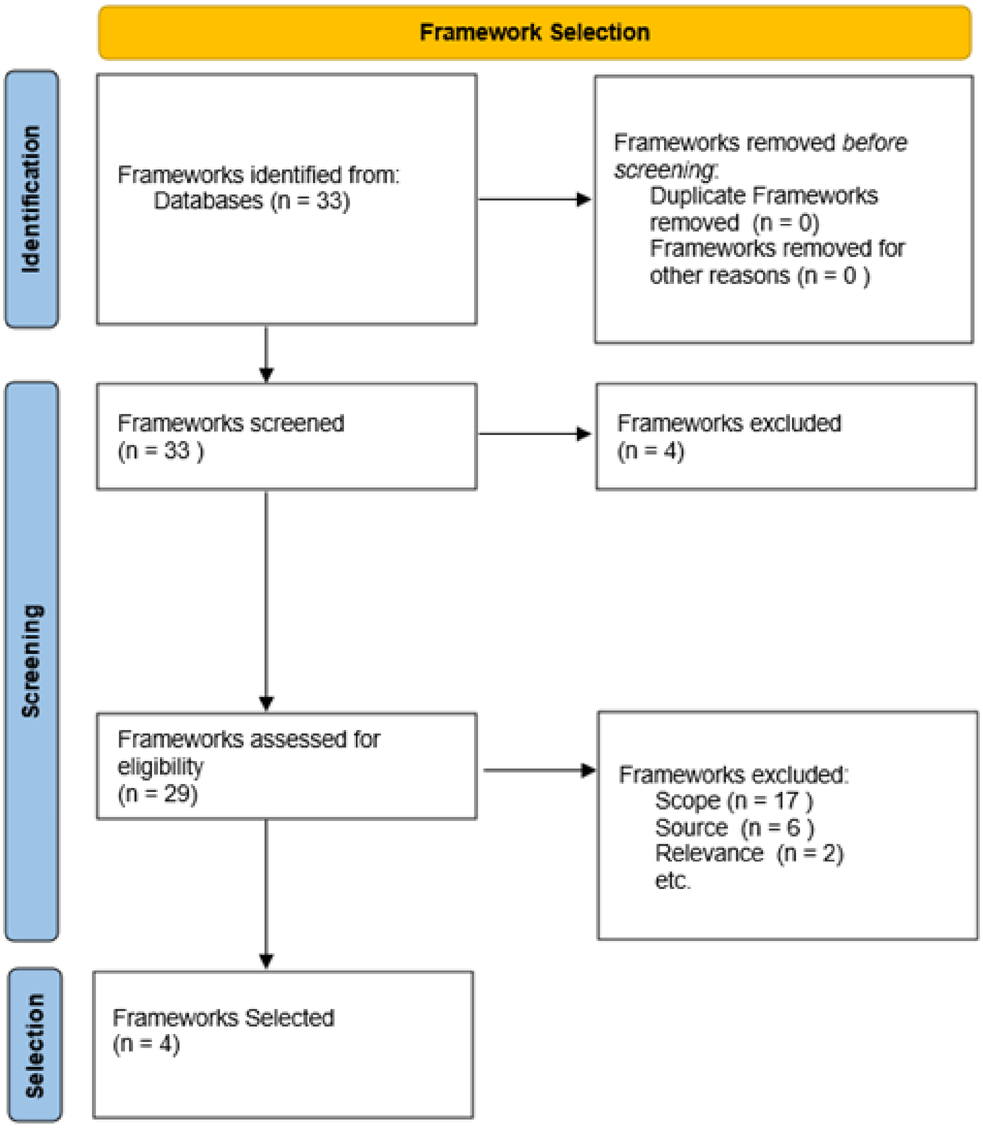


Figure 3.1: Framework Selection Flowchart

On the other hand, bottom-up or idiographic measures are locally generated and customized for a specific place (B. Pfefferbaum et al., 2015). These studies generally use a qualitative methodology and often emphasize the resilience of institutions and governance structures using inputs from the local community. Table 3.3 provides several examples of bottom-up frameworks.

Table 3.3: Examples of Community Resilience Frameworks with bottom-up approach

Framework	Type	Scale	Focus	Method	Reference
Community Advancing Resilience Toolkit (CART)	Tool	Community	All-hazards environment	Bottom-Up	(R. Pfefferbaum et al., 2013)
Community-Based Resilience Analysis (CoBRA)	Tool	Community	Crises and Disasters	Bottom-Up	(United Nations Development Programme, 2014)
Rockefeller 100 Resilient Cities (ARUP)	Tool	Community	Shocks and Stresses	Bottom-Up	(ARUP International Development, 2011)
The Resilient City: Defining What SF Needs from its Seismic Mitigation Policies (SPUR)	Score-Card	Community	Earthquake	Bottom-Up	(SPUR, 2009)
CCRAM	Tool	Community	Disasters	Bottom-Up	(Cohen et al., 2013)
CARRI	Tool	Community	Man-made and natural disasters	Bottom-Up	(White et al., 2015)

The second criterion was the source. Although some frameworks met the other criteria, their datasheet accessibility raised concerns. As a result, six frameworks (such as UNISDR, LDRI, CRS, TOSE, HFA, and CRI.) were excluded. The final criterion was relevance. Two frameworks were found to be too specific to one particular coastal hazard, such as tsunamis or oil rig leakage (Courtney et al., 2008; Finucane et al., 2020), which were not directly relevant to our research.

Ultimately, 17 frameworks were excluded due to scope, six for source-related issues and two for irrelevance, leaving four frameworks for final analysis (See Table 3.4).

Table 3.4: Final Selected Frameworks

Framework	Type	Scale	Focus	Method	Reference
Baseline Resilience Indicators for Communities (BRIC)	Index	County	Disasters	Top-Down	(Cutter et al., 2014)
Community Disaster Resilience Index (CDRI)	Index	Coastal County	Disasters	Top-Down	(Peacock et al., 2010)
PEOPLES Resilience Framework	Tool	Community	Extreme events or disasters	Top-Down	(Cimellaro et al., 2016)
An indicator-based approach to assess coastal communities' resilience against climate-related disasters in Indian Sundarbans	Index	Coastal rural communities	Climate-related disasters	Top-Down	(Dasgupta & Shaw, 2015)

3.3 Mining Strategy for Extracting Indicators

Once the relevant frameworks were selected, the process of indicator extraction began. initialy 363 indicators were extracted. The extraction process followed a structured, manual review of each framework's key components, focusing specifically on the frameworks proposed for community resilience. The following approach was taken:

Each framework was thoroughly reviewed to identify the broad dimensions of resilience indicators—such as social, economic, organizational, environmental, and infrastructural. After this, the specific indicators within each framework were manually categorized into their respective dimensions. Indicators were grouped into relevant categories, including Infrastructure Establishments, Community Services and Facilities, Transportation and Communication, Utilities and Energy Infrastructure, and Housing, among others.

Once categorized, indicators from different frameworks were systematically compared (Using PowerQuery) to identify both overlapping indicators (similar in meaning but expressed differently) and duplicates (identical indicators). As a result, 140 indicators were removed due to these overlaps and duplications. For instance, indicators such as Transportation (Cimellaro et al., 2016; Cutter et al., 2014), Physician access (Cimellaro et al., 2016; Cutter et al., 2014), Local food suppliers (Cimellaro et al., 2016; Cutter et al., 2014), English language competency (Cimellaro et al., 2016; Cutter et al., 2014), Population Density (Cutter et al., 2014; Dasgupta & Shaw, 2015), Percent of population having ownership of their house, and Homeownership (Cutter et al., 2014; Dasgupta & Shaw, 2015), Percent of population below the poverty line (Dasgupta & Shaw, 2015), Income equality (Cimellaro et al., 2016), School dropout rate (Dasgupta & Shaw, 2015), and Per capita income (Kusumastuti et al., 2014; Peacock et al., 2010), Implementation of Disaster Insurance and Hazard Insurance Coverage (Cimellaro et al., 2016; Dasgupta & Shaw, 2015) and others were found to be either identical or highly similar, leading to their removal.

After this refinement process, a final set of 223 indicators was selected. Additionally, some economic indicators, not initially part of the reviewed frameworks, were included from standalone studies due to their relevance to the analysis, such as Gross Regional Domestic Product (GRDP) per capita, Income per capita, and Trade Openness (Kusumastuti et al., 2014; Noy & Yonson, 2018), further enhancing the framework's comprehensiveness and cover the limited number of generic economic indicators.

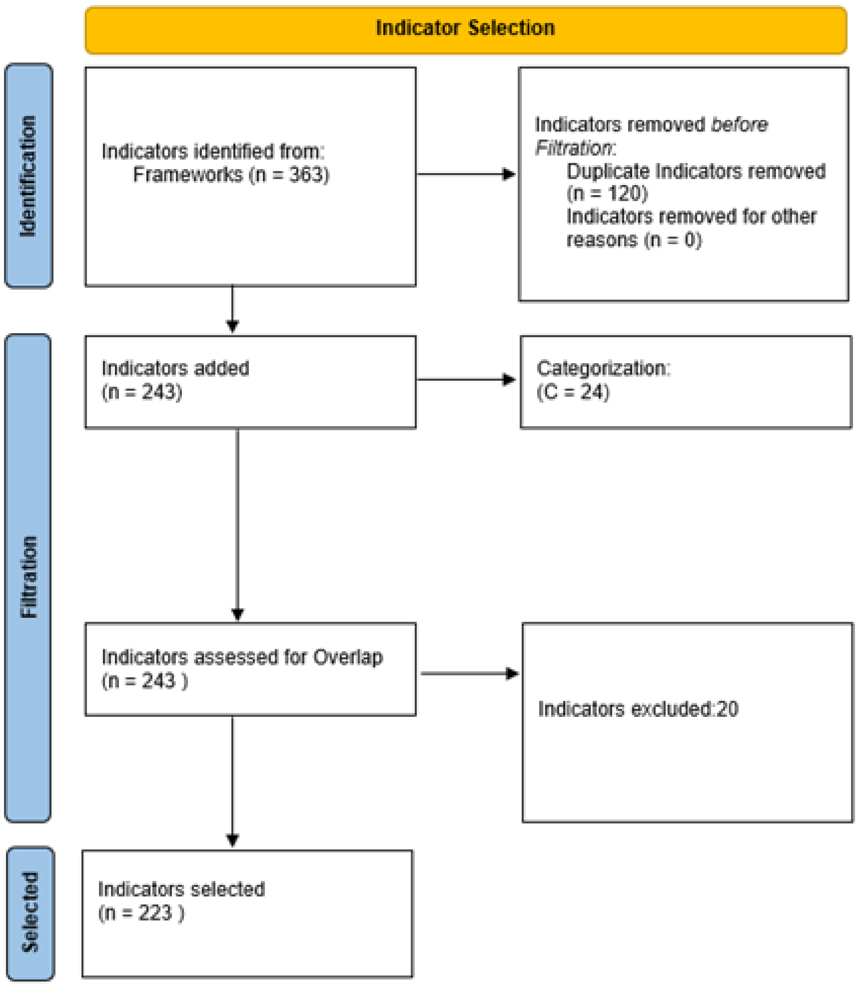


Figure 3.2: Indicator Selection Flowchart

3.4 Synthesis of Indicators

After completing all the steps, the results have been structured into Excel sheets as depicted in Figure 3.3. In the following section, the research question will be answered, and the indicators are presented in Table 3.5. Due to layout limitations, detailed information about the indicators is not included in this document. For full access to the indicator data, please contact the author.

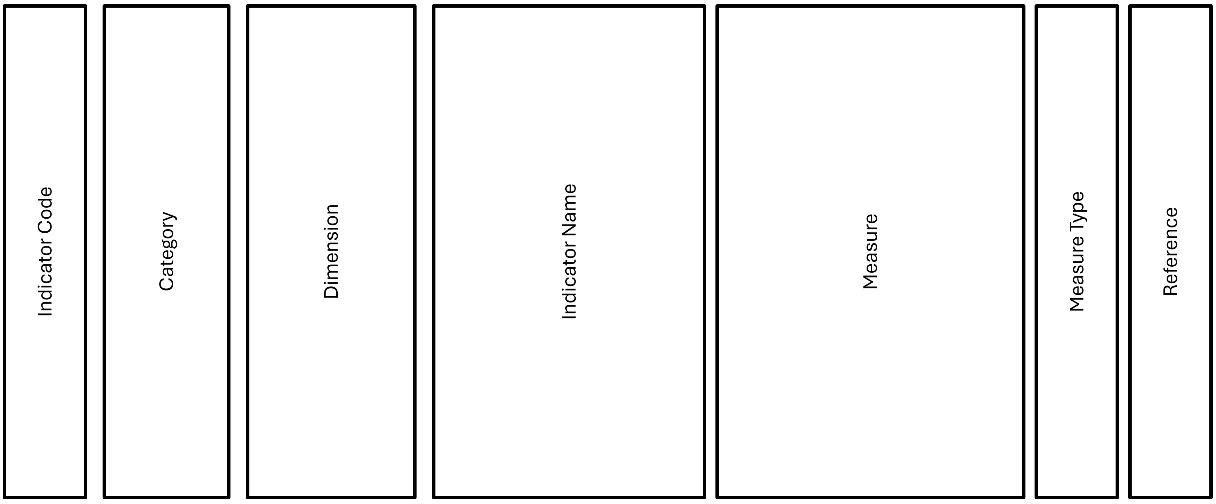


Figure 3.3: Schematic Synthesis of Indicators

3.5 Conclusion

RQ2: What are the essential dimensions and indicators that contribute to coastal community resilience against coastal hazards?

Community resilience of Coastal communities to hazards such as flooding, storms, and sea-level rise is addressed in the literature by five key dimensions: social, organizational, economic, infrastructure, and environmental. Furthermore, these dimensions can be classified further into categories. The social dimension concerns community well being, social connections, and societal cohesion. The organizational dimension focuses on governance and planning, while the economic dimension addresses economic stability and resilience. The infrastructure dimension covers critical infrastructure and land use management, and the environmental dimension includes environmental conditions and natural resource management.

After conducting the indicator mining, 223 indicators were identified from the literature (see Table 3.5), classified into 59 social, 37 organizational, 25 economic, 61 infrastructure, and 41 environmental. These indicators were synthesized, validated, and grouped into 24 categories to form a complete collection of data for next steps of the research.

Table 3.5: Mined Indicators

Code	Dimension	Indicators	References
1	Infrastructure	Building construction establishments	(Peacock et al., 2010)
2	Infrastructure	Highway, street, and bridge construction establishments	(Peacock et al., 2010)
3	Infrastructure	Number of Hospitals	(Peacock et al., 2010)
4	Infrastructure	Number of Hotels and motels	(Peacock et al., 2010)
5	Infrastructure	Land subdivision establishments	(Peacock et al., 2010)
6	Infrastructure	Environment and conservation establishments	(Peacock et al., 2010)
7	Infrastructure	Economic infrastructure exposure	(Cimellaro et al., 2016)
8	Infrastructure	Road use compared to overall land use	(Dasgupta & Shaw, 2015)
9	Infrastructure	Status of Jetties and inter-island communication	(Dasgupta & Shaw, 2015)
10	Infrastructure	Provision of fishermen tracking systems	(Dasgupta & Shaw, 2015)
11	Infrastructure	Quality of service / network accessibility	(Dasgupta & Shaw, 2015)
12	Infrastructure	Radio stations	(Peacock et al., 2010)
13	Infrastructure	Internet service providers	(Peacock et al., 2010)
14	Infrastructure	Occupied housing units with vehicle available	(Peacock et al., 2010)
15	Infrastructure	Percent of houses living under the avg. flood line	(Dasgupta & Shaw, 2015)
16	Infrastructure	Community Housing	(Peacock et al., 2010)
17	Organizational	Developed Policies and Plans	(Courtney et al., 2008)
18	Organizational	Funds allocation to Disaster Risk Reduction activities	(Dasgupta & Shaw, 2015)
19	Organizational	Availability of emergency Aids	(Dasgupta & Shaw, 2015)
20	Organizational	Implemented and Monitored Community Development Plans, Policies and Programs	(Courtney et al., 2008)
21	Organizational	Coordination with political leaders	(Dasgupta & Shaw, 2015)
22	Organizational	Coordination with NGO	(Dasgupta & Shaw, 2015)
23	Organizational	Adequacy of trained emergency response team	(Dasgupta & Shaw, 2015)
24	Organizational	Availability of evacuation centre	(Dasgupta & Shaw, 2015)
25	Organizational	Disaster risk reduction measures integrated into post disaster recovery and rehabilitation activities	(Cimellaro et al., 2016)
26	Social	Race/ethnicity	(Cimellaro et al., 2016)
27	Social	Percent of Rural Population	(Dasgupta & Shaw, 2015)
28	Social	Percentage of population covered by comprehensive plan	(Peacock et al., 2010)
29	Social	Social capital: religious organizations	(Cimellaro et al., 2016)
30	Social	Gender income equality	(Cimellaro et al., 2016)
31	Social	Adult education and training programs	(Cimellaro et al., 2016)
32	Social	Integration of disaster risk reduction in educational curriculum	(Cimellaro et al., 2016)
33	Social	Building construction workers	(Peacock et al., 2010)
34	Social	Environment and conservation workers	(Peacock et al., 2010)

Table 3.2 (Continued)

Code	Dimension	Indicators	References
35	Social	Land subdivision workers	(Peacock et al., 2010)
36	Social	Property and causality insurance workers	(Peacock et al., 2010)
37	Social	Physician access	(Cutter et al., 2014)
38	Social	Commercial establishments	(Cimellaro et al., 2016)
39	Social	Political engagement	(Cimellaro et al., 2016)
40	Social	Place attachment-not recent immigrants	(Cutter et al., 2014)
41	Economical	Non-dependence on primary/tourism sectors	(Cutter et al., 2014)
42	Economical	Business establishments	(Peacock et al., 2010)
43	Economical	Manufacturing	(Cimellaro et al., 2016)
44	Economical	Gross regional domestic product (GRDP) per capita	(Kusumastuti et al., 2014)
45	Economical	Financial resource equity	(Cimellaro et al., 2016)
46	Economical	Research and development firms	(Cimellaro et al., 2016)
47	Environmental	Land use stability	(Cimellaro et al., 2016)
48	Environmental	Protected land	(Cimellaro et al., 2016)
49	Environmental	Contamination of ground water in coastal aquifers (e.g., Arsenic)	(Dasgupta & Shaw, 2015)
50	Environmental	Air pollution	(Cimellaro et al., 2016)
51	Environmental	Physical impact caused by sea level rise	(Dasgupta & Shaw, 2015)
52	Environmental	Population affected by contaminated water	(Dasgupta & Shaw, 2015)
53	Environmental	Total mass of organisms	(Cimellaro et al., 2016)
54	Environmental	Mangrove deterioration (loss of species) due to salinity	(Dasgupta & Shaw, 2015)
55	Environmental	Integration of Natural hazard Maps in planning	(Dasgupta & Shaw, 2015)
56	Environmental	Chemical pollution in mangrove food chain	(Dasgupta & Shaw, 2015)
57	Environmental	Local food suppliers	(Cutter et al., 2014)

Table 3.2 (Continued)

Code	Dimension	Indicators	References
1	Infrastructure	Heavy and civil engineering construction establishments	(Peacock et al., 2010)
2	Infrastructure	Building inspection establishments	(Peacock et al., 2010)
3	Infrastructure	Ambulances	(Peacock et al., 2010)
4	Infrastructure	Community food service facilities	(Peacock et al., 2010)
5	Infrastructure	Licensed child care facilities	(Peacock et al., 2010)
6	Infrastructure	Legal services establishments	(Peacock et al., 2010)
7	Infrastructure	Scarcity of drinking water and seasonal variation of water availability	(Dasgupta & Shaw, 2015)
8	Infrastructure	Industrial resupply potential	(Cimellaro et al., 2016)
9	Infrastructure	Percent of waterways compared to overall land use	(Dasgupta & Shaw, 2015)
10	Infrastructure	School and employee buses	(Dasgupta & Shaw, 2015)
11	Infrastructure	Percent population having mobile phone	(Dasgupta & Shaw, 2015)
12	Infrastructure	Percent population having access to electricity	(Dasgupta & Shaw, 2015)
13	Infrastructure	Number of hours of average disruption of electricity supply	(Dasgupta & Shaw, 2015)
14	Infrastructure	Percent of population in co-operative housing	(Dasgupta & Shaw, 2015)
15	Infrastructure	Sturdier housing types	(Cutter et al., 2014)
16	Organizational	Mitigation spending	(Cimellaro et al., 2016)
17	Organizational	Administrative initiatives for coastal greenings	(Dasgupta & Shaw, 2015)
18	Organizational	Implementation of rainwater harvesting scheme	(Dasgupta & Shaw, 2015)
19	Organizational	Contingency plan degree including an outline strategy for postdisaster recovery and reconstruction	(Cimellaro et al., 2016)
20	Organizational	Performance regimes-nearest metro area	(Cutter et al., 2014)
21	Organizational	Coordination with neighboring blocks	(Dasgupta & Shaw, 2015)
22	Organizational	Development of forestry & Plantation at administrative initiatives	(Dasgupta & Shaw, 2015)
23	Organizational	Existence of early warning system	(Dasgupta & Shaw, 2015)
24	Organizational	Adequacy of manpower in existing block administration	(Dasgupta & Shaw, 2015)
25	Social	Population stability	(Cimellaro et al., 2016)
26	Social	Gender	(Cimellaro et al., 2016)
27	Social	Population distribution	(Cimellaro et al., 2016)
28	Social	Percentage of population covered by building codes	(Peacock et al., 2010)
29	Social	Race/ethnicity income equality	(Cimellaro et al., 2016)
30	Social	Income	(Cimellaro et al., 2016)
31	Social	Education programs on disaster risk reduction and disaster preparedness for local communities	(Cimellaro et al., 2016)
32	Social	Child and elderly care programs	(Cimellaro et al., 2016)
33	Social	Colleges, universities, and professional schools employees	(Peacock et al., 2010)

Table 3.2 (Continued)

Code	Dimension	Indicators	References
34	Social	Population employed in legal services	(Peacock et al., 2010)
35	Social	Heavy and civil engineering construction workers	(Peacock et al., 2010)
36	Social	Mental health support	(Cutter et al., 2014)
37	Social	Religious organizations	(Cimellaro et al., 2016)
38	Social	Cultural resources	(Cimellaro et al., 2016)
39	Economical	Occupation	(Cimellaro et al., 2016)
40	Economical	Women employment	(RIMES & BRAC, 2022)
41	Economical	Business size	(Cutter et al., 2014)
42	Economical	Business development rate	(Cimellaro et al., 2016)
43	Economical	Tax revenues	(Cimellaro et al., 2016)
44	Economical	Emergency fund	(Kusumastuti et al., 2014)
45	Economical	Hazard insurance coverage	(Cimellaro et al., 2016)
46	Environmental	Soil quality	(Cimellaro et al., 2016)
47	Environmental	Loss of soil fertility (agricultural impact)	(Dasgupta & Shaw, 2015)
48	Environmental	Coastal erosion and degree of damage	(Dasgupta & Shaw, 2015)
49	Environmental	Availability of freshwater (surface+subsurface)	(Dasgupta & Shaw, 2015)
50	Environmental	Flood occurrence and degree of damage	(Dasgupta & Shaw, 2015)
51	Environmental	Change in tidal patterns leading to river piracy/damage to dykes	(Dasgupta & Shaw, 2015)
52	Environmental	Undeveloped forest	(Cimellaro et al., 2016)
53	Environmental	Ecological buffer	(Kotzee & Reyers, 2016)
54	Environmental	Monitoring and Maintenance of environmental database	(Dasgupta & Shaw, 2015)
55	Environmental	Efficient energy use	(Cutter et al., 2014)

Table 3.2 (Continued)

Code	Dimension	Indicators	References
1	Infrastructure	Architecture and engineering establishments	(Peacock et al., 2010)
2	Infrastructure	Hospital beds	(Peacock et al., 2010)
3	Infrastructure	Nursing homes	(Peacock et al., 2010)
4	Infrastructure	Newspaper publishers	(Peacock et al., 2010)
5	Infrastructure	Implication of waste water disposal and treatment facility	(Dasgupta & Shaw, 2015)
6	Infrastructure	Distribution commercial facilities	(Cimellaro et al., 2016)
7	Infrastructure	Colleges, Universities, and Professional schools	(Dasgupta & Shaw, 2015)
8	Infrastructure	Percent of all weather accessible roads compared to existing road network	(Dasgupta & Shaw, 2015)
9	Infrastructure	Evacuation routes	(Cimellaro et al., 2016)
10	Infrastructure	Percent population having alterative source of electricity in case of disruption	(Dasgupta & Shaw, 2015)
11	Infrastructure	Implementation of renewable source of energy (Solar/wind etc.)	(Dasgupta & Shaw, 2015)
12	Infrastructure	Service quality (Frequency of dropout or distribution failure etc.)	(Dasgupta & Shaw, 2015)
13	Infrastructure	Percent of population with informal (slum etc.) settlements	(Dasgupta & Shaw, 2015)
14	Infrastructure	Percent of population living extremely close to hazardous activity (port/industry)	(Dasgupta & Shaw, 2015)
15	Infrastructure	Housing units	(Peacock et al., 2010)
16	Organizational	Integration of Disaster Risk Reduction in developmental activities	(Dasgupta & Shaw, 2015)
17	Organizational	Implementation of Disaster Insurance Statutory aids to victims	(Dasgupta & Shaw, 2015)
18	Organizational	Nuclear plant accident planning	(Cutter et al., 2014)
19	Organizational	Frequency of DRR training organized by the block	(Dasgupta & Shaw, 2015)
20	Organizational	Information sharing & risk communication with the community	(Dasgupta & Shaw, 2015)
21	Organizational	Collaboration Mechanisms Establishments	(Courtney et al., 2008)
22	Organizational	Transparency in Aid distribution process	(Dasgupta & Shaw, 2015)
23	Organizational	Local institutions' access to financial reserves to support effective disaster response and early recovery	(Cimellaro et al., 2016)
24	Organizational	Accessible Basic Services (i.e. water, transportation, security, etc.)	(Courtney et al., 2008)
25	Organizational	The proximity to the administrative headquarters	(Dasgupta & Shaw, 2015)
26	Social	Percentage of population covered by zoning regulations	(Peacock et al., 2010)
27	Social	Percentage of population covered by governmental safety department approved mitigation plan	(Peacock et al., 2010)
28	Social	Pre-retirement age	(Cutter et al., 2014)
29	Social	Homeownership	(Cimellaro et al., 2016)
30	Social	Citizen awareness of evacuation plans or drills for evacuations	(Cimellaro et al., 2016)
31	Social	English language competency	(Cutter et al., 2014)
32	Social	Population employed in scientific research and development services	(Peacock et al., 2010)
33	Social	Environmental consulting workers	(Peacock et al., 2010)

Table 3.11 (Continued)

Code	Dimension	Indicators	References
34	Social	Landscape architects and planners	(Peacock et al., 2010)
35	Social	Female labor force participation	(Cimellaro et al., 2016)
36	Social	Food provisioning capacity	(Cimellaro et al., 2016)
37	Social	Business associations/organizations	(Peacock et al., 2010)
38	Social	Social capital-civic organizations	(Cutter et al., 2014)
39	Social	Population participating in community rating system	(Cimellaro et al., 2016)
40	Social	Emergency community participation	(Cimellaro et al., 2016)
41	Economical	Public government employment	(Cutter et al., 2014)
42	Economical	Percent of population lives on coastal resources	(Dasgupta & Shaw, 2015)
43	Economical	Professional and business services	(Cimellaro et al., 2016)
44	Economical	Literacy rate	(Dasgupta & Shaw, 2015)
45	Economical	Annual Average Growth Rate	(Dasgupta & Shaw, 2015)
46	Economical	Population with health insurance	(Peacock et al., 2010)
47	Environmental	Natural subsidence	(Dasgupta & Shaw, 2015)
48	Environmental	Arable cultivated land	(Cimellaro et al., 2016)
49	Environmental	Wetland variation	(Cimellaro et al., 2016)
50	Environmental	Cyclone occurrence and degree of damage	(Dasgupta & Shaw, 2015)
51	Environmental	Heavy tidal inceptions causing substantial damage	(Dasgupta & Shaw, 2015)
52	Environmental	Loss of shorelines/permanent inundation area	(Dasgupta & Shaw, 2015)
53	Environmental	Natural flood buffers	(Cutter et al., 2014)
54	Environmental	Bio-shielded coastline	(Dasgupta & Shaw, 2015)
55	Environmental	Efficient Water Use	(Cutter et al., 2014)
56	Environmental	Control in Deep aquifer pumping	(Dasgupta & Shaw, 2015)

Table 3.2 (Continued)

Code	Dimension	Indicators	References
1	Infrastructure	Landscape architecture and planning establishments	(Peacock et al., 2010)
2	Infrastructure	Utility systems construction establishments	(Peacock et al., 2010)
3	Infrastructure	Fire stations	(Peacock et al., 2010)
4	Infrastructure	Temporary shelters	(Peacock et al., 2010)
5	Infrastructure	Property and causality insurance establishments	(Peacock et al., 2010)
6	Infrastructure	Environmental consulting establishments	(Peacock et al., 2010)
7	Infrastructure	Gas	(Cimellaro et al., 2016)
8	Infrastructure	Scientific research and development establishments	(Cimellaro et al., 2016)
9	Infrastructure	Availability of emergency vehicle/boats	(Dasgupta & Shaw, 2015)
10	Infrastructure	Access and evacuation	(Cimellaro et al., 2016)
11	Infrastructure	Owner-occupied housing units with telephone service	(Peacock et al., 2010)
12	Infrastructure	Television broadcasting	(Peacock et al., 2010)
13	Infrastructure	Percent of population having radio/television	(Dasgupta & Shaw, 2015)
14	Infrastructure	Vacant housing units	(Peacock et al., 2010)
15	Infrastructure	Temporary housing availability	(Cimellaro et al., 2016)
16	Organizational	Implementation flood/erosion control	(Dasgupta & Shaw, 2015)
17	Organizational	Implementation of regular developmental plans	(Dasgupta & Shaw, 2015)
18	Organizational	Off-disaster activities of Block Disaster Management Authority	(Dasgupta & Shaw, 2015)
19	Organizational	Crop insurance coverage	(Cutter et al., 2014)
20	Organizational	Performance regimes-state capital	(Cutter et al., 2014)
21	Organizational	Coordination among government departments	(Courtney et al., 2008)
22	Organizational	Available Technical and Financial Support Mechanisms	(Courtney et al., 2008)
23	Organizational	Local government access to resources and expertise to assist victims of psychosocial impacts of disasters	(Cimellaro et al., 2016)
24	Organizational	Public Private partnerships in developmental activities	(Dasgupta & Shaw, 2015)
25	Social	Family stability	(Cimellaro et al., 2016)
26	Social	Percent backward/tribal population	(Dasgupta & Shaw, 2015)
27	Social	Social capital: disaster volunteerism	(Cimellaro et al., 2016)
28	Social	Equity	(Cimellaro et al., 2016)
29	Social	Poverty	(Cimellaro et al., 2016)
30	Social	Educational attainment equality	(Cimellaro et al., 2016)
31	Social	Citizen disaster preparedness and response skills	(Cutter et al., 2014)
32	Social	Fire fighters, prevention, and law enforcement workers	(Peacock et al., 2010)
33	Social	Population employed in special need transportation services	(Peacock et al., 2010)
34	Social	Architecture and engineering workers	(Peacock et al., 2010)

Table 3.11 (Continued)

Code	Dimension	Indicators	References
35	Social	Building inspectors	(Peacock et al., 2010)
36	Social	Non-special needs	(Cutter et al., 2014)
37	Social	Recreational centers(bowling, fitness, golf clubs) and sport organizations	(Peacock et al., 2010)
38	Social	Professional associations/organizations	(Peacock et al., 2010)
39	Social	Place attachment-native born residents	(Cutter et al., 2014)
40	Economical	Percent of population lives on Eco−tourism	(Dasgupta & Shaw, 2015)
41	Economical	Large retail-regional/national geographic distribution	(Cutter et al., 2014)
42	Economical	Access to financial institutes	(RIMES & BRAC, 2022)
43	Economical	Income per capita	(Noy & Yonson, 2018)
44	Economical	Trade openness	(Noy & Yonson, 2018)
45	Economical	Livestock protection management in a disaster	(RIMES, 2023)
46	Environmental	Pervious surfaces	(Cimellaro et al., 2016)
47	Environmental	Protective measures (bouldering/cementing) to control erosion	(Dasgupta & Shaw, 2015)
48	Environmental	Water quality/quantity	(Cimellaro et al., 2016)
49	Environmental	River water salinity	(Dasgupta & Shaw, 2015)
50	Environmental	Rate of sea level rise in the block	(Dasgupta & Shaw, 2015)
51	Environmental	Density of green vegetation across an area	(Cimellaro et al., 2016)
52	Environmental	Living species	(Noy & Yonson, 2018)
53	Environmental	Implementation of Environmental Protection Act	(Dasgupta & Shaw, 2015)
54	Environmental	Involvement of Scientific communities in Environmental R & D	(Dasgupta & Shaw, 2015)
55	Environmental	Chemical contamination mitigation	(Dasgupta & Shaw, 2015)

3.6 Transition to Expert Consultation

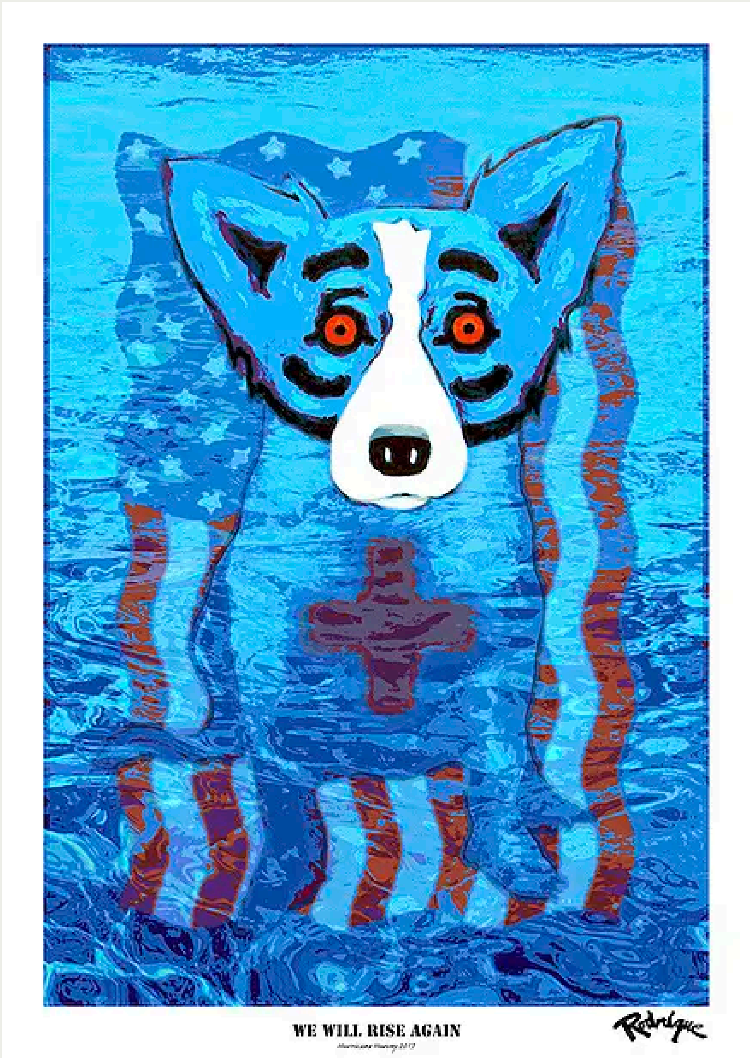
In this chapter, essential indicators and dimensions were identified through a systematic review and indicator mining. While all of the indicators have been scientifically validated by scholars and can be considered essential, questions remain about the extent of their essentiality. Even after determining their level of importance, how can they collectively be operationalized, or how can we integrate them into a new framework that is favorable to decision-makers? In the next chapter, these questions will be explored further.

CHAPTER

4

Expert Consultation

Incorporating Expert Knowledge in Framework Development



We Will Rise Again By George Rodrigue

Source: arthive.com

4 Expert Consultation

This chapter addresses RQ1 and RQ4. Expert consultations were conducted to assess indicator importance using a 5-point Likert scale, and content analysis was applied to interpret key insights from the interviews. First, expert selection is discussed, followed by details on the survey and interview process. The chapter then elaborates on the analysis methods used, concluding with the results of this stage.

4.1 Expert Selection

Experts for this study were selected using the Snowball Sampling technique, a non-probability method often employed to identify and recruit participants from specialized or hard-to-reach populations. This approach uses the networks of initial participants to expand the sample size incrementally (Goodman, 1961; Naderifar et al., 2017). The process begins by identifying a small group of initial participants (seeds) who meet the study's criteria. These seeds are then asked to refer others who also fit the criteria. As each new participant is recruited, they are likewise asked to provide additional referrals, creating a chain of recruitment (Parker et al., 2019; Shafie, 2010).

In this research, special criteria was set to ensure a diverse selection of experts in terms of both geography and expertise. Experts were drawn from disaster-prone regions, including Iran, the USA, Italy, the Netherlands, Japan, and Australia (Figure **??**). These countries have experienced significant natural disasters, making them valuable sources of insight. Furthermore, experts from both the global north and global south were included to ensure a wide range of perspectives on resilience concepts.

As shown in Figure 4.2, the experts represented a mix of sectors, with academia forming the largest group (63.0%). However, experts also made contributions from the Dutch Ministry of Infrastructure and Water Management (18.5%), the Federal Government (7.4%), research institutes (7.4%), and the industry sector (3.7%). This diversity in roles and responsibilities was intentional to optimize the range of insights and perspectives gathered for this stage of the research.

The experience levels of these experts varied. Academics had a broad range of experience, primarily between 10 and 35 years, with notable peaks around 15 and 20 years. Experts from the Dutch Ministry of Infrastructure and Water Management typically had between 15 and 25 years of experience, with a peak around 20 years. Government-affiliated experts showed peaks at 18 and 34 years, while research institute participants had between 15 and 20 years of experience. The industry sector was represented by experts with around 23 years of experience.

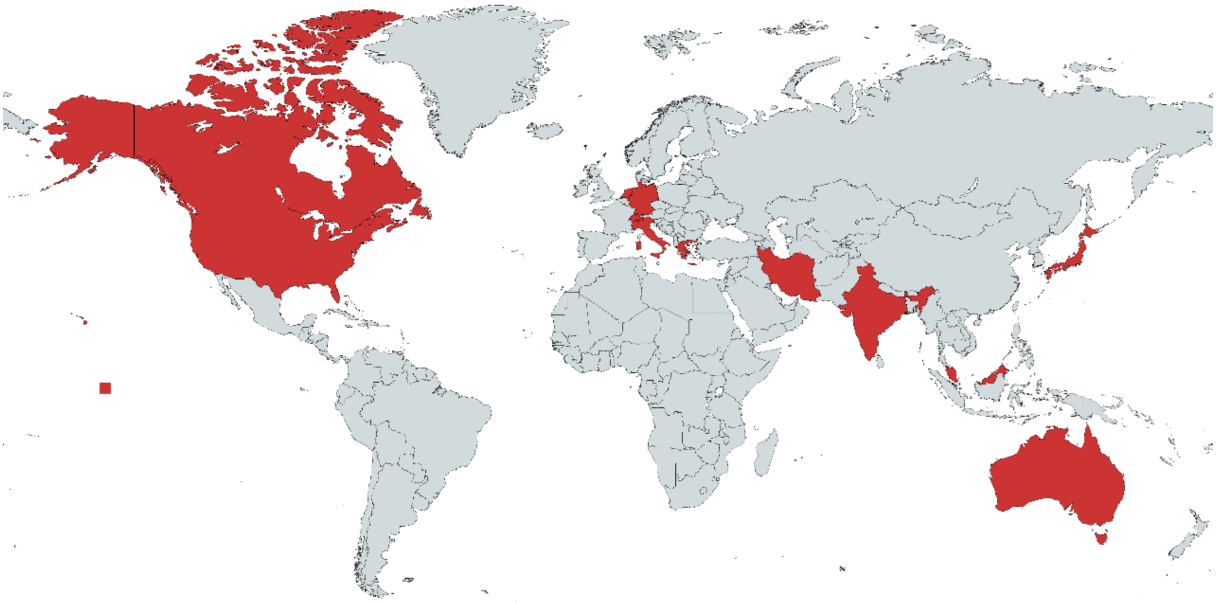


Figure 4.1: Global Distribution of Experts (Generated by: mapchart.net)

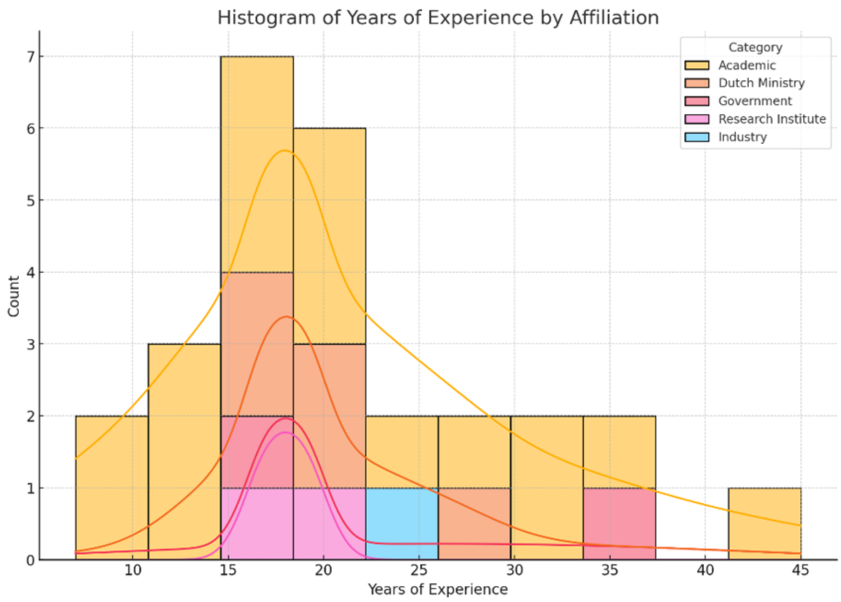


Figure 4.2: Expert's Years of Experience by Affiliation

4.2 Tools

This research utilized a structured questionnaire and semi-structured interviews to gather expert opinions and data. The following subsections detail the development and use of these tools and their roles in data collection.

4.2.1 Questionnaire

One of the key components of this research was conducting a survey with experts, which involved developing a questionnaire based on indicators collected from the literature. The purpose of the questionnaire was to contribute to the answer to one of the crucial research sub-questions:

RQ3: What key indicators ensure a multi-dimensional approach to assessing coastal community resilience to hazards, with universal applicability or flexibility for specific contexts?

Through this questionnaire, both quantitative and qualitative data were systematically gathered from experts on which indicators they considered most important for assessing coastal community resilience against coastal hazards. A standard Likert scale was used, which is widely recognized and validated for research purposes (Alizadeh & Sharifi, 2020; Brown et al., 2017; Charles et al., 2023; Pescaroli et al., 2020; Rajaei et al., 2021; Rokooei et al., 2022; Ryan & Caltabiano, 2009; Van de Walle et al., 2016). First introduced by psychologist Rensis Likert in 1932, the Likert scale is a psychometric tool commonly used to measure attitudes, opinions, or perceptions. It allows respondents to express the degree to which they agree or disagree with specific statements on a symmetric agree-disagree scale (Batterton & Hale, 2017).

In the design and analysis of the Likert scale data, several important steps, as outlined by Mirahmadizadeh et al. (2018), were followed (see Table 4.1). These steps included selecting a 5-point scale, which is both widely used in community resilience research (Guo et al., 2020; Joseph et al., 2020; Pazhuhan et al., 2023; Sobhaninia et al., 2023). Clarity and relevance in the questions were ensured to keep each question directly aligned with the study's objectives. A pilot test was conducted with a small group to identify and resolve any potential issues before full distribution. The 5-point Likert scale typically includes: ”Strongly Disagree,” ”Disagree,” ”Neutral,” ”Agree,” and ”Strongly Agree.” This format provides a range of options for the experts. Table 4.2 shows the Likert Scale range and its interval values used in this research.

After finalizing the Likert survey range, the collected indicators were divided into four questionnaires due to practical limitations (See Table 4.3). Each questionnaire covers all five dimensions: social, economic, infrastructure, environmental, and organizational. The aim was to ensure that the categories in all questionnaires had a consistent structure. Another reason for using four questionnaires was that there were 24 experts available. By distributing the questionnaires in this way, each indicator would receive six ratings overall.

Table 4.1: Dos and Don’ts for Likert Scale Design and Analysis

Dos	Don’ts
✓ Use a 5-point scale	✓ Avoid double-barreled questions
✓ Ensure clarity and relevance	✓ Don’t assume interval data for all analyses
✓ Pilot test the questionnaire	✓ Avoid too many scale points
✓ Use appropriate statistical tests	✓ Don’t ignore the need for a neutral midpoint
✓ Calculate reliability (Cronbach’s alpha)	

Table 4.2: Likert Scale Range and Intervals

Likert Scale Range	Interval
Very Low	1
Low	2
Medium	3
High	4
Very High	5

Table 4.3: Summary of Survey Data

Questionnaire	Indicators	Dimensions	Categories	Experts
Questionnaire 1	57	5	23	6
Questionnaire 2	55	5	24	6
Questionnaire 3	56	5	24	6
Questionnaire 4	55	5	24	6

4.2.2 Interview

The second tool used in this research was the semi-structured interview. Interviews were used as an approach to not only ask questions but also to discuss the topic with the experts. Two interview sessions per expert were scheduled through Microsoft Teams, chosen for its effective recording and transcription add-ins. The purpose of the first half-hour session was to introduce and discuss the topic and research project with the experts. Subsequently, a main interview session, lasting a maximum of 60 minutes, was planned with each expert. The primary objective of conducting these interviews was to answer two subquestions mentioned in the earlier chapters.

RQ4: How can the collected indicators be operationalized to ensure practicality and effectiveness in decision-making?

RQ1: What are the specific needs and expectations of decision-makers regarding community resilience assessments that can be effectively integrated into the design of the new framework?

In order to provide answers to these questions, the interview protocol (See Appendix A) was designed to cover two main concepts as follows:

1. Operationalization: Three main questions related to operationalization were asked and discussed with the experts. These questions focused on the issue of having numerous frameworks but a lack of operational frameworks in the field of resilience, addressing the gap between academic research and practical application, and understanding the perspectives of individuals from different backgrounds—both academic and practical—on these matters. The goal was to gain insights into these challenges and explore potential solutions by utilizing the diverse expertise of the participants.

2. Decision makers' needs and expectations: For this category, straightforward questions were posed to the experts to understand the main needs and expectations of decision-makers when utilizing frameworks. Specifically, the questions aimed to identify what decision-makers consider the most favorable factors of a framework. Experts were asked to discuss what makes a framework practical, effective, and user-friendly from the perspective of those in decision-making positions. The objective was to gather insights on the key features and functionalities that decision-makers prioritize, such as ease of implementation, clarity, adaptability to different contexts, and the ability to provide actionable insights.

In addition to category-specific questions, profile-related questions were asked at the beginning of each interview to gain insights into the experts' backgrounds and work experiences. This approach helped steer the interview effectively and allowed for more tailored and relevant follow-up questions and discussions.

At the closure of each interview, experts were asked about the quality of the interview, whether they liked it, and for any comments, recommendations, or final words. This feedback is crucial because conducting interviews, especially in research involving human subjects, is never perfect from the start and requires ongoing improvement. Each interview benefits from the insights gained from previous ones, and this can refine the discussions better.

4.3 Data Analysis

The data collected through the questionnaire and interviews were analyzed using both quantitative and qualitative methods. To ensure the reliability of the questionnaire data, Cronbach's alpha was applied as a measure of internal consistency. For the qualitative data from the interviews, content analysis was conducted using a combination of manual coding and ATLAS.ti software. The following subsections outline the processes used for both reliability checks and content analysis.

4.3.1 Reliability check

In this research, Cronbach's alpha is used to assess the reliability and internal consistency of a set of survey or questionnaire items. It indicates how well the items in a test measure the same underlying construct. The Cronbach's Alpha ranges from 0 to 1, as shown in Table 4.4.

Table 4.4: Cronbach's Alpha and Reliability

Cronbach's Alpha (α)	Reliability
$\alpha > 0.9$	Excellent reliability
$0.8 < \alpha < 0.9$	Good reliability
$0.7 < \alpha < 0.8$	Acceptable reliability
$0.6 < \alpha < 0.7$	Questionable reliability
$0.5 < \alpha < 0.6$	Poor reliability
$\alpha < 0.5$	Unacceptable reliability

4.3.2 Content Analysis

Content analysis was used to analyze the insights from the interviews, combining manual analysis with ATLAS.ti. ATLAS.ti can assist the researcher in keeping track of search terms, keywords, database sources, journals, scholars, and management system programs (Smit & Scherman, 2021). ATLAS.ti follows a specific structure for analyzing qualitative data derived from interviews. The input for the software can include various formats such as video or mp3 recordings, transcriptions, and text files. For this part, auto-transcriptions from MS Teams were obtained and polished manually to remove irrelevant terms such as names, redundant phrases, and time stamps. Next, the unnecessary questions were filtered out based on the categories mentioned above, and all the responses were compiled into two documents: one labeled ”Framework Operationalization” and the other ”Decision Makers’ Needs and Expectations.” These documents were then uploaded (Step 1) into a newly created project in ATLAS.ti for further analysis.

The transcripts were coded in ATLAS.ti by labeling text segments with codes representing themes and categories relevant to the research questions. This allowed for the systematic organization of qualitative data. Codes were applied to words, phrases, or paragraphs based on their significance. In the next step, ATLAS.ti tools, such as document coding analysis and Sankey diagrams, were used to identify trends and correlations between ”Framework Operationalization” and ”Decision Makers’ Needs and Expectations.” This approach visually represented interconnections, highlighted key patterns, and explored relationships within the data (Russmann & Flick, 2022).

In the third step, the coding involved grouping the codes based on their relevance to each other. This allowed for the identification of the main themes within the expert insights. The themes were then integrated with the research questions to create a coherent narrative that effectively addressed the research objectives. The output of the content analysis was represented in various Sankey diagrams, some of which highlighted the main themes, general insights, and trade-offs between different insights provided by the experts.

4.4 Results

This section presents the findings from both the survey and interview processes. The survey results highlight the expert evaluation of key indicators for assessing coastal community resilience, while the interview analysis provides insights into expert perspectives on framework operationalization and decision-makers’ needs. The following subsections summarize the key factors and aspects mentioned by experts.

4.4.1 Survey

The survey was conducted with the main objective of consulting the collected indicators with experts to identify the importance level of indicators for assessing coastal community resilience.

Responses from 24 participants were analyzed to create heatmaps for each survey, as shown in Figure 4.3. Cronbach’s alpha was calculated for each survey, as depicted in Figure 4.4. Q3 had the highest value, while Questionnaire 1, Questionnaire 2, and Questionnaire 4 varied, with three out of four surveys scoring above 7. Although Questionnaire 1 was below 7, it was still deemed reliable. The heatmaps reveal different rating patterns: Questionnaire 3 had the most high ratings, reflected by green and yellow areas, correlating with its highest Cronbach’s alpha. Questionnaires 2 and 4 displayed more variation with lower ratings, while Questionnaire 1 showed moderate ratings between Questionnaire Q3 and the others.

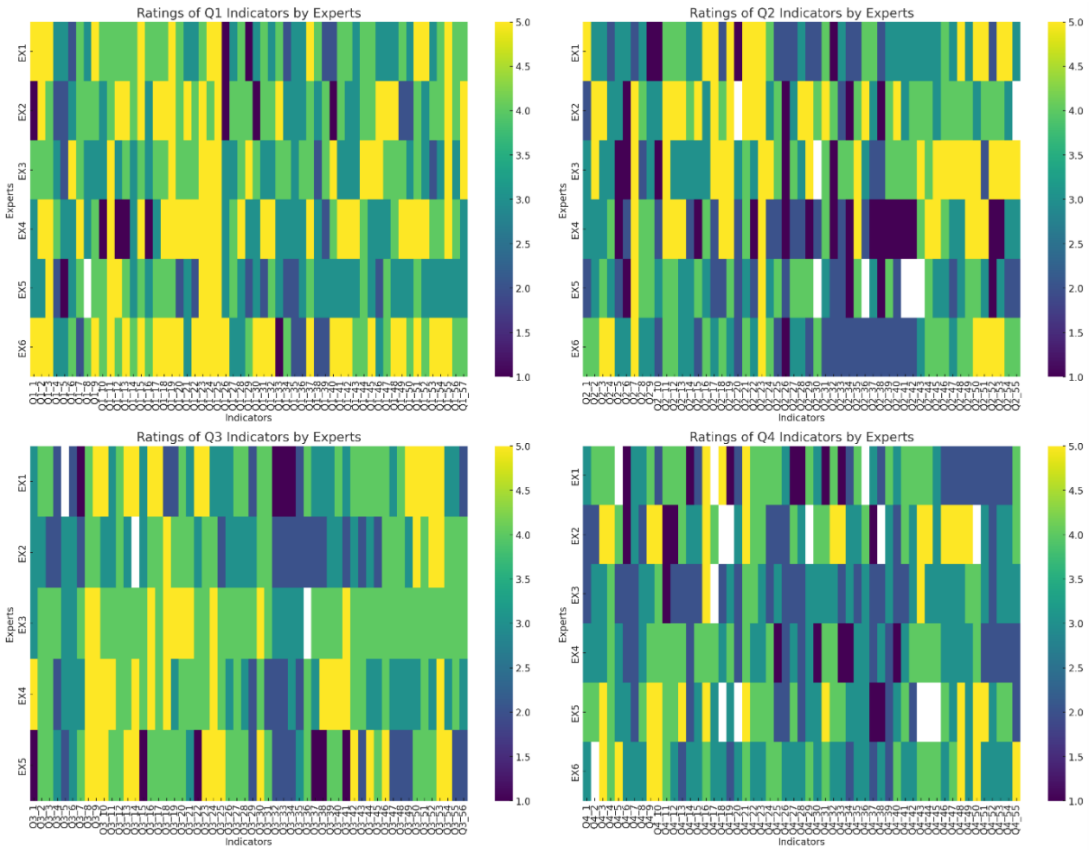


Figure 4.3: Heatmap of responses

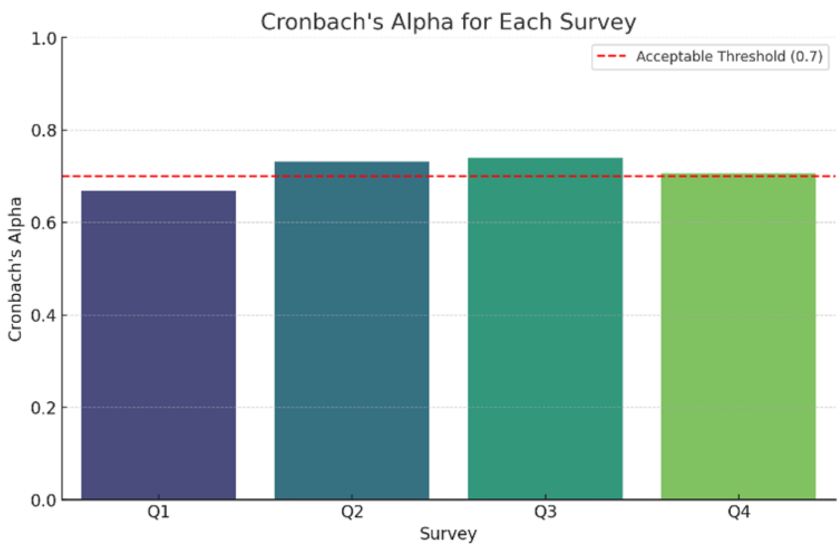


Figure 4.4: Calculated Cronbach’s Alpha for each survey

4.4.2 Interview

The interviews produced interview notes that were analyzed with the help of a specialized software package, namely Atlas.ti. More specifically the content of the interviews was analyzed in order to find and highlight underlying information. That information was obtained in the form of codings and resulted in a Sankey diagram (See Appendix A). For illustration purposes, codes were grouped as shown in Figure 4.5.

In order to have an operational framework,"Clarity and Simplicity" emerged as key factors. Experts frequently emphasized that a lack of clarity would hinder the practical application of frameworks. The following section explores why clarity and simplicity are crucial, according to the experts.

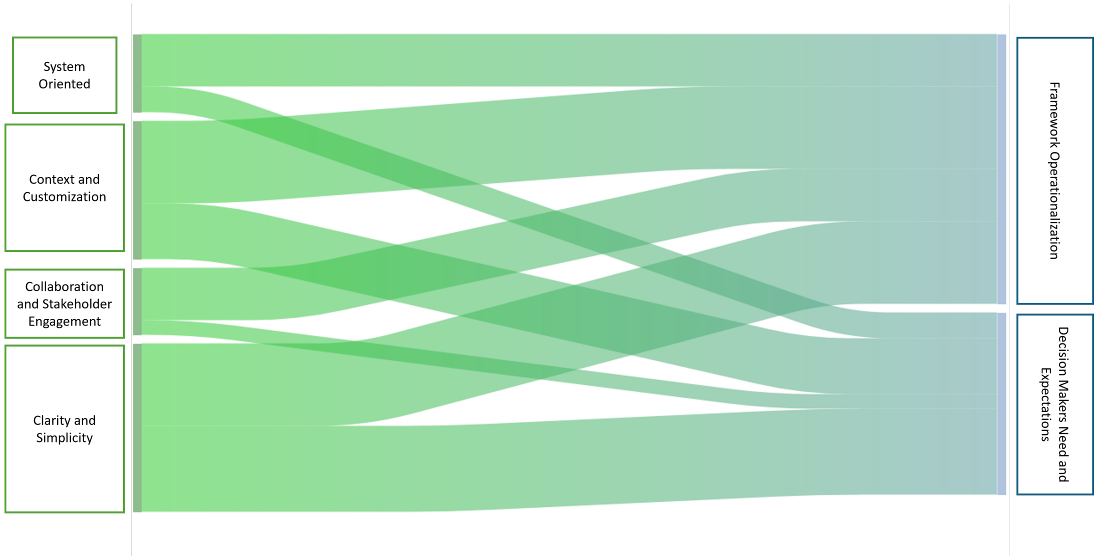


Figure 4.5: Sankey Diagram For Content Analysis (Coding Groups)

4.4.2.1 Clarity and Simplicity

Clarity and simplicity were among the main factors frequently mentioned by experts (See Figure 4.6). The primary reasoning from the experts was that a framework lacking clarity and simplicity would not be used in practice. They acknowledged that most frameworks today are not operational and primarily fulfill theoretical aspects. One expert suggested, "Keeping frameworks simple and focused on the most critical aspects can enhance their usability." Another expert added another factor that could make frameworks operational. He observed that most frameworks today have a long-term scope; however, he believed, "There's a long-term framework, and within that long-term, you could devise short-term frameworks that could be adapted to the situation."

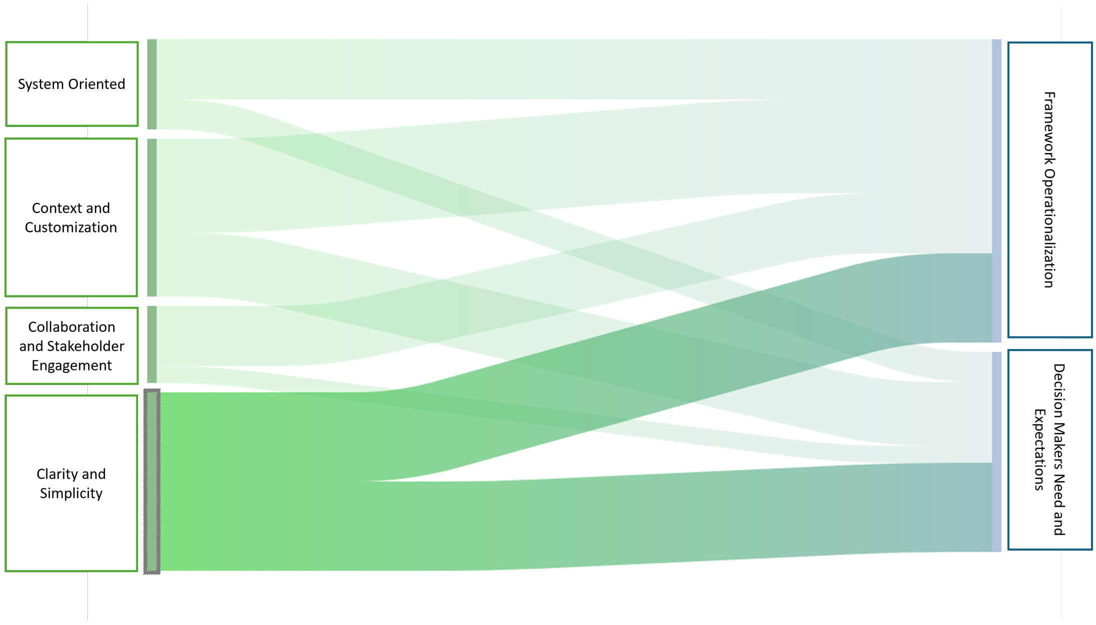


Figure 4.6: Clarity and Simplicity

Two experts highlighted the importance of the attractiveness of the framework, which is somehow related to its clarity and structure. One of them mentioned, ”Not only should the content be easy to understand, but it should also have a good layout, creating a clear link to what people can do,” while the other focused more on the fact that all frameworks should have an end user. Considering the end user’s language is crucial, and by language, this can mean either the spoken language or the organizational one. For instance, if an academic body wants to develop a framework for an organization, it must ensure that the framework can be operational within the culture and language of that organization. This aligns with another expert who mentioned, ”Frameworks must be accompanied by organizational adaptability and proper coordination mechanisms. Only then can we determine which framework is the best.”

There was a debate between the two experts, as they had relatively opposing ideas about resilience frameworks in terms of scope. One expert mentioned, ”We should not treat resilience issues as bulk problems but address them individually.” This means that if the framework is about a specific community or specific hazard, it may become operational and realistic. The other expert, however, stated, ”We should treat resilience in a systematic way, and only looking at one aspect is narrow-minded.” Frameworks should be simple and straightforward. One expert emphasized, ”Frameworks need to be easy to understand. No jargon or overly complicated concepts; we need to make them clear and simple.”

Another expert looked at frameworks specifically from the decision-maker’s point of view, stating, ”Will they benefit from it in their daily work? Being clear about what the framework is and what it is not is also important. A framework is a model, and it cannot be everything. There must be some focus. If it’s too broad, it may seem vague, but if it’s too specific, it may not be useful.” One expert highlighted that decision-makers, often politicians seeking re-election, may find frameworks appealing if they demonstrate long-term success, stating, ”They are in the position for the people, but also for themselves.” Another expert emphasized that policymakers prefer cost-effective frameworks with minimal negative impacts, explaining, ”Frameworks need to work with minimal costs. Policymakers are more likely to adopt frameworks that are economical and can express results in monetary terms.” Simplicity and adaptability were also identified as key factors for usability.

4.4.2.2 Context and Customization

While clarity and simplicity ensure that frameworks are accessible and usable, experts also highlighted the need for these frameworks to be adaptable to specific contexts (See Figure 4.7). In particular, the ability to localize frameworks to meet the unique needs of different regions is critical to their effectiveness.

Frameworks need to be flexible to fit different regions' unique needs and risks. One expert said, ”Rather than a common framework, we need a common understanding. There can be a parent framework adapted to different regions based on their priorities.” This helps each region stay resilient while addressing its specific challenges. Another expert had a different view, stating, ”However, there should be efforts to combine these perspectives to create a more comprehensive and universally applicable framework.” Despite this, most experts emphasized the importance of context. One expert noted, ”Applying a broad resilience framework to a city is impractical unless it is contextualized and broken down into manageable parts.” They added, ”Some efforts are being made in this direction, but it's a complex and ongoing challenge.” Another expert commented, ”Frameworks are often highly contextual and cannot be universally applied, as priorities and issues differ across communities.”

Combining different frameworks can make them more effective by using their strengths and reducing their weaknesses. Machine learning and big data can help with this by showing performance and trade-offs. As one expert said, ”Showing trade-offs matters and utilization of machine learning and AI can provide this opportunity for us.” However, another expert pointed out, ”This diversity is valuable because each framework offers a unique perspective that may be more suitable for specific circumstances and contexts. We were somewhat naive in thinking we could combine them into a single, unified framework.”

Another expert added that even with all the progress in resilience frameworks, ”They must be accompanied by organizational adaptability and proper coordination mechanisms. Only then can we determine which framework is the best.” He emphasized that for public organizations, internal resilience should come first, saying, ”It's always nice to be resilient against hazards, but if the organization itself is not resilient enough, even the best frameworks will become useless.” He also mentioned the importance of using social media data to build effective resilience frameworks.

Another expert highlighted his research on how context affects the use of frameworks. He said, ”For instance, BRIC (Building Resilient Infrastructure and Communities), a widely accepted framework, cannot be used in a global south country.” He added, ”Scientists, especially in the global south, often rely on theories developed in the global north, which may not be fully applicable to their contexts."

Another expert from a global north country shared a similar experience, saying, "Once we wanted to apply a declared universal framework in one of the most important provinces of our country; however, due to some minor differences between our culture and the culture of the origin country, we were about to make very wrong decisions." He emphasized, "No matter if the country is in the global south or north, we cannot have the same framework unless we can identify what needs to be changed. "

Decision-makers often prefer frameworks tailored to local conditions, as local adaptation is essential for effective resilience strategies. One expert emphasized, "While you might have a standard set of vulnerability assessments with many indicators, local relevance is crucial." Another expert pointed out a significant issue with decision-makers: "They often feel that the framework from academia is not fit for purpose, which is another consideration for why there are so many frameworks and why they are not widely adopted." This was highlighted by several other experts, who stated that despite the progress in this field, many conservative individuals in the industry still do not want to adapt and comply with resilient thinking.

Frameworks should also consider multiple hazards at once, providing a proper vulnerability assessment. An expert explained this complexity: "Communities can be vulnerable to multiple hazards simultaneously. This complexity adds to the challenge of creating a suitable vulnerability assessment." This perspective highlights that countries aiming for resilience must prepare for multiple hazards, often occurring at different times of the year. For example, the simultaneous risks of heat waves and flooding are a clear example of this challenge in the Netherlands.

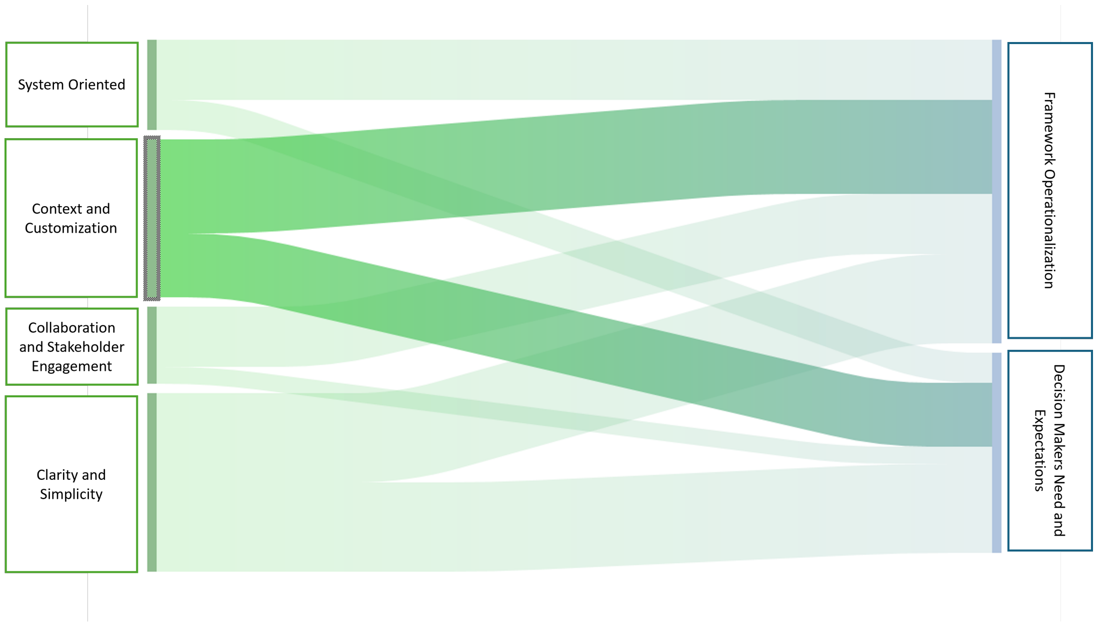


Figure 4.7: Context and Customization

4.4.2.3 System Oriented

While adaptability to local contexts is important, experts also emphasized that a more systematic perspective is required to ensure that frameworks account for all aspects of resilience (See Figure 4.8). This systematic approach helps integrate technical, social, and organizational factors, creating a comprehensive and operational framework.

Integral design, which incorporates various disciplines and stakeholder needs, can lead to more comprehensive and accepted solutions. As noted, ”Integral design, which incorporates various disciplines and stakeholder needs, can lead to more comprehensive and accepted solutions. However, it is important to maintain clarity about the project’s primary objectives and avoid diluting the focus by trying to address too many issues simultaneously”.

While system-oriented approaches are important from a framework operationalization perspective, they do not appear to be the primary concern for decision-makers, as reflected by the relatively narrower width in the Sankey diagram (See Figure 4.8). Decision-makers are more focused on practical, actionable solutions tailored to specific contexts rather than on whether a systematic perspective has been used.

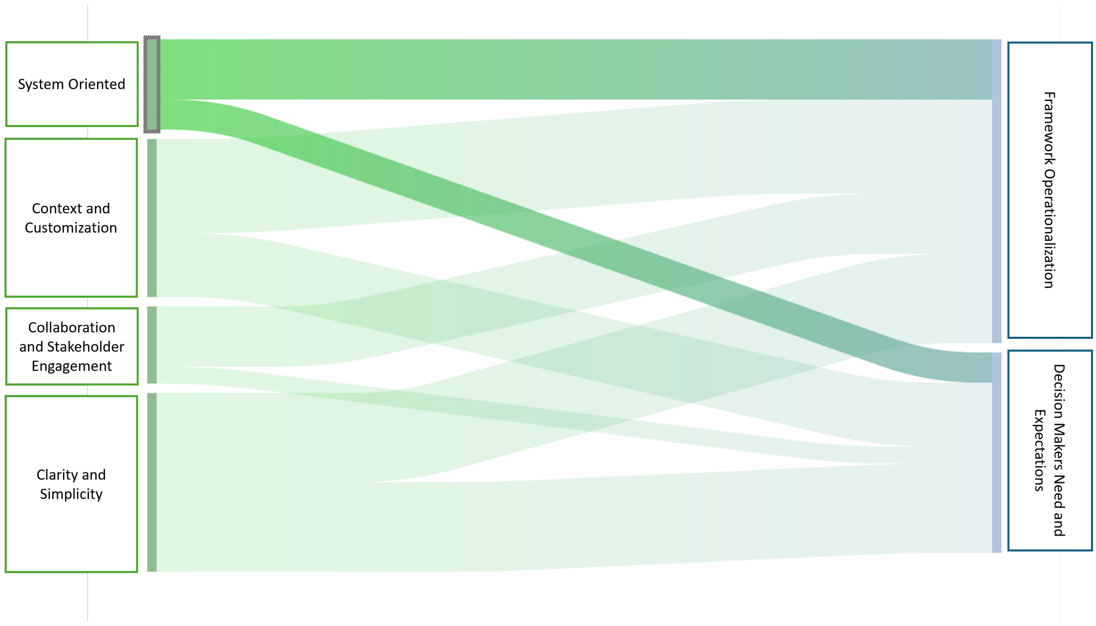


Figure 4.8: System Oriented

4.4.2.4 Collaboration and Stakeholder Engagement

Given the complexity of a systematic approach, collaboration with practitioners and stakeholders becomes essential (See Figure 4.9). By engaging experts from various fields, frameworks can better address the technical, social, and organizational elements necessary for resilience. Collaboration ensures that frameworks are not only comprehensive but also practical and grounded in real-world application.

Improving collaboration between scientists and practitioners is essential for better outcomes. Another expert emphasized, ”Efforts are being made to improve collaboration between scientists and practitioners for better outcomes.” Integrating inputs from various stakeholders ensures the frameworks are comprehensive, accepted, and implemented effectively.

Frameworks must be practical and easy to use, with clear, actionable strategies. Engaging end users throughout the development process ensures the frameworks meet their needs and are practical. One expert stated, ”Practitioners need to understand these strategies in a practical way to implement them effectively.” The substantial width of the ”Collaboration and Stakeholder Engagement” category in the Sankey diagram reflects its critical role in ensuring frameworks are effective and user-friendly.

Frameworks should work with available data while protecting sensitive information. This ensures that decision-makers can implement the frameworks effectively. Another expert suggested, ”Frameworks should be designed to work with the available data and protect sensitive information, and available data is usually the issue.” When stakeholders are involved in developing the framework, they can see the trade-offs and potential gains, which could help solve the issue of data availability.

Figure 4.9: Collaboration and Stakeholder Engagement

4.5 Conclusion

RQ1: What are the specific needs and expectations of decision-makers regarding coastal community resilience assessments that can be effectively integrated into the design of the new framework?

To address decision-makers specific needs and expectations, Figure 4.10 presents the critical factors and themes experts prioritize for resilience assessments. The width of each flow illustrates the relative importance placed on these factors.

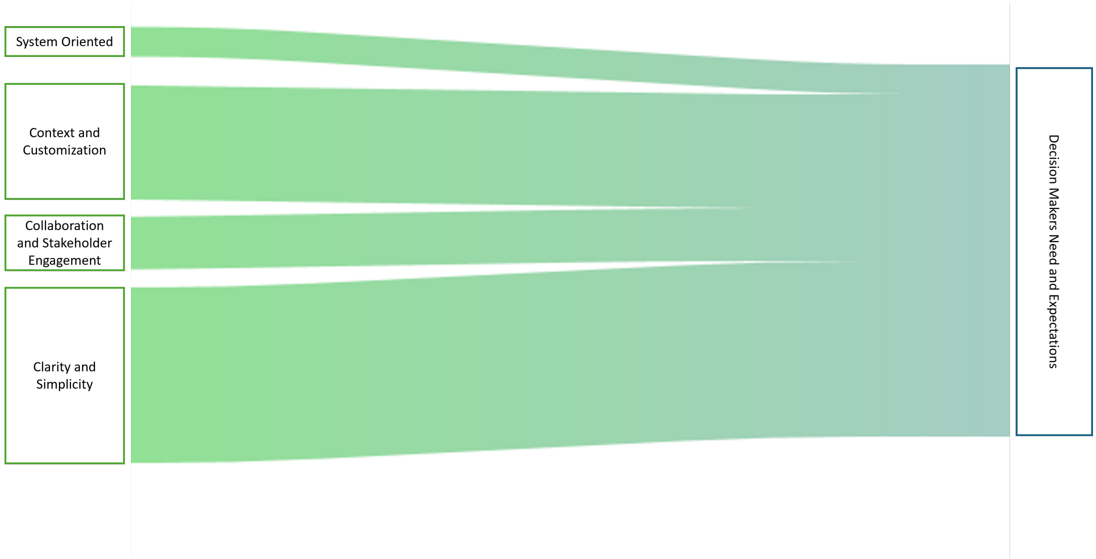


Figure 4.10: Factors Contribution to the Specific Needs and Expectations of Decision-makers

Experts prioritized clarity and simplicity in community resilience assessments. Decision-makers require frameworks that are straightforward, easy to understand, and free from jargon. This need for simplicity ensures that the frameworks are user-friendly and easily adaptable. One expert emphasized, ”Frameworks need to be easy to understand. No jargon or overly complicated concepts; make it clear and simple”. Additionally, policymakers are more likely to adopt frameworks that are cost-effective and express results in monetary terms. ”Frameworks need to work with minimal costs. Policymakers are more likely to adopt frameworks that are economical and can express results in monetary terms”. By focusing on these aspects, frameworks become more attractive and practical for decision-makers, facilitating their adoption and implementation.

While clarity and simplicity are vital for making frameworks user-friendly, decision-makers also emphasized the importance of adapting frameworks to specific local contexts. The need for context-specific and customizable frameworks ensures that resilience strategies are relevant and actionable in diverse regional settings. ”While you might have a standard set of vulnerability assessments with many indicators, local relevance is crucial”. This adaptability ensures that the assessments are relevant and effective, focusing on the unique needs of different regions. By addressing local specifics, frameworks can provide more precise and actionable insights.

Decision-makers prefer practical, actionable solutions tailored to their specific contexts rather than system-oriented approaches. They are focused on frameworks that offer clear guidance on steps to enhance resilience within their specific contexts. Their primary goal is to showcase progress during their election cycle, and they prefer simplicity and visible impact. Therefore, it is important to provide frameworks that deliver concrete, demonstrable results, ensuring that their actions are noticeable and effective.

Beyond clarity and customization, the effectiveness of resilience frameworks is also deeply influenced by how well they incorporate input from practitioners and stakeholders. Decision-makers expect frameworks to be developed collaboratively, ensuring they address the needs and realities of those implementing them. As noted, ”The framework shall be developed collaboratively with input from all relevant stakeholders, leading to more comprehensive and accepted solutions.” Engaging stakeholders throughout the development process helps in identifying and addressing the specific needs and constraints of different communities. this will make the frameworks more practical and applicable. By involving stakeholders in the development of the framework, it is possible to show the trade-offs and benefits, which can potentially solve the issue of data availability and enhance the overall effectiveness of the framework. By integrating these needs and expectations into the design of new resilience frameworks, it is possible to create tools that are not only scientifically sound but also practical and usable for decision-makers. This approach ensures that the frameworks can effectively guide and support community resilience efforts, leading to improved outcomes and greater acceptance among policymakers.

RQ4: How can the collected indicators be operationalized to ensure practicality and effectiveness in decision-making processes

Having explored the key needs and expectations of decision-makers, the focus now shifts to operationalizing these insights. RQ4 examines how the collected indicators can be made practical and effective in supporting decision-makers during the implementation phase. Figure 4.11 builds on the previous discussions by visually representing the factors that play a key role in operationalizing the resilience frameworks. These factors highlight the emphasis on context, clarity, and stakeholder collaboration as well.

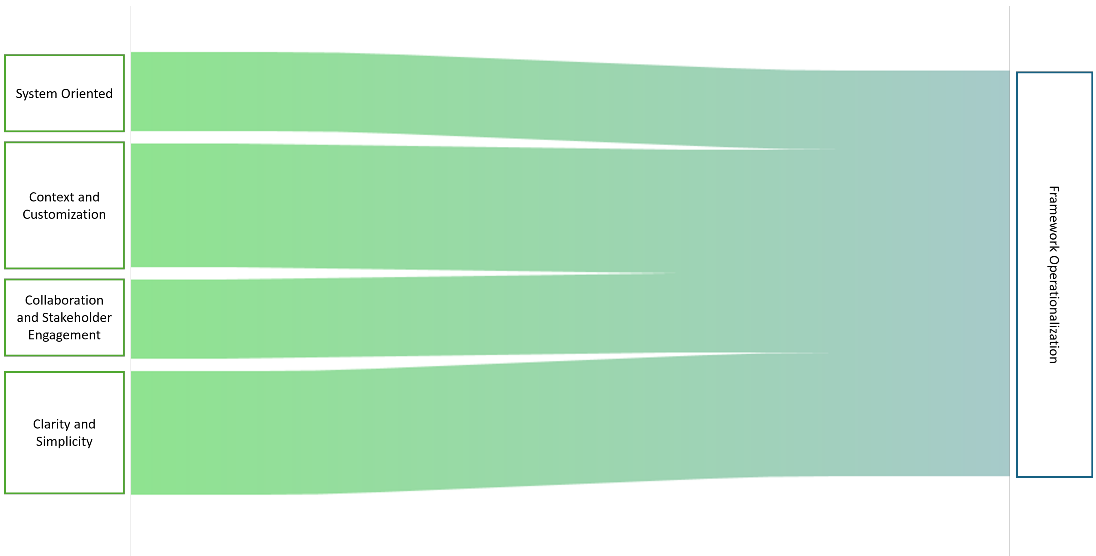


Figure 4.11: Factors Contribution to Framework Operationalization

The collected indicators should be aligned with the specific needs and priorities of decision-makers. This involves identifying which indicators are most relevant to the local context and ensuring that they provide actionable insights. By tailoring indicators to the unique conditions of each region, decision-makers can use them to make informed, context-specific decisions. As highlighted by one of the experts, ”While you might have a standard set of vulnerability assessments with many indicators, local relevance is crucial.”

Furthermore, only tailored indicators would not be enough. To ensure that indicators are practical and effective, it is essential to involve stakeholders in their selection and implementation. This collaborative approach helps understand the specific requirements of the stakeholders involved. One of the experts discussed the importance of this engagement: ”The framework shall be developed collaboratively with input from all relevant stakeholders, leading to more comprehensive and accepted solutions.”

To ensure that these frameworks are both practical and actionable, the indicators must align with the broader principles of clarity and contextual relevance. Simplifying the indicators ensures they can be easily understood and applied in diverse decision-making environments. One of the expert’s remarks emphasizes this need: ”Frameworks should be easy to comprehend.”

The operational indicators depend on the quality and accessibility of the data as well. Decision-makers need reliable, accurate, and timely data to make informed decisions. Furthermore, Decision-makers should be provided with tools and training for interpretation and use, including user-friendly dashboards and analytical tools.

4.6 Transition to Framework Calibration

The insights from the expert consultations in Chapter 4 highlighted the need for clarity, context-specific adaptability, and effective collaboration between stakeholders, which are integral for a practical framework. With these factors in mind, Chapter 5 explains the first part of the calibration process, where Principal Component Analysis (PCA) is used to refine the collected indicators.

CHAPTER

5

Calibration (Part A)

Indicator Refinement Using Principal Component Analysis

The Last Day of Pompeii by Karl Bryullov

Source: arthive.com

5 Calibration (Part A)

In this chapter, descriptive statistics will be applied to the importance ratings gathered from experts. Additionally, the first part of the framework calibration using Principal Component Analysis will be explored. Finally, the selection of the final indicators and the response to RQ3 will be provided.

5.1 The Role of Context in Framework Calibration

In the process of calibrating the framework, it is crucial to recognize that understanding the importance of individual indicators is only part of the task. As highlighted by the experts in Chapter 4, the framework must also be adaptable to the distinct environmental, cultural, and infrastructural factors that vary from one region to another. Simply knowing which indicators are important is not enough—those indicators must also be refined and adjusted to meet the specific challenges and priorities of different regions. This calibration process, therefore, allows the framework to strike a balance between generalizability and local relevance. By refining the framework's architecture in this way, we ensure that it is not only widely applicable but also precisely tailored to the needs and conditions of each community.

5.2 Descriptive Statistics

Now that the ratings from the experts have been gathered, it is important to assess their perspectives on each indicator and determine the level of importance assigned to them. For this matter, descriptive statistics were conducted on the four questionnaires. While all questionnaires were analyzed, this chapter focuses specifically on Questionnaire 1, as the same methodology was applied to the others. The analysis for the remaining questionnaires can be found in Appendix D.

The descriptive statistics for Questionnaire 1, which included 57 indicators, were analyzed to assess the importance levels assigned by the first group of six experts. The analysis focused on median and mean values, providing key insights into how each indicator was rated regarding its importance for coastal community resilience.

The mean ratings for the indicators in Q1 ranged from 0.333 (A5) to 1.000 (A25), with an overall mean of 0.708. Indicators such as A25, A3, A11, A15, and A19 received the highest possible ratings consistently, with means close to or exactly at 1.000. This suggests that these indicators were considered highly important by the experts. Most indicators have median values ranging from 0.5 to 1.0. For example, A1 has a median of 0.625, while A25 has a median of 1.0. This shows that for many indicators, at least half of the experts rated them as very important (0.75 or higher).

To further refine the analysis, the mean score for each indicator was calculated and sorted (See Table 5.1). Three distinct levels of importance emerged. Indicator A25, *"Disaster risk reduction measures integrated into post-disaster recovery and rehabilitation activities,"* was ranked as the highest priority, with an average rating of 1. This high rating highlights the crucial role of incorporating disaster risk reduction into recovery efforts to enhance resilience and sustainability (UNDRR, 2018). In contrast, A5, *"Land subdivision establishments,"* had the lowest average rating of 0.333, likely reflecting its perceived lower relevance to disaster risk reduction. According to Peacock et al. (2010), an establishment refers to a single physical location where business is conducted, which may explain its lower ranking due to its less immediate impact on resilience.

The intermediate indicators, with mean scores ranging from 0.333 to 1, reflect varying levels of importance. For instance, A31 (*Adult education and training programs*), A54 (*Mangrove deterioration due to salinity*), and A47 (*Land use stability*) were categorized as medium-rated indicators. Adult education is crucial for preparing communities to respond effectively to disasters, with research showing that disaster training significantly improves preparedness, knowledge, and values related to disaster risk reduction (Ayuningtyas et al., 2023). Mangrove deterioration is also a significant concern, as mangroves serve as natural barriers against storm surges; their loss exacerbates the vulnerability of coastal areas during extreme weather events (Raihan et al., 2023). Similarly, land use stability plays a vital role in mitigating disaster impacts by preventing construction in high-risk areas, thereby reducing the exposure of vulnerable populations to disasters (Roy & Ferland, 2015).

As noted in Chapter 4, the indicators in each questionnaire are organized into five main dimensions: organizational, social, economic, environmental, and infrastructure. For Q1, the ratings revealed a clear emphasis on organizational indicators, which were the most highly rated (See Table 5.2), while social indicators received less attention (See Table 5.3). This finding is particularly relevant in the context of climate change and associated hazards, as well as several factors that contribute to this trend.

Table 5.1: Questionnaire 1 Indicators Importance Level

Indicators	Mean	Importance Level
A25	1	High
A19	0.958	High
A23	0.958	High
A24	0.958	High
A55	0.917	High
A3	0.917	High
A11	0.917	High
A15	0.917	High
A2	0.875	High
A18	0.875	High
A37	0.875	High
A51	0.875	High
A9	0.792	High
A17	0.792	High
A44	0.792	High
A20	0.75	High
A32	0.75	High
A41	0.75	High
A45	0.75	High
A48	0.75	High
A57	0.75	High
A13	0.708	Medium
A22	0.708	Medium
A31	0.708	Medium
A49	0.708	Medium
A7	0.708	Medium
A21	0.708	Medium
A42	0.708	Medium
A52	0.708	Medium
A28	0.708	Medium
A47	0.708	Medium
A54	0.708	Medium
A12	0.667	Low
A56	0.667	Low
A1	0.625	Low
A46	0.625	Low
A53	0.625	Low
A43	0.625	Low
A14	0.625	Low
A27	0.625	Low
A40	0.583	Low
A33	0.583	Low
A6	0.583	Low
A50	0.583	Low
A8	0.583	Low
A29	0.542	Low
A30	0.542	Low
A10	0.542	Low
A16	0.5	Low
A34	0.5	Low
A36	0.5	Low
A39	0.458	Low
A4	0.458	Low
A38	0.458	Low
A26	0.417	Low
A35	0.417	Low
A5	0.333	Low

Organizational indicators cover leadership, coordination, and disaster management plans, which are crucial for quick and effective disaster response and recovery. These aspects are often prioritized because they form the backbone of a well-organized disaster management strategy and make sure that resources are used efficiently and efforts are well-coordinated (Boin, 2003; Comfort, 2002).

In the organizational dimension, A25 received the highest average rating of 5. Another highly-rated indicator is A24, with an average rating of 4.83. A24 represents *the availability of evacuation centers*, highlighting the importance of having accessible and well-established places for people to go during emergencies. According to Ayashm et al. (2023), evacuation is the first stage of emergency management, and two criteria have to be considered for it. The evacuation centers must be in a ”Safe Space” and a ”Safe building” to be effective. A23, which focuses on *the adequacy of trained emergency response teams*, also has an average rating of 4.83. This high rating reflects the importance of having skilled personnel ready to respond to emergencies effectively. However, this can be challenging. According to Ghabili et al. (2012), during the earthquake of Ahar and Varzaqan in northwestern Iran, medical air assistance could not rescue the survivors during the night, which slowed down the rescue operation considerably.

On the lower end, A22 received lower ratings, showing that it is seen as less important in this context. A21, which deals with *coordination with NGOs and political leaders*, also had lower ratings. This suggests there may be challenges in working together effectively with these groups during a disaster, or it might be the case that these indicators cannot be considered important for community resilience. However, if we look at these indciators with the first perspective, There is often unnecessary conflict between government and non-governmental organizations (NGOs) in disaster governance (Mubah, 2013). For example, after the Aceh tsunami 2004, NGOs had considerably low coordination with the local government. The local government claimed that these organizations did not understand local capacities, and language became a barrier. On the other hand, NGOs mainly accused the Indonesian government of not responding quickly to disasters in general (Mubah, 2013).

Table 5.2: Organizational Dimension (Questionnaire 1)

Organizational Dimension Experts Group 1 (Q1)

	EX 1	EX 2	EX 3	EX 4	EX 5	EX 6	mean	min	25%	50%	75%	max
A17	4	5	4	3	4	5	4.17	3	4	4	5	5
A18	4	5	4	5	4	5	4.5	4	4	5	5	5
A19	5	5	5	5	4	5	4.83	4	5	5	5	5
A20	4	4	4	5	2	5	4	2	4	4	5	5
A21	3	5	4	5	3	3	3.83	3	3	4	5	5
A22	3	4	4	5	2	5	3.83	2	3	4	5	5
A23	4	5	5	5	5	5	4.83	4	5	5	5	5
A24	5	4	5	5	5	5	4.83	4	5	5	5	5
A25	5	5	5	5	5	5	5	5	5	5	5	5

Social indicators play a crucial role in resilience, but they may not be seen as immediately important due to their longer-term impact and less direct benefits compared to organizational structures (Adger, 2003). Despite this, building social resilience is key to ensuring communities can adapt and reduce their long-term vulnerability to climate-related hazards (Norris et al., 2007).

For example, A37, related to *physician access*, received the highest rating in the social dimension (4.5), reflecting the importance of having medical professionals available during disasters. Health facilities are vital as they serve as safe spaces for the vulnerable (Ghabili et al., 2012). However, the availability of medical staff can depend on individual risk assessments, as some may choose to stay on duty, while others may not (Iserson et al., 2008).

Similarly, A32, rated at 4, emphasizes the need to integrate disaster risk reduction (DRR) into educational curriculums. This indicator is important since educating communities, particularly those focused on children, and teaching them about disaster preparedness can enhance proactive responses during emergencies (Pratiwi et al., 2023). A multidisciplinary approach, such as integrating geography and sociology, can address various aspects of disaster management and fulfill this importance (Pratiwi et al., 2023).

On the other hand, specific indicators like A26 (*Race and Ethnicity*) and similar were rated lower. However, the role of race in disaster response is complex and varies based on context. While diversity in social networks can enhance response effectiveness, communication across different ethnic groups can be challenging (Fothergill et al., 1999; Murray & Zautra, 2011). This highlights both the potential advantages and difficulties in addressing ethnicity during emergencies.

Table 5.3: Social Dimension (Questionnaire 1)

Social Dimension Experts Group 1 (Q1)

	EX 1	EX 2	EX 3	EX 4	EX 5	EX 6	mean	min	25%	50%	75%	max
A26	1	1	3	3	3	5	2.67	1	1.5	3	3.5	5
A27	3	4	3	4	4	3	3.5	3	3	3.5	4	4
A28	4	4	4	5	3	3	3.83	3	3.75	4	4	5
A29	1	4	5	3	2	4	3.17	1	2.5	3	4.5	5
A30	3	1	4	3	3	5	3.17	1	3	3	4	5
A31	4	4	3	5	2	5	3.83	2	3.5	4	4.5	5
A32	3	4	3	5	4	5	4	3	3.75	4	4.25	5
A33	4	5	4	3	3	1	3.33	1	3	3.5	4	5
A34	2	3	4	3	2	4	3	2	2.5	3	3.5	4
A35	3	3	3	3	2	2	2.67	2	2.5	3	3	3
A36	3	3	4	3	3	2	3	2	2.5	3	3	4
A37	5	4	4	5	4	5	4.5	4	4	4.5	5	5
A38	4	3	2	3	3	2	2.83	2	2.5	3	3	4
A39	2	4	4	2	3	2	2.83	2	2	3	3.5	4
A40	2	1	5	4	3	5	3.67	1	3	4	5	5

5.3 Principal Component Analysis

In the descriptive statistics section, it was observed that some indicators were rated as more important than others based on the survey results. However, this is only one perspective on the data. Descriptive statistics provide a snapshot of the data, much like a ruler with two ends, offering insights into the most and least important indicators. Relying only on descriptive statistics might cause us to overlook other important trends hidden within the survey results. In the next sections, the focus will be on analyzing Questionnaire 1 using PCA. The steps will show how PCA uncovered important patterns that weren't visible with basic statistics. The analysis of the rest of the questionnaires is provided in Appendix D.

As mentioned in Research Design, PCA was used to refine the indicators and reduce the amount of the data gathered from the expert consultation phase while ensuring the essential data loss is kept to a minimum. Before running the analysis, the survey results were normalized and standardized to fit within 0 to 1 values. The process started by calculating the covariance matrix for the four questionnaires (Q1 to Q4). Next, Eigenvalues and Eigenvectors were computed to determine how much variance each component explained. The loading matrix was then derived, and by squaring the loadings, the contribution matrix was created. Finally, the contribution matrix was sorted to identify which indicators had the most significant contribution to the principal components.

5.3.1 Principal Components Retainment

One of the first steps of PCA analysis is to retain certain principal components. To determine the optimal number of principal components to retain, three key factors were considered: the explained variance (See Table 5.4), the eigenvalues, and the scree plot (See Figure 5.1). First, we looked at the explained variance. The goal was to capture between 50-60% of the total variance, and the first two components explained 56.22%—with PC1 accounting for 34.72% and PC2 for 21.49%. This made the first two components a good fit for providing a substantial amount of the total variance.

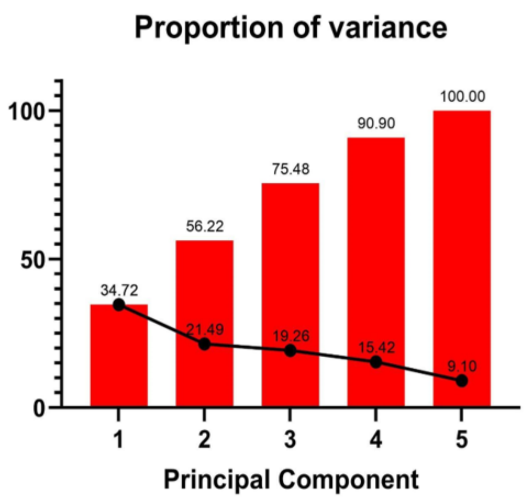
Next, eigenvalues were examined using the Kaiser-Guttman criterion, which suggests retaining components with eigenvalues greater than one, as they explain more variance than the average variable. The first component had an eigenvalue of 1.10, indicating a strong contribution, while the second component had an eigenvalue of 0.68. Even though only the first component strictly met this criterion, the second component was still retained because it added meaningful variance.

Lastly, the scree plot provided visual confirmation. It showed a steep drop in the amount of variance explained after the first component, followed by a gradual decline. This ”elbow” in the plot indicated that adding more components would contribute less to explaining the variance, making it reasonable to stop at two. Together, these three factors supported the decision to retain the first two principal components.

Table 5.4: Tabular Result Questionnaire 1

Tabular Result					
Table Analyzed	Q1				
PC summary	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	1.1	0.679	0.609	0.487	0.288
Proportion of variance	34.72%	21.49%	19.26%	15.42%	9.10%
Cumulative proportion of variance	34.72%	56.22%	75.48%	90.90%	100.00%
Component selection	Selected	Selected			

Data summary	
Total number of variables	57
Total number of components	5
Component selection method	All PCs
Number of selected components	5
Rows in table	6
Rows skipped (missing data)	0
Rows analyzed (#cases)	6



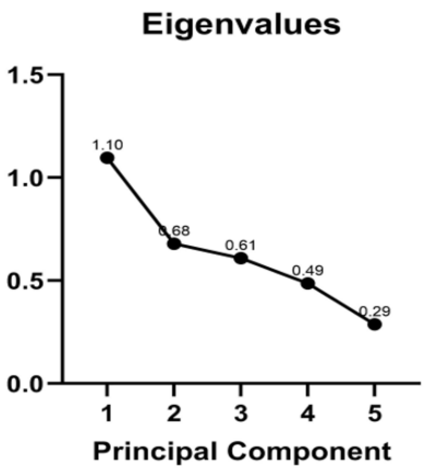


Figure 5.1: Proportion of Variance Questionnaire 1 and Eigenvalues of Principal Components Questionnaire 1

5.3.2 Loadings and Contributions

After retaining the first two components, the loading matrix was analyzed to assess each indicator's contribution to PC1 and PC2. Indicators with high loadings were identified as having a strong impact, with a threshold of 0.0175 (1/57) set to define significant contributors. Indicators exceeding this value were considered significant. It is important to note that their significance reflects their sensitivity to variance rather than overall importance.

To illustrate the contributions, The loadings diagram (See Figure 5.2) shows how each indicator is linked to the first two components. Indicators further from the center had higher loadings, which indicates greater contributions. However, due to the high number of indicators, concluding the result from the diagram was not possible. Therefore, The contribution matrix, which multiplies squared loadings by component eigenvalues, was created.

According to the contribution matrix, A13, A16, A40, and A46 are key contributors. Furthermore, Indicators A13, A33, A40, and A26 reveal an interesting dynamic between PCA contributions and expert ratings (See Table 5.5). Despite a "Medium" importance rating, A13 is a significant PC contributor, suggesting variability in expert opinions. Similarly, A33 and A40, rated as "Low," and A26, also rated "Low," show strong PCA contributions.

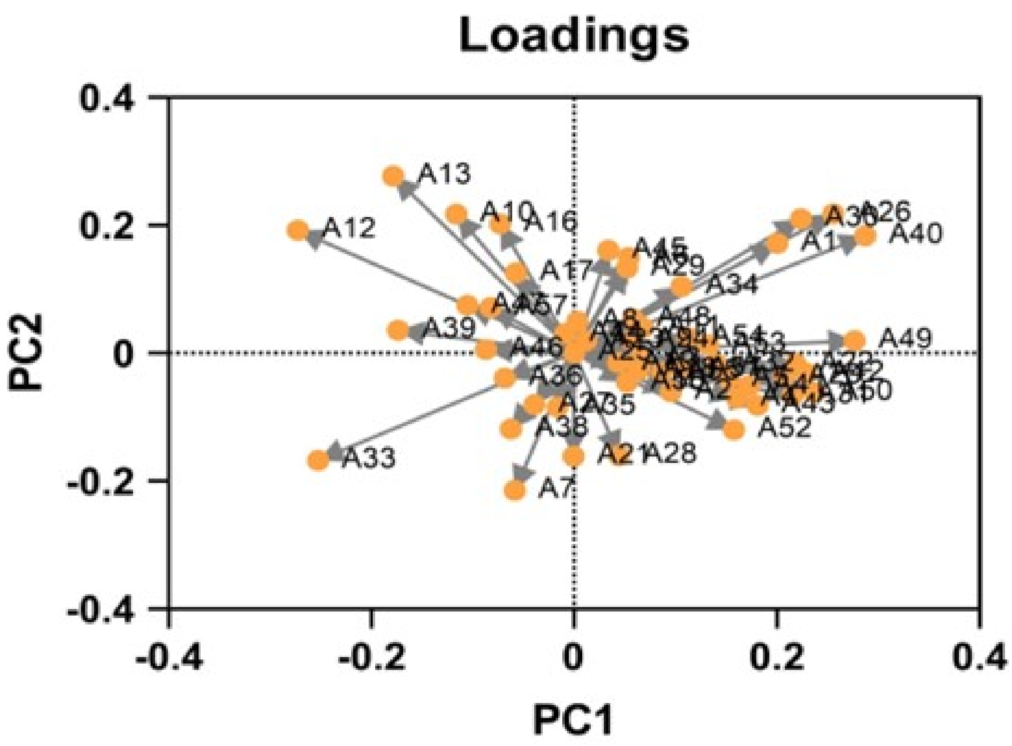


Figure 5.2: Loadings Diagram Questionnaire 1

Table 5.5: Indicators: Importance Levels, Means, and PCA Contributions

Indicator	Importance Level	Mean	Contribution to PC1/PC2
A13	Medium	0.708	High
A40	Low	0.583	High
A46	High	0.750	High
A33	Low	0.583	High
A26	Low	0.583	High

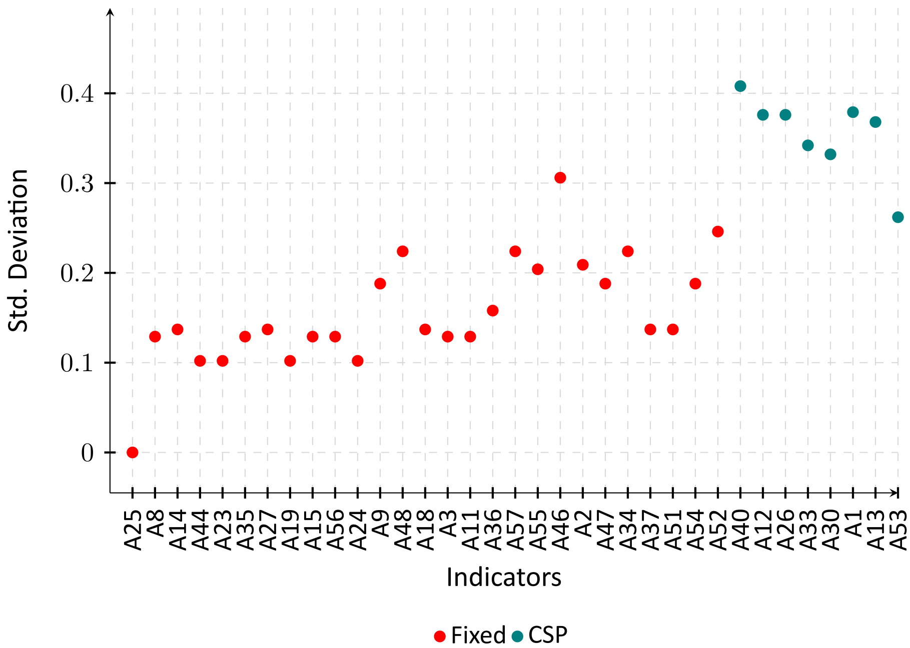
5.4 Indicator Calibration

Before starting with the calibration process of the indicators, indicators had to be selected using the outputs of PCA. Indicators were selected based on their contributions to the principal components. Indicators with contributions above the 0.0175 threshold were considered significant contributors. These indicators were then sorted by their contributions to PC1 and PC2, and duplicates were removed to focus on unique indicators for each component (See Figure 5.3).

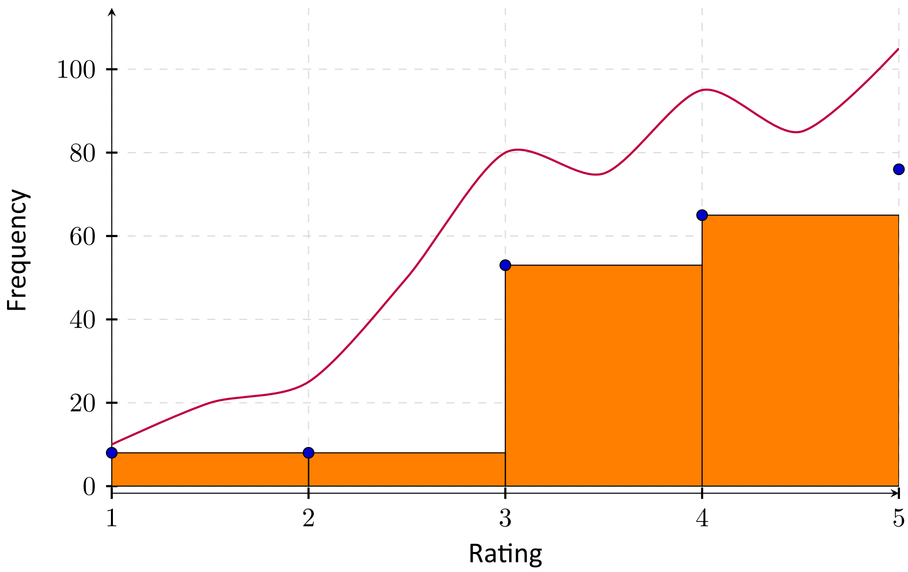
For the calibration process, the standard deviation (Variance) of the indicators is used as a criterion to identify the proper precision level for the indicators. Having said that, the calibration process identified two types of indicators: ”fixed indicators,” characterized by low variance and strong expert agreement, and ”context-specific indicators,” which exhibit high variance and less agreement. Fixed indicators are generally consistent across different situations, while context-specific indicators vary based on the context.

Several indicators, including A25 (Disaster risk reduction measures integrated into post-disaster recovery), A44 (Gross regional domestic product per capita), A8 (Road use vs. overall land use), A14 (Housing units with available vehicles), A23 (Adequacy of trained emergency response teams), A35 (Land subdivision workers), and A27 (Percent of rural population), showed minimal contributions to the principal components in the PCA analysis. This indicates their limited impact on overall variance, suggesting low sensitivity to context. Interestingly, despite high importance ratings by experts, such as for A25, A23, and A35, their low PCA contributions reveal that they do not capture significant context-specific variations.

In contrast, indicators like A40 (Place attachment), A26 (Race/ethnicity), A30 (Gender income equality), and A13 (Internet service providers) demonstrated higher contributions to PCA, indicating their significance in capturing variance and their sensitivity to different contexts. Unlike fixed indicators, these context-specific indicators not only hold importance but also reflect variations in different scenarios.



(a) Standard deviations of indicators by type.



(b) Frequency distribution of ratings with Kernel Density Estimation.

Figure 5.3: Standard deviations of indicators and the distribution of ratings.

As every selection has a removal, some indicators were removed using PCA based on the components retained during the analysis (See Table 5.7). While the Kaiser criterion, which keeps components with eigenvalues above 1, is a common method, this research used the explained variance method to decide which components to keep. Although the Kaiser criterion could have been used to keep fewer components and remove more indicators, this was not ideal because it might have led to losing important information. The chosen approach ensures that the most important data is retained.

To make the analysis more precise, the calibration process added another layer of detail to the indicators. Previously, by using descriptive statistics like mean values of ratings, it became clear which indicators were more or less important. This works well for fixed indicators, as their importance stays consistent across different situations, making it easier for decision-makers to set priorities. However, this does not apply to context-specific indicators, as their importance changes depending on the situation. Only when these indicators are looked at in their specific context can their importance be judged, similar to fixed indicators. Due to layout and readability considerations, the full table with all the details has not been included in the report. Please contact the author to obtain complete information.

5.5 Conclusion

RQ3: What key indicators ensure a multi-dimensional approach to assessing coastal community resilience to hazards, with universal applicability or flexibility for specific contexts?

After conducting the indicator mining from the literature and consulting the indicators with the experts, we managed to identify the importance of these indicators. Each indicator in itself has a value and is key to understanding the community resilience of coastal communities. However, indicators must be calibrated to be more understandable and useful. The Expert ratings and the calibration process suggest that the selected indicators can be classified into two types: ”fixed” and ”context-specific” potential indicators. The first type relates to the indicators that experts had a strong consensus about, with relatively low variance in ratings. The second type relates to the indicators that experts did not have a consensus about and have the potential to be specific to different contexts. This is evidenced by the high variance of ratings among different experts.

A total of 110 indicators were identified as fixed indicators that ensure a multi-dimensional approach to assessing coastal community resilience to hazard with potentially universal applicability (See Table 5.6). For instance, In the infrastructure dimension, indicators like *”Road use compared to overall land use”* and *”Occupied housing units with vehicle available”* are crucial. The former evaluates the percentage of land allocated to roads, offering insights into transportation infrastructure’s impact (Dasgupta & Shaw, 2015). The latter measures the number of households with at least one vehicle, highlighting mobility and accessibility (Peacock et al., 2010). Access to vehicles for evacuation is vital, although socio-economic factors, like poverty levels, influence vehicle ownership. For instance, in the Netherlands, public transportation might reduce the need for cars, while in the context of Hurricane Katrina, high poverty levels were linked to limited evacuation resources (Masozera et al., 2007).

In the organizational dimension, indicators such as *"Disaster risk reduction measures integrated into post-disaster recovery"* and *"Adequacy of trained emergency response teams"* are essential. These assess the inclusion of disaster risk reduction (DRR) in recovery efforts and the availability of trained personnel, both critical in effective disaster response.

Social indicators reflect demographic and health factors. For example, the *"Percent of rural population"* impacts resource distribution and accessibility, while *"Physician access"* gauges healthcare availability by measuring the number of doctors per 10,000 people. The ability of healthcare professionals to perform under pressure is also a significant consideration.

The economic dimension includes indicators like *"Gross regional domestic product (GRDP) per capita"* and *"Hazard insurance coverage."* GRDP per capita reflects regional economic performance (Kusumastuti et al., 2014), while hazard insurance coverage tracks the percentage of homes insured against disasters (Cimellaro et al., 2016). GRDP per capita can have mixed effects. As noted by Fischer (2021), economic performance may improve temporarily in affected and neighboring areas after a disaster due to increased demand, but this effect is often short-lived. In contrast, Raddatz (2009) argues that frequent natural disasters, such as climate-related events, negatively impact long-term real GDP per capita.

A total of 24 indicators were identified as context-specific. For example, *Race/Ethnicity*, which some experts rated as important while others did not, shows how these indicators can vary based on the situation. Organizational indicators like *"Transparency in aid distribution"* also vary, with experts noting that countries in the Global South often face different challenges compared to the Global North in terms of transparency and aid accountability.

In the environmental dimension, the *"Rate of sea-level rise"* indicator, though rated highly important, had significant variance, as sea-level rise impacts differ by region. Experts agree that local context must be considered when assessing the importance of this indicator, given the variation in sea-level changes due to regional factors.

Table 5.6: Refined Indicators After Calibration

Code	Dimension	Category	Indicator Name	Reference
A8	Infrastructure	Transportation and Communication	Road use compared to overall land use	Dasgupta and Shaw (2015)
A14	Infrastructure	Housing	Occupied housing units with vehicle available	Peacock et al. (2010)
A15	Infrastructure	Housing	Percent of houses living under the avg. flood line	Dasgupta and Shaw (2015)
A9	Infrastructure	Transportation and Communication	Status of Jetties and inter-island communication	Dasgupta and Shaw (2015)
A3	Infrastructure	Community Services and Facilities	Hospitals	Peacock et al. (2010)
A11	Infrastructure	Utilities and Energy Infrastructure	Quality of service / network accessibility	Dasgupta and Shaw (2015)
A2	Infrastructure	Infrastructure Establishments	Highway, street, and bridge construction establishments	Peacock et al. (2010)
B11	Infrastructure	Utilities and Energy Infrastructure	Percent population having mobile phone	Dasgupta and Shaw (2015)
B13	Infrastructure	Utilities and Energy Infrastructure	Number of hours of average disruption of electricity supply	Dasgupta and Shaw (2015)
B3	Infrastructure	Community Services and Facilities	Ambulances	Peacock et al. (2010)
B5	Infrastructure	Community Services and Facilities	Licensed child care facilities	Peacock et al. (2010)
B12	Infrastructure	Utilities and Energy Infrastructure	Percent population having access to electricity	Dasgupta and Shaw (2015)
B8	Infrastructure	Community Services and Facilities	Industrial resupply potential	Cimellaro et al. (2016)
B4	Infrastructure	Community Services and Facilities	Community food service facilities	Peacock et al. (2010)
B14	Infrastructure	Housing	Percent of population in co-operative housing	Dasgupta and Shaw (2015)
C6	Infrastructure	Community Services and Facilities	Distribution commercial facilities	Cimellaro et al. (2016)
C9	Infrastructure	Transportation and Communication	Evacuation routes	Cimellaro et al. (2016)
C8	Infrastructure	Transportation and Communication	Weather accessible roads compared to the existing road network	Dasgupta and Shaw (2015)
C3	Infrastructure	Community Services and Facilities	Nursing homes	Peacock et al. (2010)
C2	Infrastructure	Community Services and Facilities	Hospital beds	Peacock et al. (2010)
C4	Infrastructure	Community Services and Facilities	Newspaper publishers	Peacock et al. (2010)
C10	Infrastructure	Utilities and Energy Infrastructure	Percent population having alternative source of electricity in case of disruption	Dasgupta and Shaw (2015)
C14	Infrastructure	Housing	Percent of population living extremely close to hazardous activity (port/industry)	Dasgupta and Shaw (2015)
D7	Infrastructure	Community Services and Facilities	Gas	Cimellaro et al. (2016)
D4	Infrastructure	Community Services and Facilities	Temporary shelters	Peacock et al. (2010)
D15	Infrastructure	Housing	Temporary housing availability	Cimellaro et al. (2016)
D5	Infrastructure	Community Services and Facilities	Property and casualty insurance establishments	Peacock et al. (2010)
D9	Infrastructure	Transportation and Communication	Availability of emergency vehicle/boats	Dasgupta and Shaw (2015)
A25	Organizational	Development and Preparedness	Disaster risk reduction measures integrated into post disaster recovery and rehabilitation activities	Cimellaro et al. (2016)
A23	Organizational	Resource Allocation	Adequacy of trained emergency response team	Dasgupta and Shaw (2015)
A19	Organizational	Policy and Planning	Availability of emergency aids	Dasgupta and Shaw (2015)
A24	Organizational	Development and Preparedness	Availability of evacuation centre	Dasgupta and Shaw (2015)
A18	Organizational	Policy and Planning	Funds allocation to Disaster Risk Reduction activities	Dasgupta and Shaw (2015)
B23	Organizational	Development and Preparedness	Existence of early warning system	Dasgupta and Shaw (2015)
B18	Organizational	Policy and Planning	Implementation of rainwater harvesting scheme	Dasgupta and Shaw (2015)
B20	Organizational	Coordination and Collaboration	Performance regimes-nearest metro area	Cutter et al. (2014)
B19	Organizational	Policy and Planning	Contingency plan degree including an outline strategy for postdisaster recovery and reconstruction	Cimellaro et al. (2016)

Table 5.6 (Continued)

Code	Dimension	Category	Indicator Name	Reference
B21	Organizational	Coordination and Collaboration	Coordination with neighboring blocks	Dasgupta and Shaw (2015)
C17	Organizational	Policy and Planning	Implementation of Disaster Insurance Statutory aid to victims	Dasgupta and Shaw (2015)
C20	Organizational	Coordination and Collaboration	Information sharing & risk communication with the community	Dasgupta and Shaw (2015)
C19	Organizational	Policy and Planning	Frequency of DRR training organized by the block	Dasgupta and Shaw (2015)
C18	Organizational	Policy and Planning	Nuclear plant accident planning	Cutter et al. (2014)
C16	Organizational	Policy and Planning	Integration of Disaster Risk Reduction in developmental activities	Dasgupta and Shaw (2015)
C23	Organizational	Resource Allocation	Local institutions' access to financial reserves to support effective disaster response and early recovery	Cimellaro et al. (2016)
C21	Organizational	Coordination and Collaboration	Collaboration Mechanisms Establishments	Courtney et al. (2008)
D16	Organizational	Policy and Planning	Implementation flood/erosion control	Dasgupta and Shaw (2015)
D22	Organizational	Resource Allocation	Available Technical and Financial Support Mechanisms	Courtney et al. (2008)
D21	Organizational	Coordination and Collaboration	Coordination among government departments	Dasgupta and Shaw (2015)
D23	Organizational	Resource Allocation	Local government access to resources and expertise to assist victims of psychosocial impacts of disasters	Cimellaro et al. (2016)
D17	Organizational	Policy and Planning	Implementation of regular developmental plans	Dasgupta and Shaw (2015)
D20	Organizational	Coordination and Collaboration	Performance regimes-state capital	Cutter et al. (2014)
D19	Organizational	Policy and Planning	Crop insurance coverage	Cutter et al. (2014)
A27	Social	Demographics	Percent of rural population	Dasgupta and Shaw (2015)
A36	Social	Workforce	Property and casualty insurance workers	Peacock et al. (2010)
A34	Social	Workforce	Environment and conservation workers	Peacock et al. (2010)
A37	Social	Health Related	Physician access	Cutter et al. (2014)
B26	Social	Demographics	Gender	Cimellaro et al. (2016)
B38	Social	Governance related	Cultural resources	Cimellaro et al. (2016)
B31	Social	Education - Related	Education programs on disaster risk reduction and disaster preparedness for local communities	Cimellaro et al. (2016)
B33	Social	Education - Related	Colleges, universities, and professional schools employees	Peacock et al. (2010)
B32	Social	Education - Related	Child and elderly care programs	Cimellaro et al. (2016)
B37	Social	Demographics	Religious organizations	Cimellaro et al. (2016)
B34	Social	Workforce	Population employed in legal services	Peacock et al. (2010)
C27	Social	Demographics	Percentage of population covered by governmental safety department approved mitigation plan	Peacock et al. (2010)
C35	Social	Workforce	Female labor force participation	Cimellaro et al. (2016)
C36	Social	Health Related	Food provisioning capacity	Cimellaro et al. (2016)
C32	Social	Workforce	Population employed in scientific research and development services	Peacock et al. (2010)
C33	Social	Workforce	Environmental consulting workers	Peacock et al. (2010)
C29	Social	Money Related	Homeownership	Cimellaro et al. (2016)
C26	Social	Demographics	Percentage of population covered by zoning regulations	Peacock et al. (2010)
C30	Social	Education - Related	Citizen awareness of evacuation plans or drills for evacuations	Cimellaro et al. (2016)
C31	Social	Education - Related	English language competency	Cutter et al. (2014)
C28	Social	Demographics	Pre-retirement age	Cutter et al. (2014)

Table 5.6 (Continued)

Code	Dimension	Category	Indicator Name	Reference
C39	Social	Governance related	Population participating in community rating system	Cimellaro et al. (2016)
C34	Social	Workforce	Landscape architects and planners	Peacock et al. (2010)
D38	Social	Governance related	Professional associations/organizations	Peacock et al. (2010)
D32	Social	Workforce	Fire fighters, prevention, and law enforcement workers	Peacock et al. (2010)
D36	Social	Health Related	Non-special needs	Cutter et al. (2014)
D26	Social	Demographics	Percent backward/tribal population	Dasgupta and Shaw (2015)
D29	Social	Money Related	Poverty	Cimellaro et al. (2016)
D35	Social	Workforce	Building inspectors	Peacock et al. (2010)
D25	Social	Demographics	Family stability	Cimellaro et al. (2016)
D34	Social	Workforce	Architecture and engineering workers	Peacock et al. (2010)
A44	Economical	Economic Development	Gross regional domestic product (GRDP) per capita	Kusumastuti et al. (2014)
A46	Economical	Economic Development	Research and development firms	Cimellaro et al. (2016)
B43	Economical	Economic Development	Tax revenues	Cimellaro et al. (2016)
B45	Economical	Insurance and Protection	Hazard insurance coverage	Cimellaro et al. (2016)
B44	Economical	Economic Development	Emergency fund	Kusumastuti et al. (2014)
C42	Economical	Occupation	Percent of population lives on coastal resources	Dasgupta and Shaw (2015)
C46	Economical	Insurance and Protection	Population with health insurance	Peacock et al. (2010)
D45	Economical	Insurance and Protection	Livestock protection management in a disaster	RIMES & BRAC (2022)
D40	Economical	Occupation	Percent of population lives on Eco–tourism	Dasgupta and Shaw (2015)
D41	Economical	Business Related	Large retail-regional/national geographic distribution	Cutter et al. (2014)
D44	Economical	Economic Development	Trade openness	Noy en Yonson (2018)
A56	Environmental	Environmental Management	Chemical pollution in mangrove food chain	Dasgupta and Shaw (2015)
A48	Environmental	Earth - Soil Related	Protected land	Cimellaro et al. (2016)
A57	Environmental	Environmental Management	Local food suppliers	Cutter et al. (2014)
A55	Environmental	Environmental Management	Integration of Natural hazard Maps in planning	Dasgupta and Shaw (2015)
A47	Environmental	Earth - Soil Related	Land use stability	Cimellaro et al. (2016)
A51	Environmental	Climate Related	Physical impact caused by sea level rise	Dasgupta and Shaw (2015)
A54	Environmental	Vegetation and species	Mangrove deterioration (loss of species) due to salinity	Dasgupta and Shaw (2015)
A52	Environmental	Climate Related	Population affected by contaminated water	Dasgupta and Shaw (2015)
B49	Environmental	Climate Related	Availability of freshwater (surface+subsurface)	Dasgupta and Shaw (2015)
B46	Environmental	Earth - Soil Related	Soil quality	Cimellaro et al. (2016)
B50	Environmental	Climate related	Flood occurrence and degree of damage	Dasgupta and Shaw (2015)
B55	Environmental	Environmental Management	Efficient energy use	Cutter et al. (2014)
C51	Environmental	Climate Related	Heavy tidal inceptions causing substantial damage	Dasgupta and Shaw (2015)
C53	Environmental	Vegetation and species	Natural flood buffers	Cutter et al. (2014)
C56	Environmental	Environmental Management	Control in Deep aquifer pumping	Dasgupta and Shaw (2015)
D52	Environmental	Vegetation and species	Living species	Cimellaro et al. (2016)
A12	Infrastructure	Utilities and Energy Infrastructure	Radio stations	Peacock et al. (2010)
A1	Infrastructure	Infrastructure Establishments	Building construction establishments	Peacock et al. (2010)
A13	Infrastructure	Utilities and Energy Infrastructure	Internet service providers	Peacock et al. (2010)
C11	Infrastructure	Utilities and Energy Infrastructure	Implementation of renewable source of energy (Solar/wind etc.)	Dasgupta and Shaw (2015)
D12	Infrastructure	Utilities and Energy Infrastructure	Television broadcasting	Peacock et al. (2010)

Table 5.6 (Continued)

Code	Dimension	Category	Indicator Name	Reference
D11	Infrastructure	Utilities and Energy Infrastructure	Owner-occupied housing units with telephone service	Peacock et al. (2010)
B17	Organizational	Policy and Planning	Administrative initiatives for coastal greenings	Dasgupta and Shaw (2015)
B22	Organizational	Resource Allocation	Development of forestry & Plantation at administrative initiatives	Dasgupta and Shaw (2015)
C22	Organizational	Resource Allocation	Transparency in Aid distribution process	Dasgupta and Shaw (2015)
A40	Social	Place Attachment	Place attachment-not recent immigrants	Cutter et al. (2014)
A26	Social	Demographics	Race/ethnicity	Cimellaro et al. (2016)
A33	Social	Workforce	Building construction workers	Peacock et al. (2010)
A30	Social	Money Related	Gender income equality	Cimellaro et al. (2016)
B29	Social	Money Related	Race/ethnicity income equality	Cimellaro et al. (2016)
B25	Social	Demographics	Population stability	Cimellaro et al. (2016)
C40	Social	Governance related	Emergency community participation	Cimellaro et al. (2016)
D31	Social	Education - Related	Citizen disaster preparedness and response skills	Cutter et al. (2014)
C43	Economical	Business Related	Professional and business services	Cimellaro et al. (2016)
A53	Environmental	Vegetation and species	Total mass of organisms	Cimellaro et al. (2016)
B53	Environmental	Vegetation and species	Ecological buffer	Kotzee en Reyers (2016)
B51	Environmental	Climate related	Change in tidal patterns leading to river piracy/damage to dykes	Dasgupta and Shaw (2015)
D50	Environmental	Climate related	Rate of sea level rise in the block	Dasgupta and Shaw (2015)
D49	Environmental	Climate related	River water salinity	Dasgupta and Shaw (2015)
D51	Environmental	Vegetation and species	Density of green vegetation across an area	Cimellaro et al. (2016)

Table 5.7: Removed Indicators through PCA

Code	Dimension	Category	Indicator Name	Reference
A4	Infrastructure	Community Services and Facilities	Hotels and Motels	(Peacock et al., 2010)
A5	Infrastructure	Community Services and Facilities	Land subdivision establishments	(Peacock et al., 2010)
A6	Infrastructure	Community Services and Facilities	Environment and conservation establishments	(Peacock et al., 2010)
A7	Infrastructure	Community Services and Facilities	Economic infrastructure exposure	(Cimellaro et al., 2016)
A10	Infrastructure	Transportation and Communication	Provision of fishermen tracking systems	(Dasgupta & Shaw, 2015)
A16	Infrastructure	Housing	Community Housing	(Peacock et al., 2010)
B1	Infrastructure	Infrastrcuture Establishments	Heavy and civil engineering construction establishments	(Peacock et al., 2010)
B2	Infrastructure	Infrastrcuture Establishments	Building inspection establishments	(Peacock et al., 2010)
B6	Infrastructure	Community Services and Facilities	Legal services establishments	(Peacock et al., 2010)
B7	Infrastructure	Community Services and Facilities	Scarcity of drinking water and seasonal variation of water availability	(Dasgupta & Shaw, 2015)
B9	Infrastructure	Transportation and Communication	Percent of waterways compared to overall land use	(Dasgupta & Shaw, 2015)
B10	Infrastructure	Transportation and Communication	School and employee buses	(Dasgupta & Shaw, 2015)
B15	Infrastructure	Housing	Sturdier housing types	(Cutter et al., 2014)
C1	Infrastructure	Infrastrcuture Establishments	Architecture and engineering establishments	(Peacock et al., 2010)
C5	Infrastructure	Community Services and Facilities	Implication of waste water disposal and treatment facility	(Dasgupta & Shaw, 2015)
C7	Infrastructure	Community Services and Facilities	Colleges, Universities, and Professional schools	(Dasgupta & Shaw, 2015)
C12	Infrastructure	Utilities and Energy Infrastructure	Service quality (Frequency of dropout or distribution failure etc.)	(Dasgupta & Shaw, 2015)
C13	Infrastructure	Housing	Percent of population with informal (slum etc.) settlements	(Dasgupta & Shaw, 2015)
C15	Infrastructure	Housing	Housing units	(Peacock et al., 2010)
D1	Infrastructure	Infrastrcuture Establishments	Landscape architecture and planning establishments	(Peacock et al., 2010)
D2	Infrastructure	Infrastrcuture Establishments	Utility systems construction establishments	(Peacock et al., 2010)
D3	Infrastructure	Community Services and Facilities	Fire stations	(Peacock et al., 2010)
D6	Infrastructure	Community Services and Facilities	Environmental consulting establishments	(Peacock et al., 2010)
D8	Infrastructure	Community Services and Facilities	Scientific research and development establishments	(Cimellaro et al., 2016)
D10	Infrastructure	Transportation and Communication	Access and evacuation	(Cimellaro et al., 2016)
D13	Infrastructure	Utilities and Energy Infrastructure	Percent of population having radio/television	(Dasgupta & Shaw, 2015)
D14	Infrastructure	Housing	Vacant housing units	(Peacock et al., 2010)
A17	Organizational	Policy and Planning	Developed Policies and Plans	(Courtney et al., 2008)

Table 5.7 (Continued)

Code	Dimension	Category	Indicator Name	Reference
A20	Organizational	Policy and Planning	Implemented and Monitored Community Development Plans, Policies and Programs	Courtney et al. (2008)
A21	Organizational	Coordination and Collaboration	Coordination with political leaders	Dasgupta and Shaw (2015)
A22	Organizational	Coordination and Collaboration	Coordination with NGO	Dasgupta and Shaw (2015)
B16	Organizational	Policy and Planning	Mitigation spending	Cimellaro et al. (2016)
B24	Organizational	Development and Preparedness	Adequacy of manpower in existing block administration	Dasgupta and Shaw (2015)
C24	Organizational	Development and Preparedness	Accessible Basic Services (i.e. water, transportation, security, etc.)	(Courtney et al., 2008)
C25	Organizational	Development and Preparedness	The proximity to the administrative headquarters	Dasgupta and Shaw (2015)
D18	Organizational	Policy and Planning	Off-disaster activities of Block Disaster Management Authority	Dasgupta and Shaw (2015)
D24	Organizational	Development and Preparedness	Public-Private partnerships in developmental activities	Dasgupta and Shaw (2015)
A28	Social	Demographics	Percentage of rural population	Peacock et al. (2010)
A29	Social	Demographics	Percentage of population covered by comprehensive plan	Cimellaro et al. (2016)
A31	Social	Education Related	Adult education and training programs	Cimellaro et al. (2016)
A32	Social	Education Related	Integration of disaster risk reduction in educational curriculum	Cimellaro et al. (2016)
A35	Social	Workforce	Land subdivision workers	Peacock et al. (2010)
A38	Social	Governance related	Commercial establishments	Cimellaro et al. (2016)
A39	Social	Governance related	Political engagement	Cimellaro et al. (2016)
B27	Social	Demographics	Population distribution	Cimellaro et al. (2016)
B28	Social	Demographics	Percentage of population covered by building codes	Peacock et al. (2010)
B30	Social	Money Related	Income	Cimellaro et al. (2016)
B35	Social	Workforce	Heavy and civil engineering construction workers	Peacock et al. (2010)
B36	Social	Health Related	Mental health support	Cutter et al. (2014)
C37	Social	Governance related	Business associations/organizations	Peacock et al. (2010)
C38	Social	Governance related	Social capital-civic organizations	Cutter et al. (2014)
D27	Social	Demographics	Social capital: disaster volunteerism	Cimellaro et al. (2016)
D28	Social	Demographics	Equity	Cimellaro et al. (2016)
D30	Social	Education Related	Educational attainment equality	Cimellaro et al. (2016)
D33	Social	Workforce	Population employed in special need transportation services	Peacock et al. (2010)
D37	Social	Governance related	Recreational centers(bowling, fitness, golf clubs) and sport organizations	Peacock et al. (2010)
D39	Social	Governance related	Place attachment-native born residents	Cutter et al. (2014)

Table 5.7 (Continued)

Code	Dimension	Category	Indicator Name	Reference
A41	Economical	Occupation	Non-dependence on primary/tourism sectors	Cutter et al. (2014)
A42	Economical	Business Related	Business establishments	Peacock et al. (2010)
A43	Economical	Business Related	Manufacturing	Cimellaro et al. (2016)
A45	Economical	Economic Development	Financial resource equity	Cimellaro et al. (2016)
B39	Economical	Occupation	Occupation	Cimellaro et al. (2016)
B40	Economical	Occupation	Women employment	(RIMES & BRAC, 2022)
B41	Economical	Business Related	Business size	Cutter et al. (2014)
B42	Economical	Business Related	Business development rate	Cimellaro et al. (2016)
C41	Economical	Occupation	Public government employment	Cutter et al. (2014)
C44	Economical	Economic Development	Literacy rate	Dasgupta and Shaw (2015)
C45	Economical	Economic Development	Annual Average Growth Rate	Dasgupta and Shaw (2015)
D42	Economical	Business Related	Access to financial institutes	(RIMES & BRAC, 2022)
D43	Economical	Economic Development	Income per capita	(Noy & Yonson, 2018)
A49	Environmental	Climate related	Contamination of ground water in coastal aquifers (e.g., Arsenic)	Dasgupta and Shaw (2015)
A50	Environmental	Climate related	Air Pollution	Cimellaro et al. (2016)
B47	Environmental	Earth - Soil Related	Loss of soil fertility (agricultural impact)	Dasgupta and Shaw (2015)
B48	Environmental	Earth - Soil Related	Coastal erosion and degree of damage	Dasgupta and Shaw (2015)
B52	Environmental	Vegetation and Species	Undeveloped forest	Cimellaro et al. (2016)
B54	Environmental	Environmental Management	Monitoring and Maintenance of Environmental Databases	Dasgupta and Shaw (2015)
C47	Environmental	Earth - Soil Related	Natural subsidence	Dasgupta and Shaw (2015)
C48	Environmental	Earth - Soil Related	Arable cultivated land	Cimellaro et al. (2016)
C49	Environmental	Earth - Soil Related	Wetland variation	Cimellaro et al. (2016)
C50	Environmental	Climate related	Cyclone occurrence and degree of damage	Dasgupta and Shaw (2015)
C52	Environmental	Climate related	Loss of shorelines/permanent inundation area	Dasgupta and Shaw (2015)
C54	Environmental	Vegetation and Species	Bio-shielded coastline	Dasgupta and Shaw (2015)
C55	Environmental	Environmental Management	Efficient Water Use	Cutter et al. (2014)
D46	Environmental	Earth - Soil Related	Pervious surfaces	Cimellaro et al. (2016)
D47	Environmental	Earth - Soil Related	Protective measures (bouldering/cementing) to control erosion	Dasgupta and Shaw (2015)
D48	Environmental	Climate related	Water quality/quantity	Cimellaro et al. (2016)
D53	Environmental	Environmental Management	Implementation of Environmental Protection Act	Dasgupta and Shaw (2015)
D54	Environmental	Environmental Management	Involvement of Scientific communities in Environmental R & D	Dasgupta and Shaw (2015)
D55	Environmental	Environmental Management	Chemical contamination mitigation	Dasgupta and Shaw (2015)

CHAPTER
6

Calibration (Part B)

Modifying Indicators for Local Relevance

The Scream by Edvard Munch

Source: arthive.com

6 Calibration (Part B)

The Calibration (Part B) chapter refines the indicators for a specific context, starting with an overview of how the Netherlands addresses coastal hazards and a general background of Zeeland province. Then, the exploratory scan process will be discussed. This chapter serves as a guideline and offers a blueprint for other communities to refine the indicators for their context by following the outlined procedure.

6.1 Netherlands and Sea Level Rise

Climate change has accelerated sea-level rise, posing a serious threat to coastal regions, especially in the Netherlands, where much of the land lies below sea level. Advanced models, such as the Marine Ice Cliff Instability (MICI) and Structured Expert Judgment (SEJ), project a rise of over 15 meters by 2300 in worst-case scenarios (KNMI, 2023) (See Figure 6.1). However, more moderate estimates suggest a rise of 0.3 to 1 meter by 2100, depending on global emissions and adaptation efforts (KNMI, 2023). While these levels are less extreme, this rapid sea-level rise still threatens the safety of both infrastructure and communities.

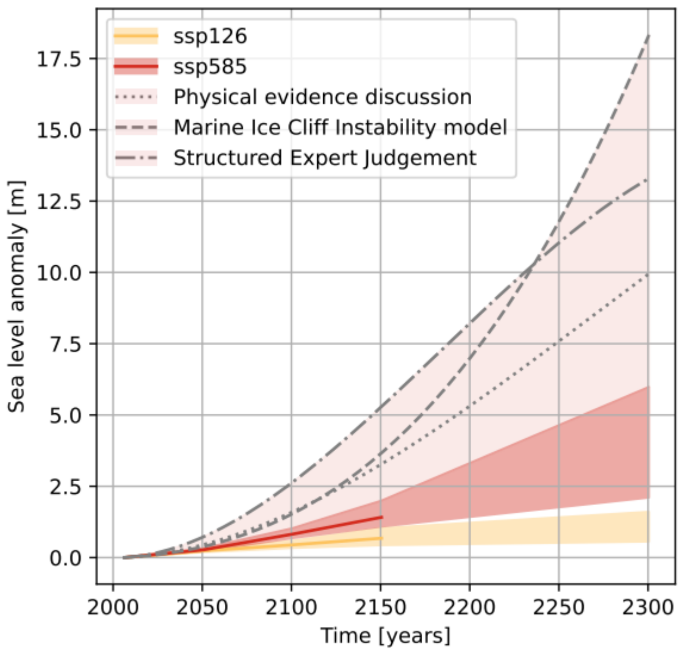


Figure 6.1: Scenarios up to 2300 of the sea level in the Netherlands. (KNMI, 2023)

The Royal Netherlands Meteorological Institute (KNMI) and international bodies like the Intergovernmental Panel on Climate Change (IPCC) have consistently warned that unless substantial efforts are made to mitigate climate change, coastal communities worldwide, including in the Netherlands, will face increasing risks. According to Carter et al. (2018), the northwest coasts of Europe are more exposed to coastal hazards than the average level of exposure across the continent (See Figure 6.2). While the Netherlands has an extensive network of coastal defenses, including levees, dunes, and storm surge barriers, these systems are already under pressure. As sea levels rise and storms become more frequent and intense, these defenses may no longer be enough to protect vulnerable areas. This is particularly important because they are intended to safeguard the Dutch coastline, which, according to that rely on them for safety and stability.

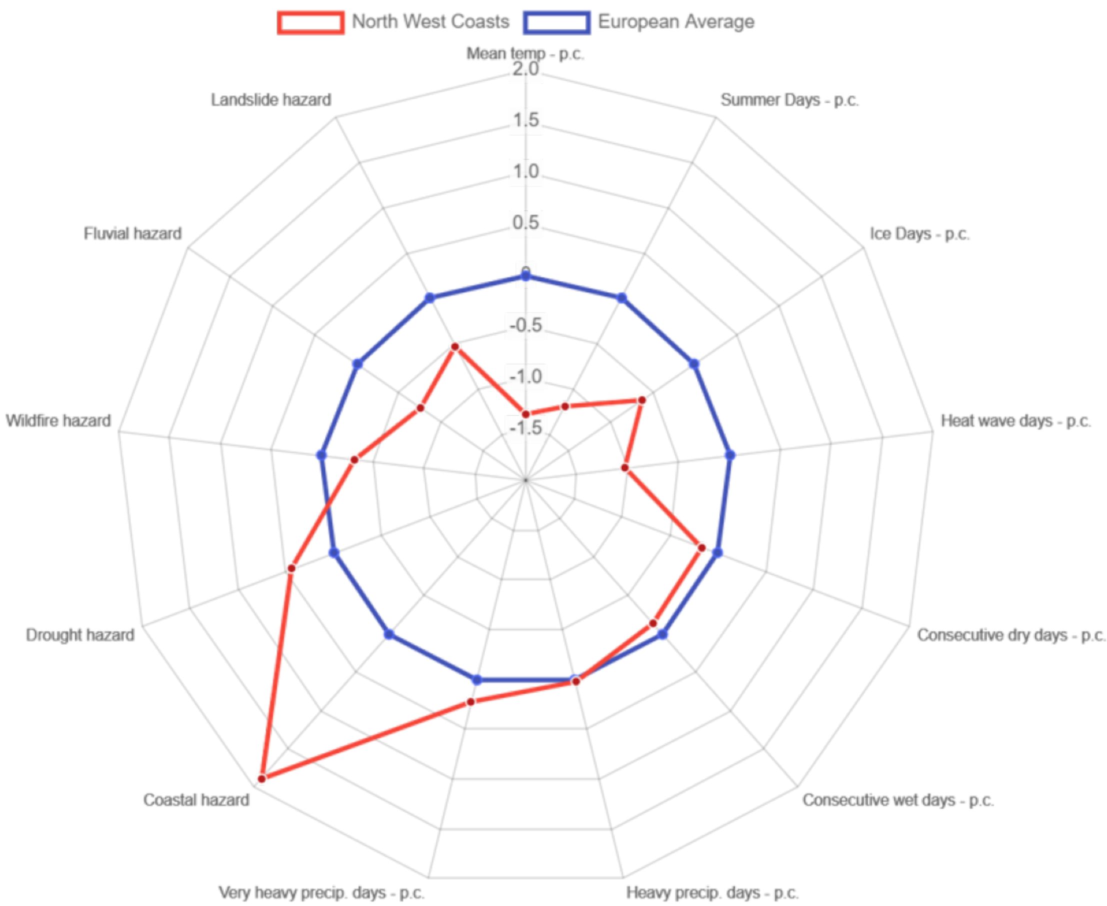


Figure 6.2: Spider diagram comparing hazard frequency of northwest coasts of Europe to the European average (Carter et al., 2018)

According to VNK Project Office (2016), not all structures face equal risk, with some levees and coastal defenses particularly vulnerable based on their location and environmental conditions (Figure 6.5). For example, ”piping” — a process where water seeps beneath levees, eroding the underlying soil — poses a significant threat in areas where rivers remain at high levels for prolonged periods. While these threats are present in river-adjacent regions, coastal defenses and other critical infrastructure systems (See Figure 6.3), such as dunes, roads, railways, and barriers, will also be affected.

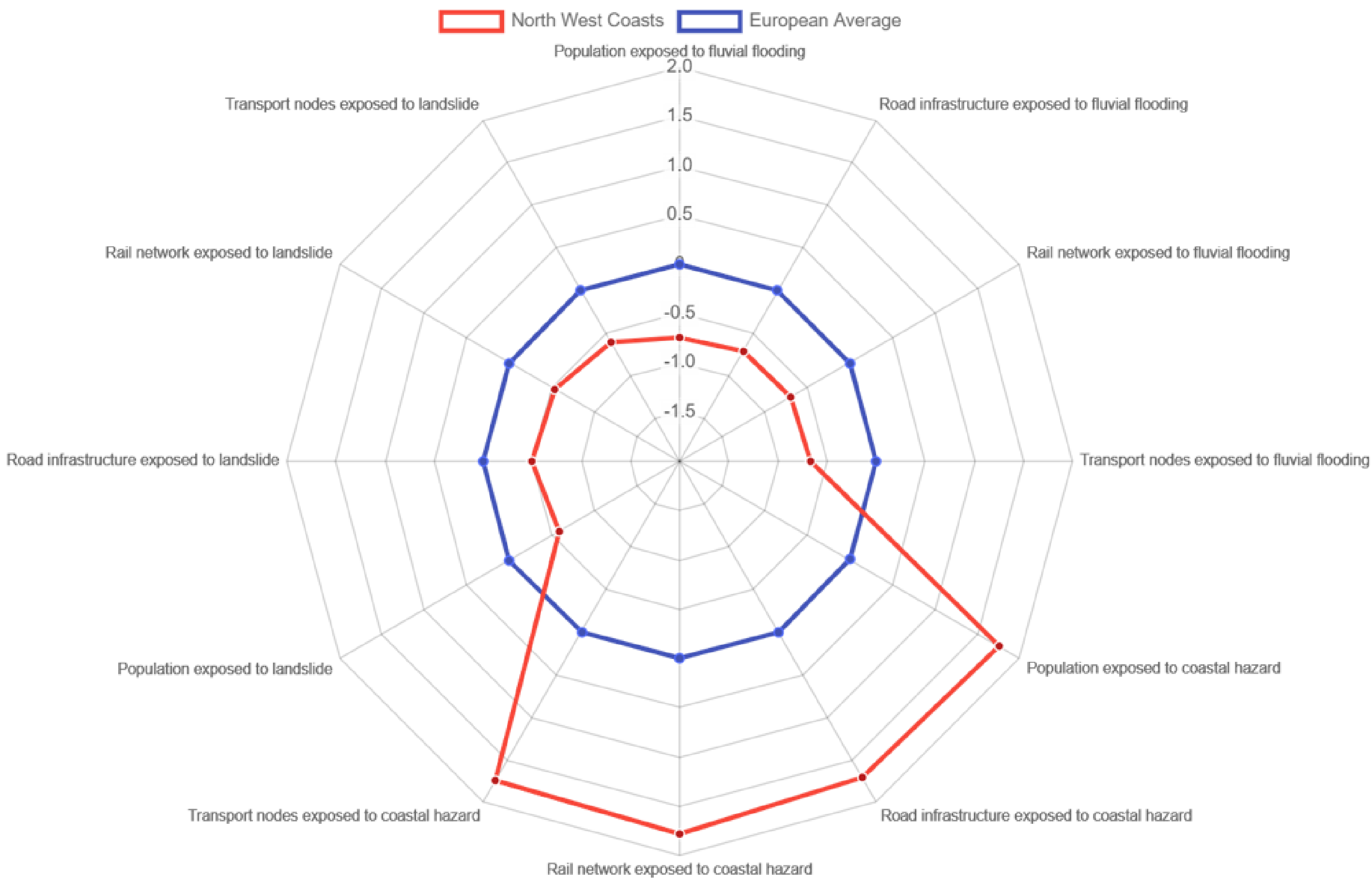


Figure 6.3: Spider diagram comparing hazard exposure of northwest coasts of Europe to the European average (Carter et al., 2018)

Beyond the physical risk, VNK Project Office (2016) emphasizes the broader socio-economic consequences of flooding. The risk to human life is notably higher in certain regions where levee failures could result in substantial casualties (See Figure 6.6). Meanwhile, coastal areas protected by dunes typically experience a lower individual risk, though breaches in these defenses could still result in severe consequences.

Furthermore, Financial risk is another major concern, particularly in densely populated and economically crucial regions like the Randstad (See Figure 6.4). A flood in these areas could cause billions of euros in damages, impacting homes, businesses, and essential infrastructure (Figure 6.7).

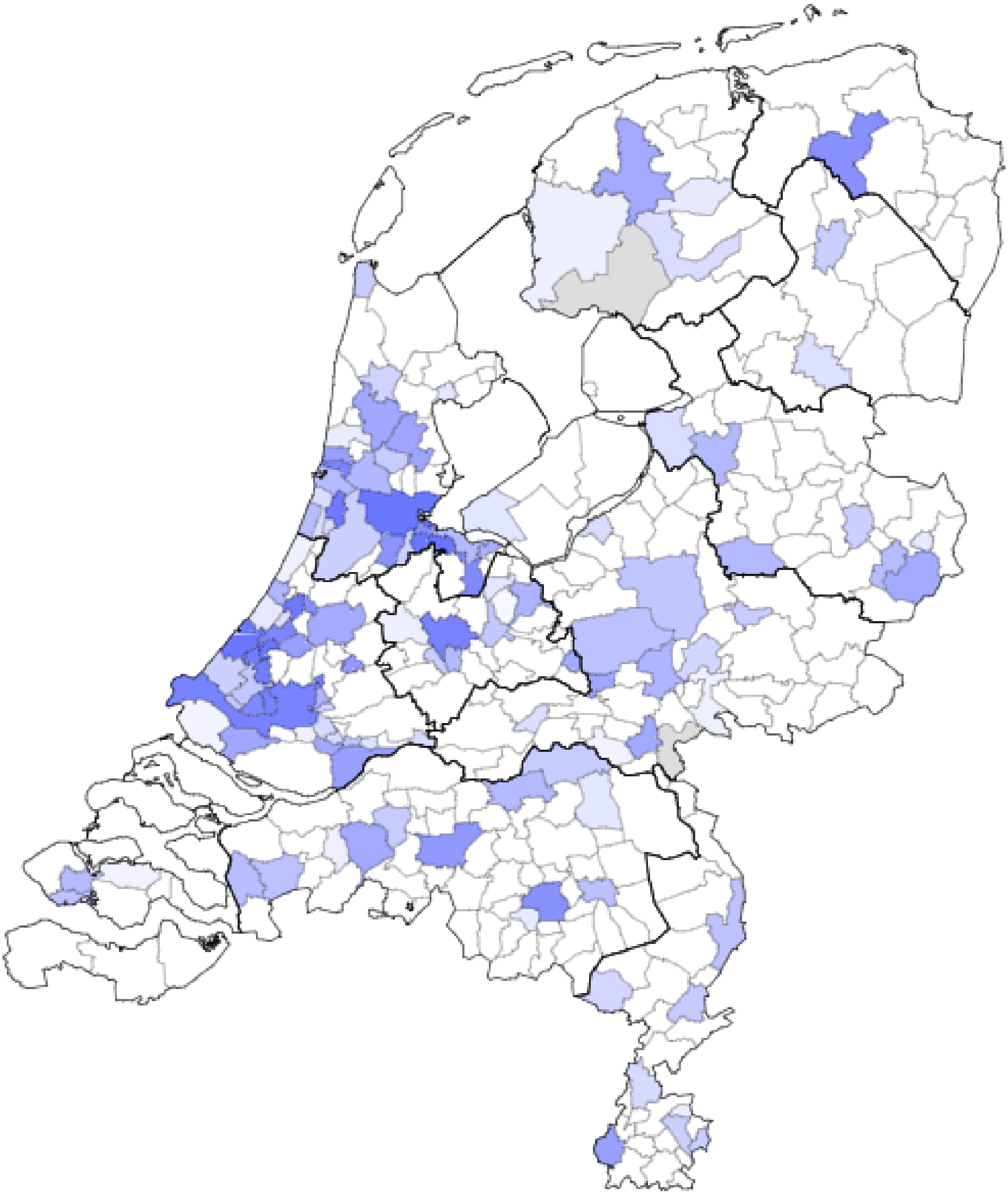


Figure 6.4: Urbanization in The Netherlands. Source: citypopulation.de

Figure 6.5: The Failure Probability of Hydraulic Structures in the Netherlands (VNK Project Office, 2016)

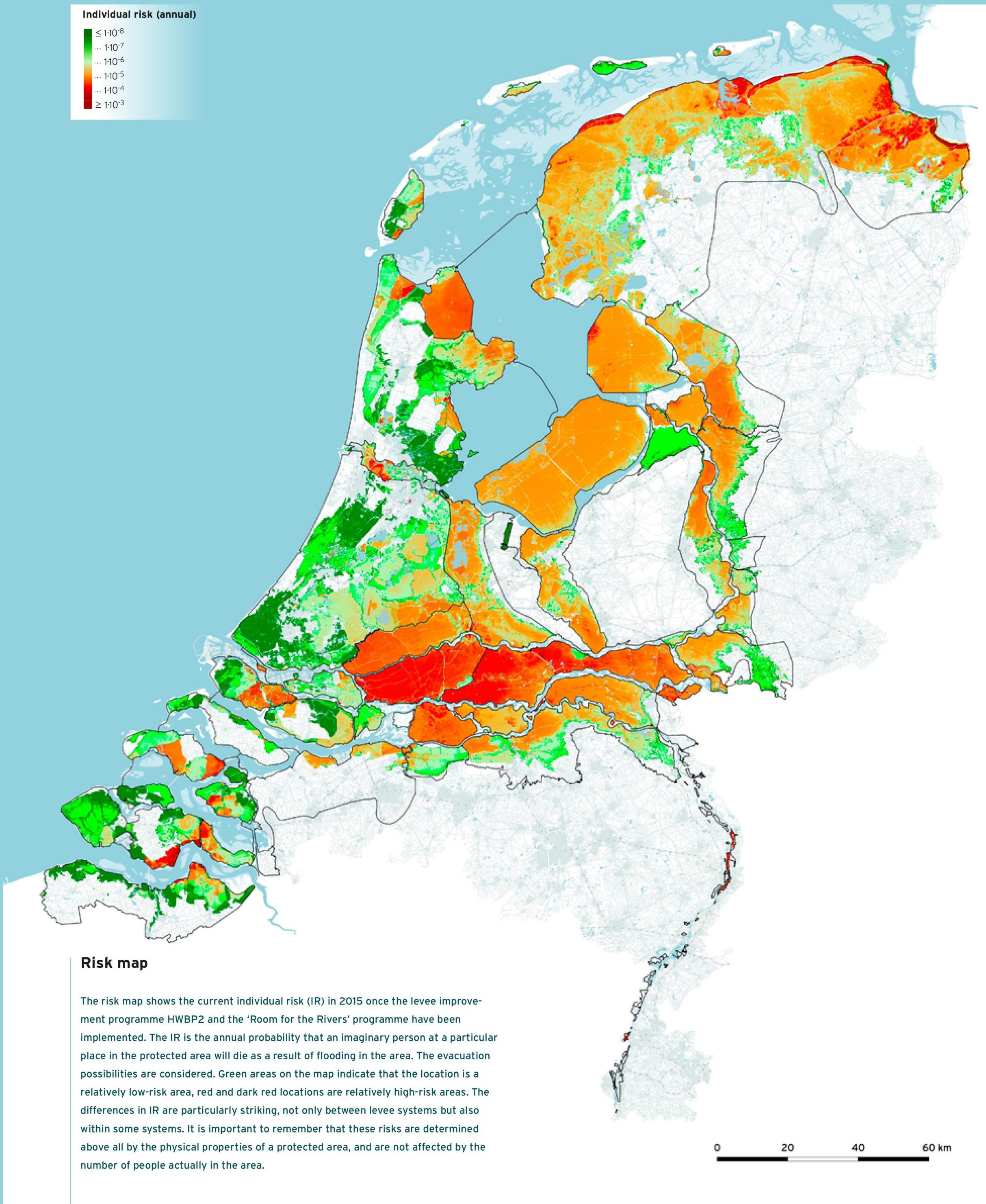


Figure 6.6: The map of individual risk in the Netherlands (VNK Project Office, 2016)

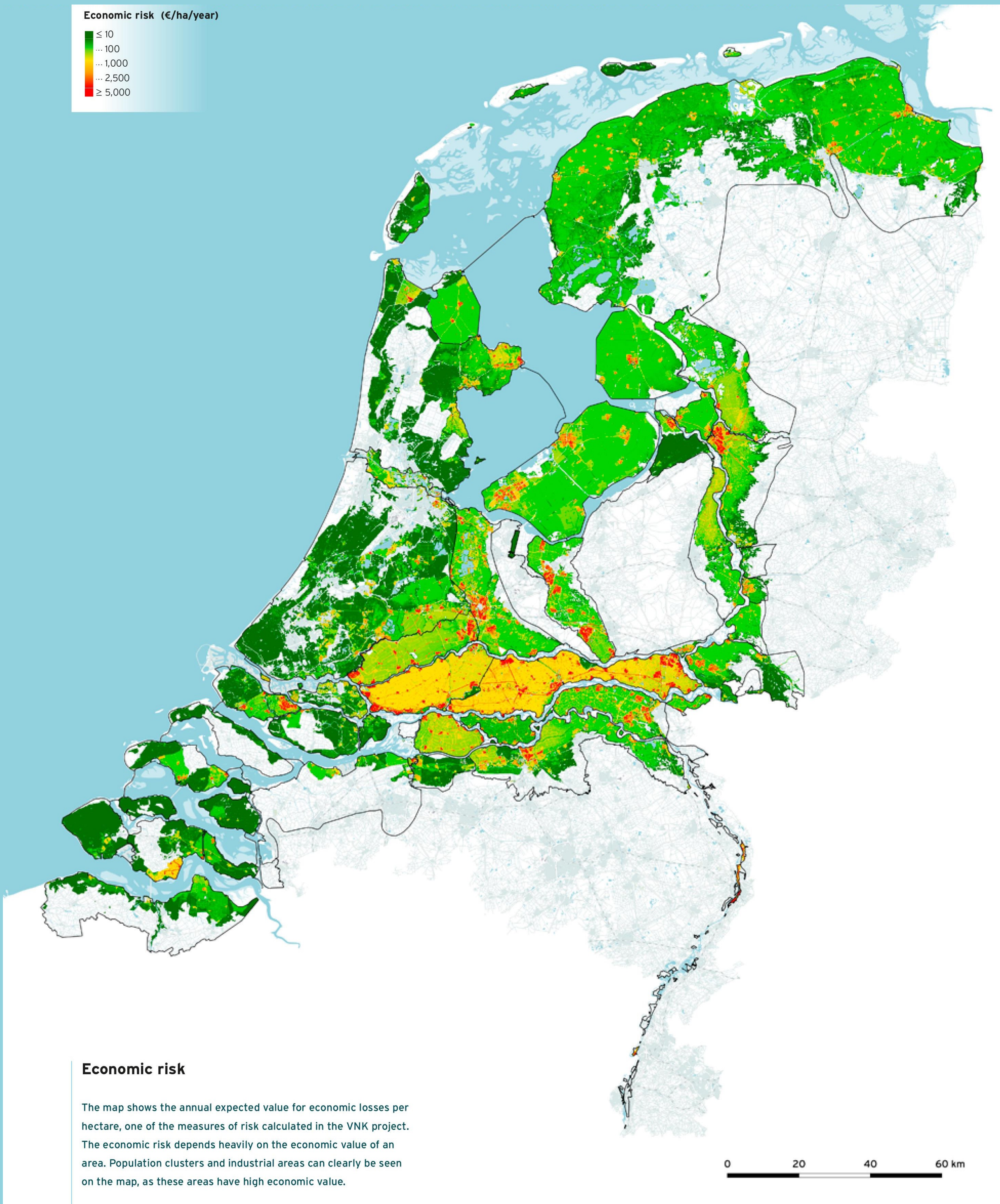


Figure 6.7: The map of economic risk in the Netherlands (VNK Project Office, 2016)

6.1.1 Context of Zeeland

In 1953, one of the most devastating floods in Dutch history struck the southwestern part of the Netherlands. The North Sea Flood, triggered by a powerful storm surge and high spring tides, overwhelmed the region's coastal defenses. Over 1,800 lives were lost, and tens of thousands of homes were destroyed or damaged. The provinces of Zeeland, South Holland, and North Brabant were among the hardest hit, with vast areas submerged underwater. This disaster showed the vulnerability of the Netherlands' low-lying regions to coastal flooding. Also, it prompted the government to develop the Delta Works, an ambitious system of dams, sluices, and storm surge barriers to prevent such a catastrophe from occurring again.

Among the most affected areas was Zeeland, where large portions of the province were inundated (See Figure 6.8). The flood caused extensive damage to the region's communities and infrastructure, leading the government to prioritize Zeeland in its flood protection efforts. Central to these efforts was the construction of the Eastern Scheldt Storm Surge Barrier, completed in 1986. This barrier was designed not only to protect Zeeland from future storm surges but also to preserve the estuary's natural tidal flow, which is vital to the local ecosystem and the fishing industry (Mooyaart & Jonkman, 2017).

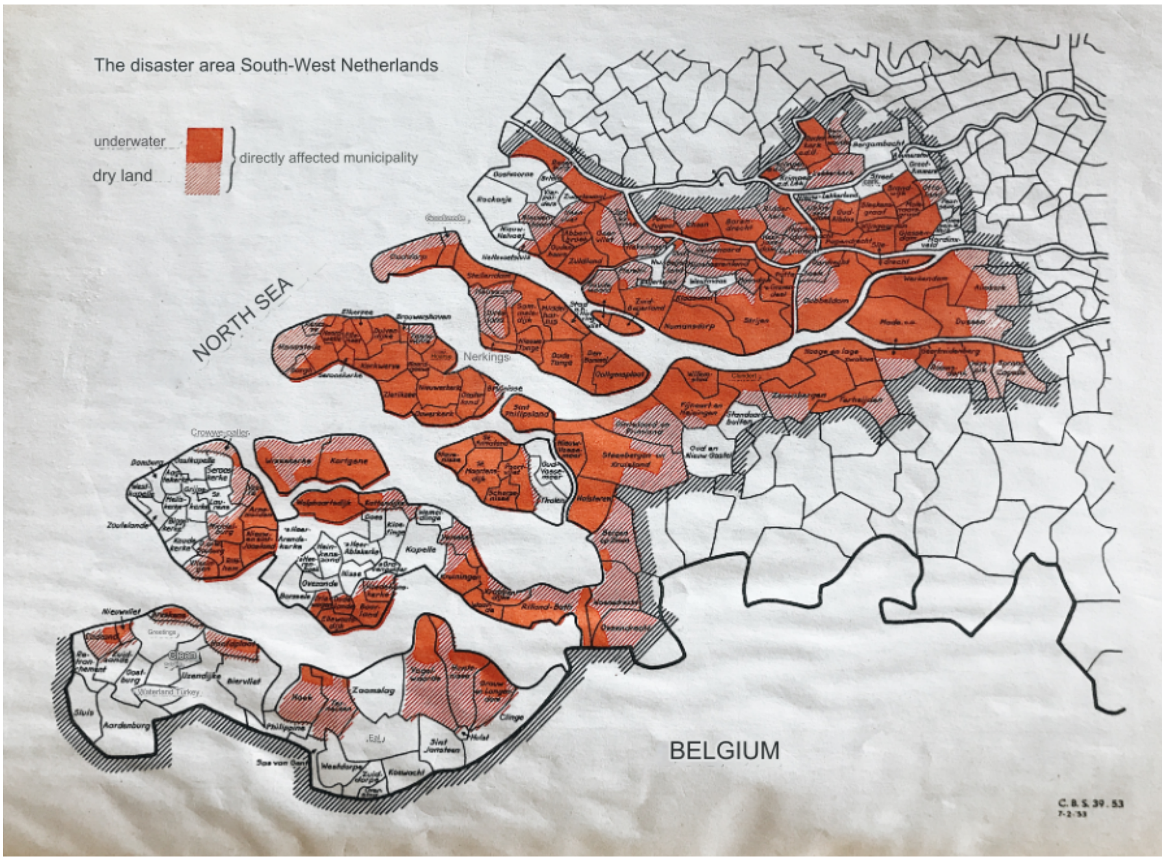


Figure 6.8: Extent of Flooding in Southwest Netherlands During the 1953 North Sea Flood. (Source: CBS)

In addition to the Eastern Scheldt barrier, a diverse network of levees, dikes, and sluices was built to enhance Zeeland's flood defenses. While Zeeland is considered reasonably safe today, the province's flood protection system is deeply integrated into the region's overall infrastructure. Roads, water management systems, and power grids are all interdependent on these flood defenses, forming an interconnected system where each element relies on the other. This interdependence means that any disruption to the flood protection system could have a cascading effect on the region's essential services. Thus, maintaining and upgrading this integrated network remains crucial not only for preventing floods but also for ensuring the smooth operation of the entire community infrastructure.

From a demographics standpoint, In Zeeland, the population is divided into ten age groups (see Figure 6.9). Children and youth aged 0-9 years comprise 10% of the population, while teenagers aged 10-19 make up 11%. Similarly, young adults aged 20-29, as well as individuals aged 30-39 and 40-49, each represent 11% of the population. The older range, specifically those aged 50-59, accounts for 15% of the total population. Additionally, people aged 60-69, 70-79, and 80-89 constitute 14%, 12%, and 5% of the population, respectively. Lastly, the population aged 90 and over is quite small, representing only 1% of the total. This snapshot further highlights that, despite the many years that have passed since 1953, the importance of people cannot be overlooked. The data clearly shows that we are discussing diverse age groups that may be directly or indirectly affected by a similar hazard.

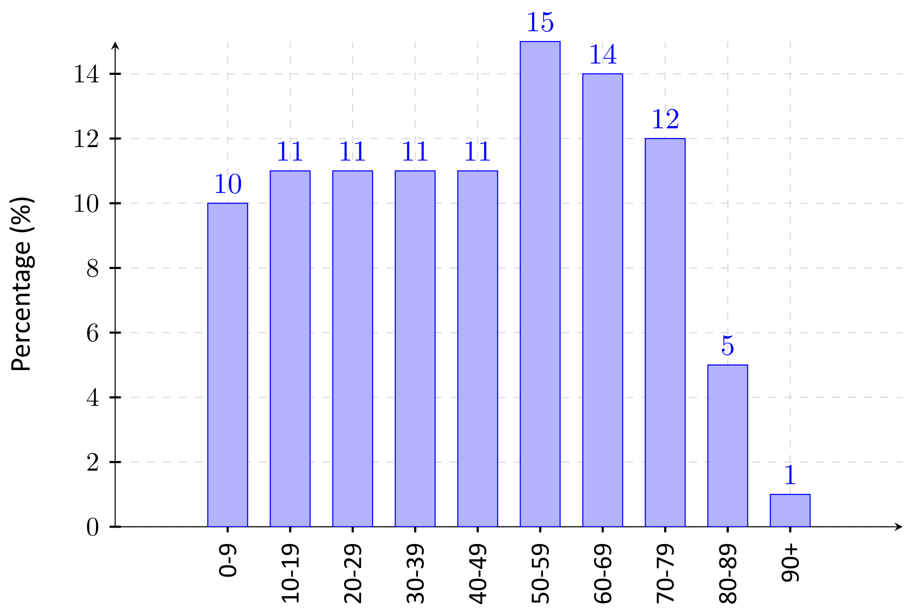


Figure 6.9: Age Distribution in Zeeland (Data source: citypopulation.de)

6.2 Exploratory Scan

As previously discussed, the uncertainty caused by sea-level rise and climate change places coastal communities in vulnerable positions, both economically and in terms of safety. Economic assets are at risk of being lost, while individuals face the potential danger of fatalities. The importance of safeguarding infrastructure in order to protect these communities has also been emphasized. Additionally, the specific context of the Netherlands, particularly the province of Zeeland with its history and socio-technical characteristics, has been explored.

Building on this, an exploratory scan was conducted to further refine the collected indicators and address the unique needs of the Zeeland context. Experts from two key organizations (Focus Groups), Rijkswaterstaat and the Safety District of Zeeland, were involved due to their critical roles in regional disaster response and their deep understanding of the Eastern Scheldt barrier and coastal protection.

A dialogue session was organized with these experts to evaluate the applicability of the collected indicators to the specific challenges faced in Zeeland. The focus of the discussion was on identifying context-specific indicators and assessing their relevance to the region's coastal resilience. The goal was to explore ways to adapt and refine these indicators to better suit local needs, guided by the question:

How can the previously identified context-specific potential indicators be refined to address the context of Zeeland?

During the dialogue session, participants were requested to rate context-specific potential indicators on a Likert scale ranging from 1 to 5, with one denoting least applicable and five most applicable (See Figure 6.10). During this step, participants were put in different virtual rooms to analyze the indicators separately and prepare notes for open discussion.

The findings uncovered important insights. *Citizen disaster preparedness and response skills, emergency community participation, changes in tidal patterns leading to river piracy or damage to dykes, and ecological buffers* all received high ratings (around 4.5). These factors are essential for the region's effective disaster management and coastal protection.

On the other hand, indicators such as *Radio stations, Race/ethnicity income equality, and Professional and business services* received low ratings (around 1.0 to 1.5), suggesting they are less critical in this specific context. Other indicators, such as building construction establishments, Internet service providers, television broadcasting, and renewable energy sources, were rated moderately (around 3.0 to 3.5).

The participants rated communication-related indicators moderately. However, the experts agreed that clustering these indicators is essential. One expert noted that *radio stations, television broadcasting, and housing units with telephones* in the Netherlands could be clustered due to the high dependency among them. Nowadays, most communication tools use the internet, so having a stable internet connection can fulfill the requirements and needs of others at the same time. This makes the internet more vital than before, as its instability may disrupt the other tools. Therefore, having alternatives is essential. Participants also suggested clustering some climate-related indicators such as *Changes in tidal patterns leading to river piracy/damage to dykes, Rate of sea level rise in the block, Ecological buffer, and Density of green vegetation across an area.*

Participants also suggested removing certain indicators and proposed modifications for others. Based on the discussions, some social indicators, such as *Race/Ethnicity*, *Race/Ethnicity Income Equality*, *Gender Income Equality*, and *Professional and Business Services*, were irrelevant to the context of Zeeland and therefore needed to be excluded.

Participants emphasized the importance of considering context on a more regional scale. They stated, " While the Netherlands may perform well on this indicator internally and externally, neighboring countries may face challenges. Even if the performance within the Netherlands is excellent, resilience cannot be fully ensured if nearby countries encounter difficulties." Participants illustrated this point using the indicator *Number of Construction Establishments*. They noted, " This indicator is important for community resilience, but the key question is how." They further explained that the number alone is insufficient. " For instance, it's not just about having construction companies in the area, but also about ensuring the availability of building materials within a certain distance and within a specific timeframe—whether days, weeks, months, or years." This highlights that evaluating a community's preparedness in isolation may overlook the fact that other interconnected communities, such as neighboring European states that could assist in disaster recovery might not be adequately prepared. Additionally, participants proposed modifying the indicator related to *River Salinity* to *Salt Intrusion*, as the primary issue arises from coastal areas.

After refining the context-specific indicators, participants participated in a live poll and were asked whether fixed indicators should be tailored to the specific context. They concluded that while fixed indicators should not be changed entirely, they should be adjusted to some extent. The participants highlighted that the identified fixed indicators are reliable and generally applicable. However, in the context of Zeeland, the only aspect that can be modified is the measures. For example, participants from the Safety District pointed out that "it is important to have a baseline for each indicator that aligns with the context of the Netherlands, and specifically Zeeland, even though your indicators work." For example, "the indicators related to educating the community with Red Cross training in the Netherlands are much higher than the baseline mentioned as a measure in the list. Therefore, further research is required to localize the measures for fixed indicators to make them more precise".

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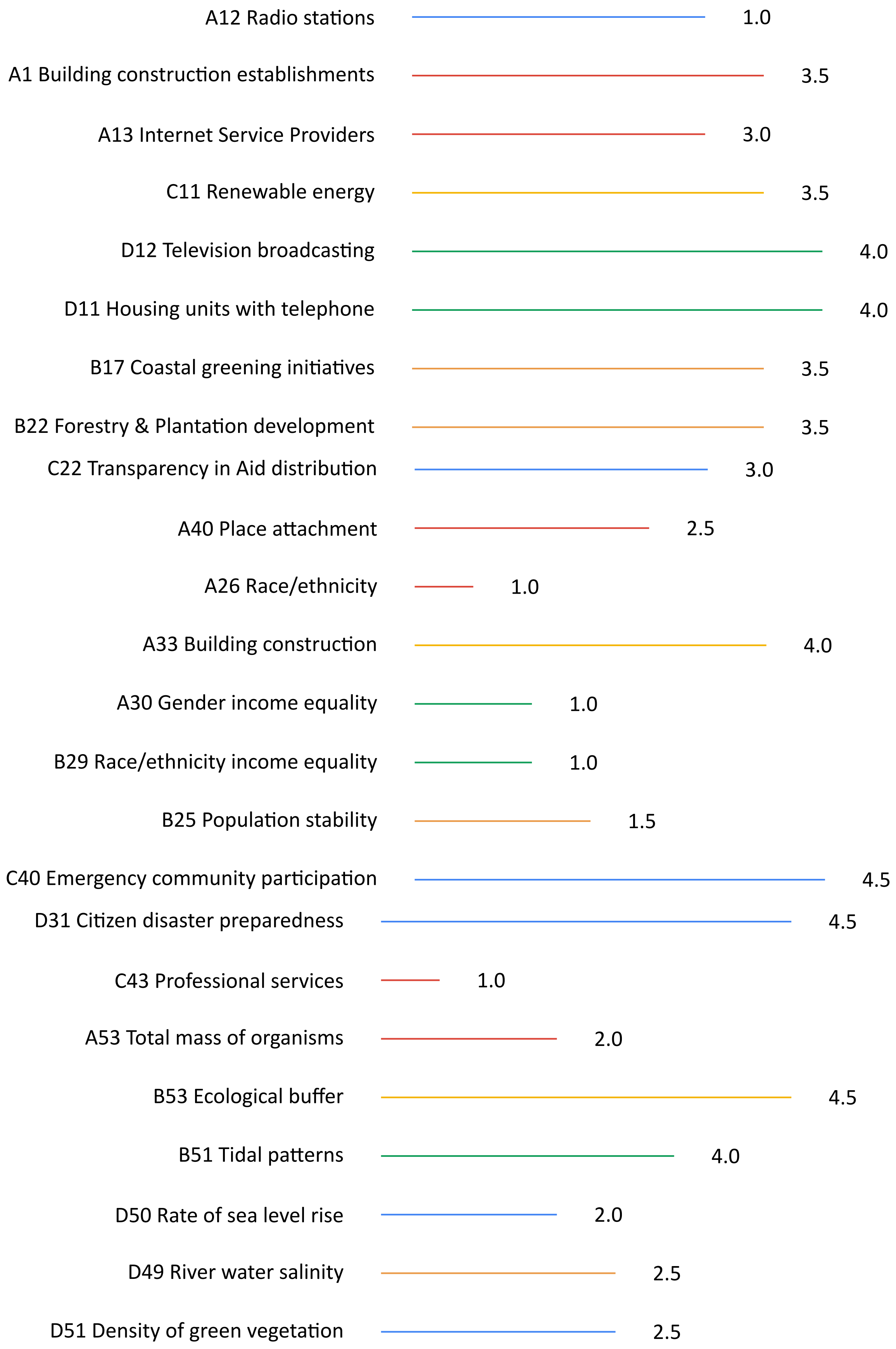


Figure 6.10: Context Specific Potential Indicators rated by participants

6.2.1 Additional findings

During the dialogue, participants underscored the critical role of information sharing in disaster management and response. They stressed that timely and accurate information flow is essential for effective decision-making (See Figure 6.11). The Safety District of Zeeland emphasized that receiving updates from Rijkswaterstaat before a disaster occurs is crucial for them to properly inform the public and avoid reactive measures. They highlighted the uncertainty inherent in disaster scenarios, stating, "We don't know the impact or where it will be felt," making early information sharing even more important. In this context, Rijkswaterstaat agreed, offering to share crucial information about their assets, including construction methods and potential technical risks.

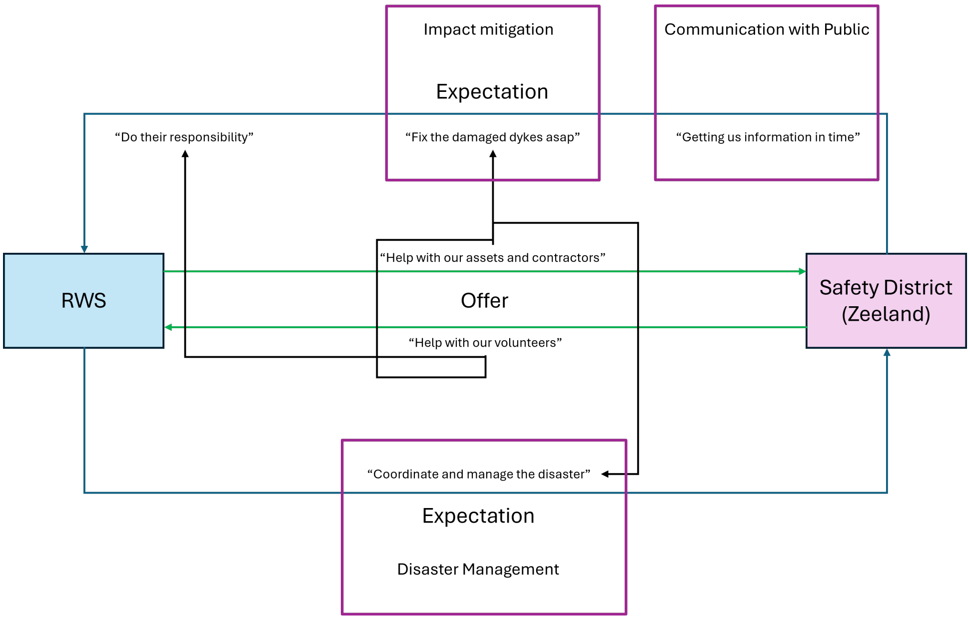


Figure 6.11: Expectations vs. Offers between RWS and Safety District Zeeland

In the current situation, participants from the Safety District expressed satisfaction with the level of information sharing, describing it as high and adequate. They reported a strong, ongoing exchange with Rijkswaterstaat, which keeps them well-informed about any changes in the system that might affect regional disaster planning. This positive dynamic extends beyond Rijkswaterstaat; other parties, such as the waterboard, also contribute to this enhanced preparedness. A key factor behind this successful collaboration is the close personal relationships between individuals in both organizations, which facilitates smooth communication and coordination.

Despite these positive developments, several challenges remain. The Safety District had concerns about the continuity of disaster management during crises, specifically highlighting resource shortages that may hinder 24-hour coverage and the potential need to involve the army. Both groups also acknowledged difficulties in the recovery phase, with Rijkswaterstaat pointing to the complexity of contingency planning for their assets. Participants agreed that addressing these challenges does not always require overly complex solutions; rather, simple, routine activities—like improving evacuation routes or optimizing parking for faster escapes—could significantly boost preparedness. Additionally, the aging workforce in both organizations was noted as a concern, with participants advocating for more young professionals to drive organizational renewal and resilience thinking.

6.3 Conclusion

How can the previously identified context-specific potential indicators be refined to address the context of Zeeland?

To answer the question, the exploratory scan demonstrated that while the core set of indicators is relevant, several require adaptation to reflect the specific conditions of Zeeland (See Table 6.1). Indicators like *citizen disaster preparedness, changes in tidal patterns, and ecological buffers* were rated highly for their importance to coastal resilience. Conversely, indicators such as *Race/Ethnicity and professional services* were deemed less relevant in this context and should be removed. Experts also suggested clustering related indicators, such as communication tools, to better reflect their interdependencies, especially in a region like Zeeland where internet stability is key to multiple communication platforms.

Additionally, modifications were proposed for several indicators to better align with Zeeland's socio-technical characteristics. For example, the indicator related to *river salinity* was refined to *salt intrusion*, reflecting the coastal nature of the region. Participants stressed the importance of not completely changing fixed indicators but tailoring their measures to local conditions, ensuring that the framework is both generalizable and context-specific. This involves setting baselines for measures that align with regional realities, such as the preparedness of communities and the state of infrastructure.

In wrapping up this chapter, the findings reinforce the reasoning that resilience indicators must be both flexible and adaptable to local conditions. Zeeland's unique challenges—its reliance on complex flood defense systems and the interdependencies between infrastructure and socio-economic factors—require ongoing refinement of indicators to ensure relevance and operationality. This chapter not only provided a tailored approach for Zeeland but also offered a guide for other regions to follow and ensure resilience assessments remain context-sensitive.

Table 6.1: Modified Context Specific indicators

Code	Dimension	Category	Indicator Name	Reference	Cluster	Irrelevant to context
A12*	Infrastructure	Utilities and Energy Infrastructure	Radio stations	Peacock et al. (2010)	A13,D12,D11	
A1*	Infrastructure	Infrastructure Establishments	Companies with building material resources within a certain distance and availability in time (days, weeks, months, years).	Proposed		
A13	Infrastructure	Utilities and Energy Infrastructure	Internet service providers	Peacock et al. (2010)	A12,D12,D11	
C11	Infrastructure	Utilities and Energy Infrastructure	Implementation of renewable source of energy (Solar/wind etc.)	Dasgupta and Shaw (2015)		
D12*	Infrastructure	Utilities and Energy Infrastructure	Television broadcasting	Peacock et al. (2010)	A12,A13,D11	
D11*	Infrastructure	Utilities and Energy Infrastructure	Owner-occupied housing units with telephone service	Peacock et al. (2010)	A12,A13,D12	
B17	Organizational	Policy and Planning	Administrative initiatives for coastal greenings	Dasgupta and Shaw (2015)		
B22	Organizational	Resource Allocation	Development of forestry & Plantation at administrative initiatives	Dasgupta and Shaw (2015)		
C22	Organizational	Resource Allocation	Transparency in Aid distribution process	Dasgupta and Shaw (2015)		
A40*	Social	Place Attachment	Place attachment-not recent immigrants	Cutter et al. (2014)	A26,A30,B29	
A26*	Social	Demographics	Race/ethnicity	Cimellaro et al. (2016)	A40,A30,B29	
A33	Social	Workforce	Building construction workers	Peacock et al. (2010)		
A30*	Social	Money Related	Gender income equality	Cimellaro et al. (2016)	A26,A40,B29	
B29*	Social	Money Related	Race/ethnicity income equality	Cimellaro et al. (2016)	A26,A30,A40	
B25	Social	Demographics	Population stability	Cimellaro et al. (2016)		
C40	Social	Governance related	Emergency community participation	Cimellaro et al. (2016)		
D31	Social	Education - Related	Citizen disaster preparedness and response skills	Cutter et al. (2014)		
C43	Economical	Business Related	Professional and business services	Cimellaro et al. (2016)		
A53	Environmental	Vegetation and species	Total mass of organisms	Cimellaro et al. (2016)		
B53	Environmental	Vegetation and species	Ecological buffer	Kotzee en Reyers (2016)		
B51	Environmental	Climate related	Change in tidal patterns leading to river piracy/damage to dykes	Dasgupta and Shaw (2015)		
D50	Environmental	Climate related	Rate of sea level rise in the block	Dasgupta and Shaw (2015)	B51, D49*	
D49*	Environmental	Climate related	Salt Intrusion	Proposed	D50, B51	
D51	Environmental	Vegetation and species	Density of green vegetation across an area	Cimellaro et al. (2016)	D50, D49*	

CHAPTER
7

NERMI CCR Framework

The Act Of Sacrifice by Jean Antoine Théodore Gudin
Source: arthive.com

7 NERMI CCR Framework

The concluding chapter will present the NERMI (with ”Nermî” meaning the ability to recover in Kurdish Kurmanci) CCR framework in detail, covering its main features, such as scale, focus, target audience, framework architecture, and development method. Furthermore, the framework utilization procedure will be explained.

7.1 Scale, Focus, and Target Audience

The NERMI CCR framework adopts a systems-based approach to scale resilience by recognizing the complex interdependencies between various aspects within a community (see Figure 7.1). Scaling resilience requires a robust theoretical foundation, which NERMI CCR achieves through the application of systems theory. This approach ensures that the resilience of a community is analyzed holistically and acknowledges that disruptions in one area—such as infrastructure can affect the entire system. Regarding its focus, NERMI CCR adopts a mono-approach by concentrating solely on coastal hazards like flooding, sea-level rise, and storms, which allows for specialized insights but limits its scope to the specific challenges faced by coastal communities.

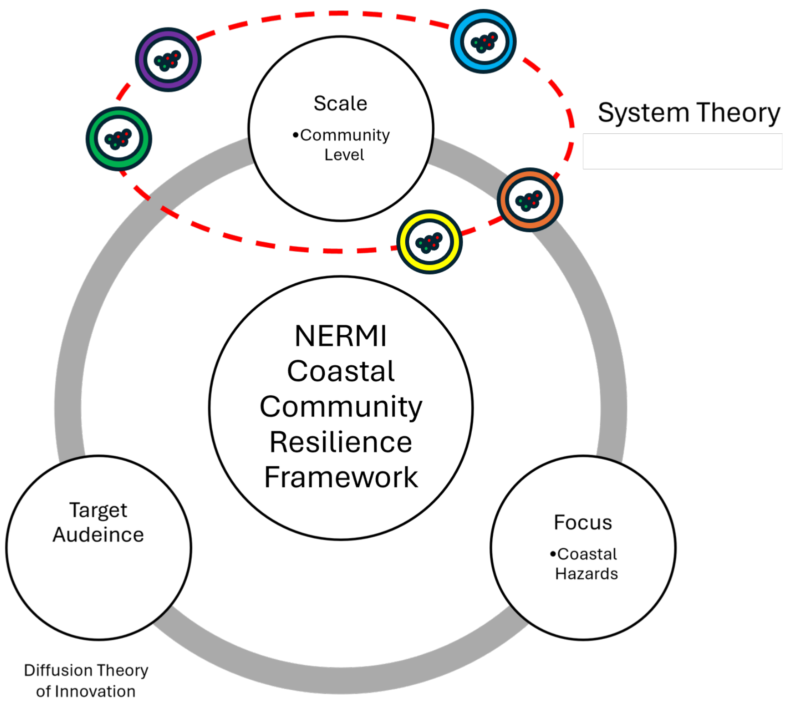


Figure 7.1: NERMI Coastal Community Resilience Framework Characteristics

The target audience for the NERMI CCR framework is identified using Everett Rogers' Diffusion of Innovations theory (Rogers, 1983) (See Figure 7.2). This theory categorizes individuals in a social system into five groups based on their readiness to adopt an innovation: innovators, early adopters, early majority, late majority, and laggards. The framework will follow a similar adoption path, starting with innovators and early adopters and eventually reaching more conservative decision-makers.

Initially, senior researchers and local government officials will act as early adopters, refining and promoting the framework. The early majority, including mid-level government managers and heads of local agencies, will adopt it to enhance resilience planning and disaster response. The late majority, such as more conservative government officials, will adopt the framework after observing its success in other areas. Finally, laggards, the most skeptical and traditional decision-makers, will adopt it only after seeing long-term evidence of its effectiveness. By focusing on decision-makers at various levels of government and academia, NERMI CCR is designed to gain widespread adoption over time as its benefits become evident.

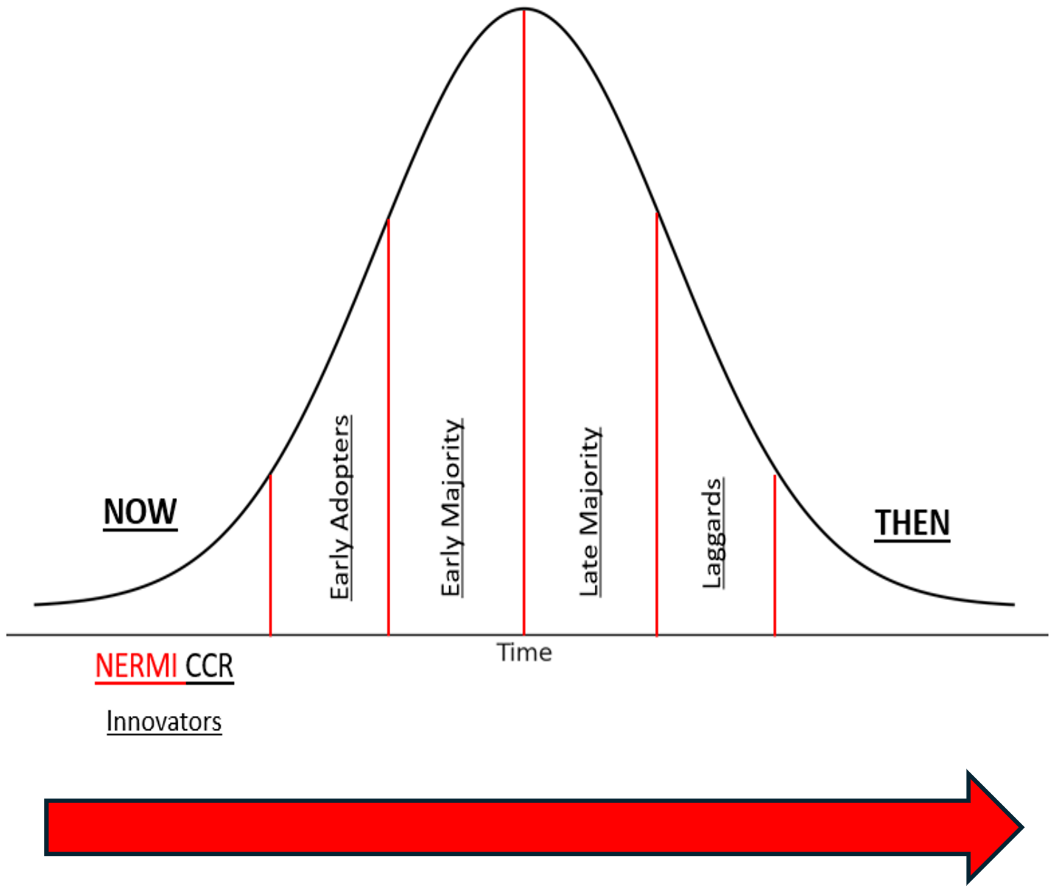


Figure 7.2: NERMI CCR Through Diffusion Theory

7.2 Framework Architecture

The NERMI CCR framework includes 134 indicators (See Table 7.1) across five dimensions to assess coastal community resilience: Social, Infrastructure, Environmental, Organizational, and Economic (See Figure 7.3). These indicators are categorized to cover different aspects of community resilience.

For instance, the Social dimension includes 40 indicators organized into categories such as Workforce, Health-Related, Demographics, Governance-Related, Education-Related, and Money-Related. These indicators encompass factors like pre-retirement age, population participating in the community rating system, Percentage backward/tribal population, family stability, non-special needs, and physician access.

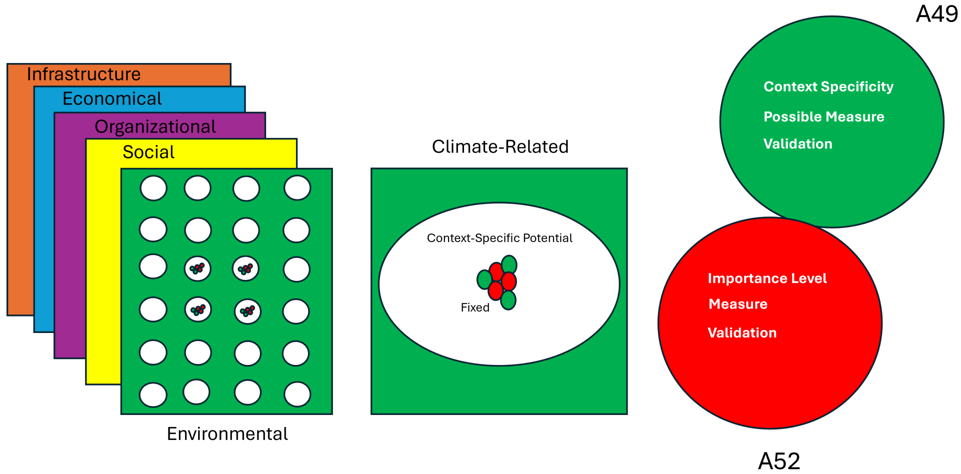
The Infrastructure dimension, including 34 indicators, focuses on categories like Transportation and Communication, Housing, Community Services and Facilities, Utilities and Energy Infrastructure, and Infrastructure Establishments, addressing aspects such as road use, Number of Hospitals, Number of Ambulances, Number of hours of average disruption of electricity supply, Percent of population in co-operative housing, Percent of population living extremely close to hazardous activity (port/industry), and housing units with vehicles.

The Environmental dimension includes 22 indicators, categorized under Environmental Management, Earth-Soil Related, Climate-Related, and Vegetation and Species, focusing on factors like freshwater availability and species diversity.

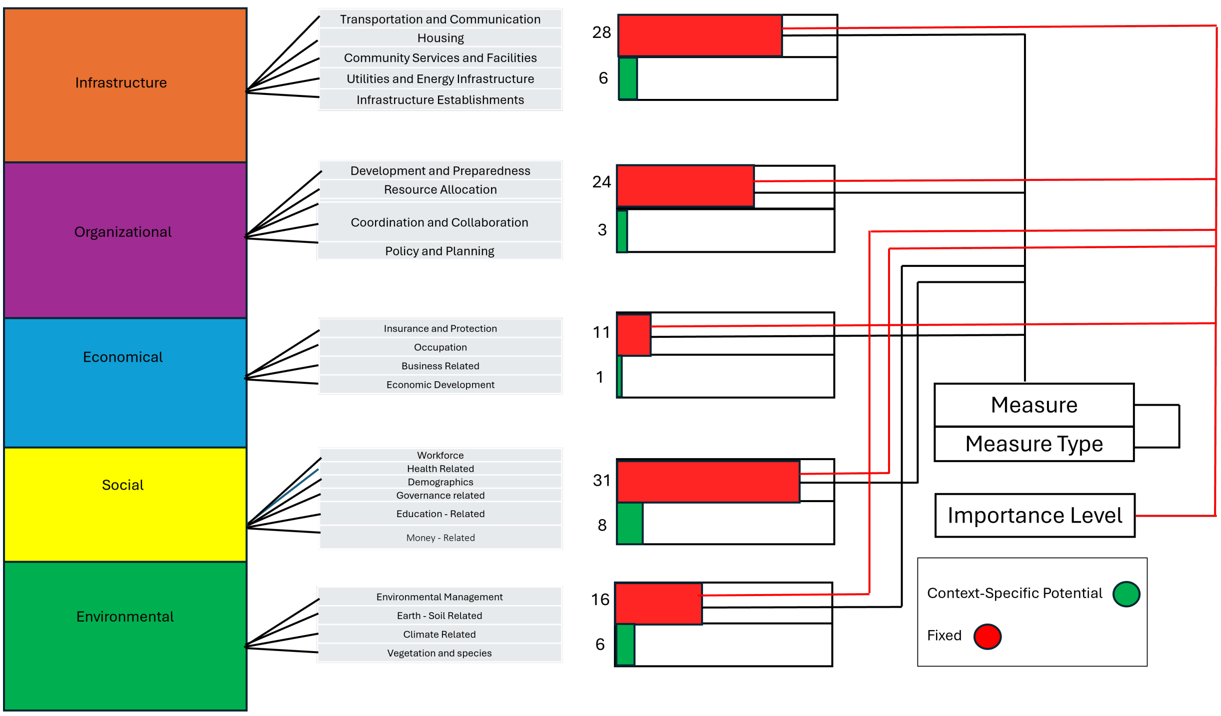
In the Organizational dimension, 27 indicators cover categories such as Development and Preparedness, Resource Allocation, Coordination and Collaboration, and Policy and Planning, addressing areas like information sharing, Local institutions' access to financial reserves to support effective disaster response and early recovery, Implementation flood/erosion control, Available Technical and Financial Support Mechanisms, Contingency plan degree including an outline strategy for postdisaster recovery and reconstruction, and resource allocation.

The Economic dimension, with 12 indicators, includes categories like Insurance and Protection, Occupation, Business-Related, and Economic Development, examining metrics like Gross Regional Domestic Product (GRDP) and trade openness.

Furthermore, all the indicators in the framework have corresponding measures and measure types. For the fixed indicators, which are represented by red lines in the scheme, the importance level has already been identified. However, the importance level has not yet been assigned to the context-specific potential indicators depicted by green lines. These context-specific indicators need to be modified first based on local conditions, and only after these modifications can an appropriate importance level be determined and assigned to them.



(a) NERMI CCR Framework Overview



(b) Detailed Framework Structure

Figure 7.3: NERMI Coastal Community Resilience Framework

7.3 Development Method

The development of the NERMI CCR framework followed a four-stage methodology: **Indicator Mining**, **Expert Consultation**, and **Calibration (Part A and Part B)**.

1. **Indicator Mining**: This stage identified relevant indicators for community resilience through a systematic literature review using the PRISMA method. The review focused on scientific databases such as Google Scholar, TU Delft Repository, and ScienceDirect, applying specific inclusion and exclusion criteria. Automation tools like Zotero and ATLAS.ti were used to manage documents and extract data, resulting in a comprehensive database of resilience indicators from multiple frameworks.

2. **Expert Consultation**: The next phase involved gathering expert insights through a 5-point Likert scale survey and in-depth interviews. The aim was to evaluate the importance of the mined indicators and understand operationalization challenges and the needs of decision-makers. Experts from diverse fields were consulted, and their feedback provided valuable input for the design of NERMI CCR.

3. **Calibration (Part A)**: After conducting indicator mining and consulting with experts, the importance of each indicator was identified. Each indicator plays a vital role in understanding the resilience of coastal communities, but to be more useful and understandable, indicators needed calibration. Based on expert ratings and the calibration process, the selected indicators were classified into two types: *fixed* and *context-specific* indicators. **Fixed indicators** showed a strong consensus among experts, with low variance in their ratings, making them universally applicable across different coastal communities. In contrast, **context-specific indicators** exhibited a high variance in expert ratings, reflecting the need to adapt them to specific regional or local contexts.

4. **Calibration (Part B)**: This stage focused on customizing the framework for the specific context of the Zeeland. Local experts from Rijkswaterstaat and the Safety District of Zeeland were consulted to refine context-specific indicators, ensuring the framework addressed local needs and conditions.

Table 7.1: NERMI CCR Framework Indicator List

Code	Dimension	Category	Indicator Name	Reference
A8	Infrastructure	Transportation and Communication	Road use compared to overall land use	Dasgupta and Shaw (2015)
A14	Infrastructure	Housing	Occupied housing units with vehicle available	Peacock et al. (2010)
A15	Infrastructure	Housing	Percent of houses living under the avg. flood line	Dasgupta and Shaw (2015)
A9	Infrastructure	Transportation and Communication	Status of Jetties and inter-island communication	Dasgupta and Shaw (2015)
A3	Infrastructure	Community Services and Facilities	Number of Hospitals	Peacock et al. (2010)
A11	Infrastructure	Utilities and Energy Infrastructure	Quality of service / network accessibility	Dasgupta and Shaw (2015)
A2	Infrastructure	Infrastructure Establishments	Highway, street, and bridge construction establishments	Peacock et al. (2010)
B11	Infrastructure	Utilities and Energy Infrastructure	Percent population having mobile phone	Dasgupta and Shaw (2015)
B13	Infrastructure	Utilities and Energy Infrastructure	Number of hours of average disruption of electricity supply	Dasgupta and Shaw (2015)
B3	Infrastructure	Community Services and Facilities	Number of Ambulances	Peacock et al. (2010)
B5	Infrastructure	Community Services and Facilities	Licensed child care facilities	Peacock et al. (2010)
B12	Infrastructure	Utilities and Energy Infrastructure	Percent population having access to electricity	Dasgupta and Shaw (2015)
B8	Infrastructure	Community Services and Facilities	Industrial resupply potential	Cimellaro et al. (2016)
B4	Infrastructure	Community Services and Facilities	Community food service facilities	Peacock et al. (2010)
B14	Infrastructure	Housing	Percent of population in co-operative housing	Dasgupta and Shaw (2015)
C6	Infrastructure	Community Services and Facilities	Distribution commercial facilities	Cimellaro et al. (2016)
C9	Infrastructure	Transportation and Communication	Evacuation routes	Cimellaro et al. (2016)
C8	Infrastructure	Transportation and Communication	Weather accessible roads compared to the existing road network	Dasgupta and Shaw (2015)
C3	Infrastructure	Community Services and Facilities	Nursing homes	Peacock et al. (2010)
C2	Infrastructure	Community Services and Facilities	Hospital beds	Peacock et al. (2010)
C4	Infrastructure	Community Services and Facilities	Newspaper publishers	Peacock et al. (2010)
C10	Infrastructure	Utilities and Energy Infrastructure	Percent population having alternative source of electricity in case of disruption	Dasgupta and Shaw (2015)
C14	Infrastructure	Housing	Percent of population living extremely close to hazardous activity (port/industry)	Dasgupta and Shaw (2015)
D7	Infrastructure	Community Services and Facilities	Gas	Cimellaro et al. (2016)
D4	Infrastructure	Community Services and Facilities	Temporary shelters	Peacock et al. (2010)
D15	Infrastructure	Housing	Temporary housing availability	Cimellaro et al. (2016)
D5	Infrastructure	Community Services and Facilities	Property and casualty insurance establishments	Peacock et al. (2010)
D9	Infrastructure	Transportation and Communication	Availability of emergency vehicle/boats	Dasgupta and Shaw (2015)
A25	Organizational	Development and Preparedness	Disaster risk reduction measures integrated into post disaster recovery and rehabilitation activities	Cimellaro et al. (2016)
A23	Organizational	Resource Allocation	Adequacy of trained emergency response team	Dasgupta and Shaw (2015)
A19	Organizational	Policy and Planning	Availability of emergency aids	Dasgupta and Shaw (2015)
A24	Organizational	Development and Preparedness	Availability of evacuation centre	Dasgupta and Shaw (2015)
A18	Organizational	Policy and Planning	Funds allocation to Disaster Risk Reduction activities	Dasgupta and Shaw (2015)
B23	Organizational	Development and Preparedness	Existence of early warning system	Dasgupta and Shaw (2015)
B18	Organizational	Policy and Planning	Implementation of rainwater harvesting scheme	Dasgupta and Shaw (2015)
B20	Organizational	Coordination and Collaboration	Performance regimes-nearest metro area	Cutter et al. (2014)
B19	Organizational	Policy and Planning	Contingency plan degree including an outline strategy for postdisaster recovery and reconstruction	Cimellaro et al. (2016)

Table 7.1 (Continued)

Code	Dimension	Category	Indicator Name	Reference
B21	Organizational	Coordination and Collaboration	Coordination with neighboring blocks	Dasgupta and Shaw (2015)
C17	Organizational	Policy and Planning	Implementation of Disaster Insurance Statutory aid to victims	Dasgupta and Shaw (2015)
C20	Organizational	Coordination and Collaboration	Information sharing & risk communication with the community	Dasgupta and Shaw (2015)
C19	Organizational	Policy and Planning	Frequency of DRR training organized by the block	Dasgupta and Shaw (2015)
C18	Organizational	Policy and Planning	Nuclear plant accident planning	Cutter et al. (2014)
C16	Organizational	Policy and Planning	Integration of Disaster Risk Reduction in developmental activities	Dasgupta and Shaw (2015)
C23	Organizational	Resource Allocation	Local institutions' access to financial reserves to support effective disaster response and early recovery	Cimellaro et al. (2016)
C21	Organizational	Coordination and Collaboration	Collaboration Mechanisms Establishments	Courtney et al. (2008)
D16	Organizational	Policy and Planning	Implementation flood/erosion control	Dasgupta and Shaw (2015)
D22	Organizational	Resource Allocation	Available Technical and Financial Support Mechanisms	Courtney et al. (2008)
D21	Organizational	Coordination and Collaboration	Coordination among government departments	Dasgupta and Shaw (2015)
D23	Organizational	Resource Allocation	Local government access to resources and expertise to assist victims of psychosocial impacts of disasters	Cimellaro et al. (2016)
D17	Organizational	Policy and Planning	Implementation of regular developmental plans	Dasgupta and Shaw (2015)
D20	Organizational	Coordination and Collaboration	Performance regimes-state capital	Cutter et al. (2014)
D19	Organizational	Policy and Planning	Crop insurance coverage	Cutter et al. (2014)
A27	Social	Demographics	Percent of rural population	Dasgupta and Shaw (2015)
A36	Social	Workforce	Property and casualty insurance workers	Peacock et al. (2010)
A34	Social	Workforce	Environment and conservation workers	Peacock et al. (2010)
A37	Social	Health Related	Physician access	Cutter et al. (2014)
B26	Social	Demographics	Gender	Cimellaro et al. (2016)
B38	Social	Governance related	Cultural resources	Cimellaro et al. (2016)
B31	Social	Education - Related	Education programs on disaster risk reduction and disaster preparedness for local communities	Cimellaro et al. (2016)
B33	Social	Education - Related	Colleges, universities, and professional schools employees	Peacock et al. (2010)
B32	Social	Education - Related	Child and elderly care programs	Cimellaro et al. (2016)
B37	Social	Demographics	Religious organizations	Cimellaro et al. (2016)
B34	Social	Workforce	Population employed in legal services	Peacock et al. (2010)
C27	Social	Demographics	Percentage of population covered by governmental safety department approved mitigation plan	Peacock et al. (2010)
C35	Social	Workforce	Female labor force participation	Cimellaro et al. (2016)
C36	Social	Health Related	Food provisioning capacity	Cimellaro et al. (2016)
C32	Social	Workforce	Population employed in scientific research and development services	Peacock et al. (2010)
C33	Social	Workforce	Environmental consulting workers	Peacock et al. (2010)
C29	Social	Money Related	Homeownership	Cimellaro et al. (2016)
C26	Social	Demographics	Percentage of population covered by zoning regulations	Peacock et al. (2010)
C30	Social	Education - Related	Citizen awareness of evacuation plans or drills for evacuations	Cimellaro et al. (2016)
C31	Social	Education - Related	English language competency	Cutter et al. (2014)
C28	Social	Demographics	Pre-retirement age	Cutter et al. (2014)

Table 7.1 (Continued)

Code	Dimension	Category	Indicator Name	Reference
C39	Social	Governance related	Population participating in community rating system	Cimellaro et al. (2016)
C34	Social	Workforce	Landscape architects and planners	Peacock et al. (2010)
D38	Social	Governance related	Professional associations/organizations	Peacock et al. (2010)
D32	Social	Workforce	Fire fighters, prevention, and law enforcement workers	Peacock et al. (2010)
D36	Social	Health Related	Non-special needs	Cutter et al. (2014)
D26	Social	Demographics	Percent backward/tribal population	Dasgupta and Shaw (2015)
D29	Social	Money Related	Poverty	Cimellaro et al. (2016)
D35	Social	Workforce	Building inspectors	Peacock et al. (2010)
D25	Social	Demographics	Family stability	Cimellaro et al. (2016)
D34	Social	Workforce	Architecture and engineering workers	Peacock et al. (2010)
A44	Economical	Economic Development	Gross regional domestic product (GRDP) per capita	Kusumastuti et al. (2014)
A46	Economical	Economic Development	Research and development firms	Cimellaro et al. (2016)
B43	Economical	Economic Development	Tax revenues	Cimellaro et al. (2016)
B45	Economical	Insurance and Protection	Hazard insurance coverage	Cimellaro et al. (2016)
B44	Economical	Economic Development	Emergency fund	Kusumastuti et al. (2014)
C42	Economical	Occupation	Percent of population lives on coastal resources	Dasgupta and Shaw (2015)
C46	Economical	Insurance and Protection	Population with health insurance	Peacock et al. (2010)
D45	Economical	Insurance and Protection	Livestock protection management in a disaster	RIMES & BRAC (2022)
D40	Economical	Occupation	Percent of population lives on Eco−tourism	Dasgupta and Shaw (2015)
D41	Economical	Business Related	Large retail-regional/national geographic distribution	Cutter et al. (2014)
D44	Economical	Economic Development	Trade openness	Noy en Yonson (2018)
A56	Environmental	Environmental Management	Chemical pollution in mangrove food chain	Dasgupta and Shaw (2015)
A48	Environmental	Earth - Soil Related	Protected land	Cimellaro et al. (2016)
A57	Environmental	Environmental Management	Local food suppliers	Cutter et al. (2014)
A55	Environmental	Environmental Management	Integration of Natural hazard Maps in planning	Dasgupta and Shaw (2015)
A47	Environmental	Earth - Soil Related	Land use stability	Cimellaro et al. (2016)
A51	Environmental	Climate Related	Physical impact caused by sea level rise	Dasgupta and Shaw (2015)
A54	Environmental	Vegetation and species	Mangrove deterioration (loss of species) due to salinity	Dasgupta and Shaw (2015)
A52	Environmental	Climate Related	Population affected by contaminated water	Dasgupta and Shaw (2015)
B49	Environmental	Climate Related	Availability of freshwater (surface+subsurface)	Dasgupta and Shaw (2015)
B46	Environmental	Earth - Soil Related	Soil quality	Cimellaro et al. (2016)
B50	Environmental	Climate related	Flood occurrence and degree of damage	Dasgupta and Shaw (2015)
B55	Environmental	Environmental Management	Efficient energy use	Cutter et al. (2014)
C51	Environmental	Climate Related	Heavy tidal inceptions causing substantial damage	Dasgupta and Shaw (2015)
C53	Environmental	Vegetation and species	Natural flood buffers	Cutter et al. (2014)
C56	Environmental	Environmental Management	Control in Deep aquifer pumping	Dasgupta and Shaw (2015)
D52	Environmental	Vegetation and species	Living species	Cimellaro et al. (2016)
A12	Infrastructure	Utilities and Energy Infrastructure	Radio stations	Peacock et al. (2010)
A1	Infrastructure	Infrastructure Establishments	Building construction establishments	Peacock et al. (2010)
A13	Infrastructure	Utilities and Energy Infrastructure	Internet service providers	Peacock et al. (2010)
C11	Infrastructure	Utilities and Energy Infrastructure	Implementation of renewable source of energy (Solar/wind etc.)	Dasgupta and Shaw (2015)
D12	Infrastructure	Utilities and Energy Infrastructure	Television broadcasting	Peacock et al. (2010)

Table 7.1 (Continued)

Code	Dimension	Category	Indicator Name	Reference
D11	Infrastructure	Utilities and Energy Infrastructure	Owner-occupied housing units with telephone service	Peacock et al. (2010)
B17	Organizational	Policy and Planning	Administrative initiatives for coastal greenings	Dasgupta and Shaw (2015)
B22	Organizational	Resource Allocation	Development of forestry & Plantation at administrative initiatives	Dasgupta and Shaw (2015)
C22	Organizational	Resource Allocation	Transparency in Aid distribution process	Dasgupta and Shaw (2015)
A40	Social	Place Attachment	Place attachment-not recent immigrants	Cutter et al. (2014)
A26	Social	Demographics	Race/ethnicity	Cimellaro et al. (2016)
A33	Social	Workforce	Building construction workers	Peacock et al. (2010)
A30	Social	Money Related	Gender income equality	Cimellaro et al. (2016)
B29	Social	Money Related	Race/ethnicity income equality	Cimellaro et al. (2016)
B25	Social	Demographics	Population stability	Cimellaro et al. (2016)
C40	Social	Governance related	Emergency community participation	Cimellaro et al. (2016)
D31	Social	Education - Related	Citizen disaster preparedness and response skills	Cutter et al. (2014)
C43	Economical	Business Related	Professional and business services	Cimellaro et al. (2016)
A53	Environmental	Vegetation and species	Total mass of organisms	Cimellaro et al. (2016)
B53	Environmental	Vegetation and species	Ecological buffer	Kotzee en Reyers (2016)
B51	Environmental	Climate related	Change in tidal patterns leading to river piracy/damage to dykes	Dasgupta and Shaw (2015)
D50	Environmental	Climate related	Rate of sea level rise in the block	Dasgupta and Shaw (2015)
D49	Environmental	Climate related	River water salinity	Dasgupta and Shaw (2015)
D51	Environmental	Vegetation and species	Density of green vegetation across an area	Cimellaro et al. (2016)

7.4 Knowledge Utilization

As explained, the NERMI CCR framework was developed by collecting indicators from the literature and confirming them through expert consultations. This phase also included pilot testing and gathering feedback. The process follows the C-K design theory introduced by Hatchuel and Weil (2003). According to this theory, design starts with existing knowledge (See Figure 7.4), goes through several rounds of development in the concept space, and eventually becomes a final concept that can be turned into new knowledge. In the NERMI CCR case, the literature review collected existing knowledge, such as indicators and important dimensions of community resilience.

These indicators were then discussed with experts, which mirrors K2 in C-K theory, where new knowledge is explored. The refined knowledge was further developed and sent for more feedback in K3, which, for NERMI CCR, was the second calibration phase. Finally, the framework moved back to the knowledge space and became new knowledge. However, creating knowledge is one thing, but applying it is another.

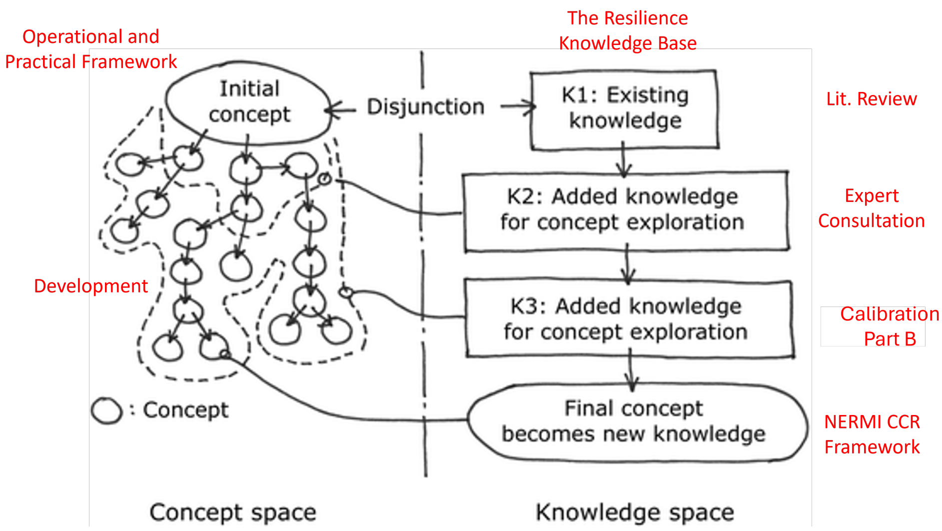


Figure 7.4: C-K Theory Implication for NERMI CCR
Inspired by Andreasen et al. (2015)

As mentioned earlier, NERMI CCR can serve as a blueprint for various coastal communities. However, specific steps must be followed to apply the knowledge provided by NERMI effectively. As shown in Figure 7.5, the process begins with a decision model that evaluates whether the framework is applicable to a particular context. According to this model, if the context does not align with NERMI CCR's key characteristics—Scope, Focus, and Scale—the process halts before reviewing the indicators. If the context meets the initial criteria, it gains access to a multidimensional framework with five dimensions and 24 categories with a total of 134 indicators, including 110 fixed and 24 context-specific potential indicators.

In the second part of the process, users must review the indicators using a similar method described in the previous chapter (Exploratory Scan). It is essential to identify focus groups for this scan, engaging them in dialogue sessions to review the context-specific potential indicators, allowing for the removal, clustering, or addition of local indicators to the existing list. Furthermore, proposed measures for both fixed and context-specific indicators are provided. Users can compare these measures with their community's local baselines, adjusting them if necessary. By following this procedure, users will have a tailored version of the NERMI CCR framework ready to conduct a spatial assessment of the coastal community in question.

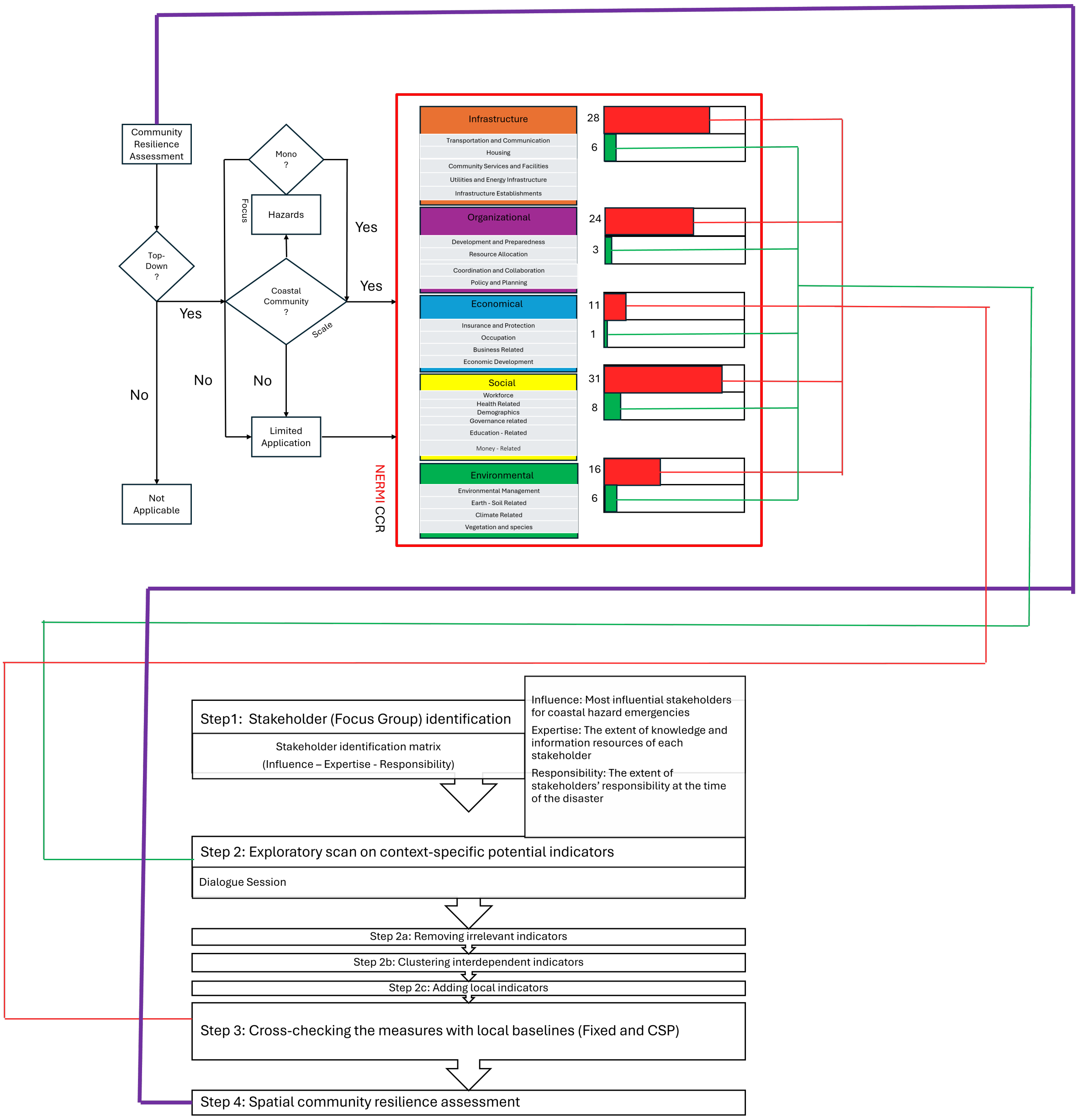


Figure 7.5: NERMI CCR Decision and Utilization Procedure

CHAPTER

8

Limitations, Conclusion, and Future Research

A Flood on Java by Raden Saleh. (Source: Royal Netherlands Institute of Southeast Asian and Caribbean Studies)

8 Limitations, Conclusion and Future Research

This chapter reflects on the limitations of the research, provides a conclusion by addressing the research questions, and suggests areas for future research.

8.1 Limitations

While the framework offers a solid foundation for assessing resilience, some limitations highlight areas for further research.

Application of the Framework: The framework was not tested in real-world case studies. However, the calibration stages in the methodology have laid important groundwork, providing a basis for future applications and further research. For instance, applying the framework in Zeeland, given the localization conducted during the Calibration Part B phase, could have provided valuable insights.

Interdependency and Weighting: The framework did not fully explore the links between indicators, dimensions, and categories, which made it difficult to create a system for ranking the indicators. For example, understanding how social and organizational dimensions are connected could give a better view of a community's resilience since proper management and public communication are important during coastal hazards.

Temporal Dynamics: The research treated disasters as single events without considering different phases (pre-disaster, during the disaster, and post-disaster), although the performance of resilience indicators may change across these periods.

Cultural Bias: While including experts from both the Global North and South was valuable, it might have introduced cultural biases. Global North experts may have focused on technological resilience, while Global South experts emphasized community-based efforts. This difference could have influenced the selection of indicators, potentially skewing the framework toward one group's priorities.

Mono Hazard Focus: Although having a specific hazard focus is a key design criterion for resilience frameworks, coastal communities are often exposed to multiple hazards, such as heat waves. This could limit the framework's usability in such contexts.

8.2 Conclusion

This research aimed to design a comprehensive framework for assessing coastal community resilience, focusing on multi-dimensionality and flexibility for diverse contexts. The research addressed the following questions:

RQ1: What are the specific needs and expectations of decision-makers regarding coastal community resilience assessments that can be effectively integrated into the framework?

At a high level, decision-makers need tools that guide them in making informed decisions about how to protect their communities from coastal hazards. They often face multiple challenges: balancing short-term political goals with long-term resilience, managing limited resources, and communicating technical issues to the public. Therefore, they look for frameworks that are practical, cost-effective, and easy to implement.

One of the main expectations is clarity. Decision-makers want frameworks that are easy to understand and free from technical jargon. For example, a mayor planning flood defenses will prefer a report that highlights clear risk levels rather than a highly technical, multi-page document. They need to be able to quickly understand the situation and communicate it to their teams and the public.

However, this need for simplicity can sometimes conflict with the complexity of resilience assessments. While simplified reports make decision-making faster, they may overlook important nuances. For instance, a quick summary of flood risks might not capture the specific vulnerabilities of certain communities. This is a trade-off between clarity and completeness.

In addition, Decision-makers also face a trade-off between cost-effectiveness and comprehensiveness. While a basic framework may be more affordable, it may lack depth in certain areas (e.g., ignoring long-term environmental impacts). On the other hand, a more detailed framework, while providing richer insights, can be costly and time-consuming to implement. Therefore, the best frameworks might offer a balance, also allowing decision-makers to adapt the framework to their specific needs and constraints.

RQ2: What are the essential dimensions and indicators that contribute to coastal community resilience against hazards?

Resilience is a multi-dimensional concept, which means that it covers several different aspects of community life. These dimensions typically include social, organizational, economic, infrastructure, and environmental. Focusing on just one dimension (e.g., infrastructure) would miss out on the broader picture of what it takes for a community to truly recover and thrive after a disaster.

To fully capture the complexity of resilience, this research identified 223 indicators from the literature and indicator mining and categorized them as shown in Table 8.1.

Table 8.1: Snapshot of Essential Indicators by Dimension

Dimension (No. of Indicators)	Example Indicators	References
Infrastructure (61)	Number of Hospitals, Occupied housing units with vehicle available, Evacuation routes	(Dasgupta & Shaw, 2015; Peacock et al., 2010)
Organizational (37)	Funds allocation to Disaster Risk Reduction, Adequacy of trained emergency response team, Coordination with NGOs	(Dasgupta & Shaw, 2015; Peacock et al., 2010)
Social (59)	Race/ethnicity, Physician access, Percentage of population covered by comprehensive plan	(Cimellaro et al., 2016; Cutter et al., 2014)
Economic (25)	Non-dependence on primary/tourism sectors, Gross regional domestic product per capita, Hazard insurance coverage	(Cutter et al., 2014; Kusumastuti et al., 2014)
Environmental (41)	Protected land, Contamination of groundwater, Mangrove deterioration	(Cimellaro et al., 2016; Dasgupta & Shaw, 2015)

Each of these indicators can be essential for a coastal community when assessing its resilience, as they cover multiple dimensions comprehensively. However, while having a detailed list of indicators is valuable, simply using the list alone does not make a community resilient or fully assess its resilience. It is important to ensure that these indicators are flexible and adaptable to the specific context.

RQ3: What essential indicators ensure a multi-dimensional approach to assessing coastal community resilience to hazards, with universal applicability or flexibility for specific contexts?

Resilience assessments must be universal enough to apply across different communities but flexible enough to adapt to local conditions. This means combining fixed indicators— a strong consensus about them —and context-specific indicators, which are tailored to the unique needs of a particular location and individuals have differing ideas about them.

Some indicators are non-negotiable across any coastal community. For instance, access to healthcare, emergency response capabilities, and availability of evacuation routes are always crucial in disaster resilience. These indicators serve as a universal baseline for assessing how prepared a community is for an upcoming coastal hazard.

On the other hand, some indicators will be highly dependent on the local context. For example, in a low-lying island community, sea-level rise might be the most concern. In contrast, in a large coastal city, transportation infrastructure and urban heat island effects might play a bigger role. Context-specific indicators allow the framework to adapt to different environmental, social, and economic settings.

However, the challenge still remains. The challenge here is balancing universality with specificity. A framework that is too rigid (focused only on fixed indicators) might miss out on key local nuances. At the same time, having too flexible (too many context-specific indicators) can make it difficult to compare across regions. The trade-off is between having comparable data across regions and having tailored locally relevant assessments. Therefore, by combining these indicators, the bigger picture can be satisfied. The framework can be multi-dimensional, while universal applicability and context flexibility can also be ensured.

In this research, 110 indicators were identified as fixed indicators that ensure a multi-dimensional approach to assessing coastal community resilience to hazards with potentially universal applicability. Furthermore, 24 indicators were identified as context-specific (See Table 8.2).

Table 8.2: Snapshot of Fixed and Context-Specific Potential Indicators

Dimension (Fixed, CSP)	Example Indicators	References
Infrastructure (28,6)	**Fixed**: Number of Hospitals, Occupied housing units with vehicle available, Evacuation routes. **CSP**: Number of Radio stations, Implementation of renewable source of energy (Solar/wind etc.)	(Dasgupta & Shaw, 2015; Peacock et al., 2010)
Organizational (24,3)	**Fixed**: Funds allocation to Disaster Risk Reduction,, Implementation flood/erosion control. **CSP**: Transparency in Aid distribution process.	(Dasgupta & Shaw, 2015)
Social (31,8)	**Fixed**: Physician access, Percentage of population covered by comprehensive plan. **CSP**: Race/ethnicity, Place attachment-not recent immigrants.	(Cimellaro et al., 2016; Cutter et al., 2014)
Economic (11,1)	**Fixed**: Gross regional domestic product per capita, Hazard insurance coverage. **CSP**: Professional and business services.	(Cimellaro et al., 2016; Cutter et al., 2014; Kusumastuti et al., 2014)
Environmental (16,6)	**Fixed**: Protected land, Contamination of groundwater, Mangrove deterioration **CSP**: Change in tidal patterns leading to river piracy/damage to dykes, Rate of sea level rise in the block	(Cimellaro et al., 2016; Dasgupta & Shaw, 2015)

RQ4: How can these indicators be operationalized to ensure practicality and effectiveness in decision-making processes?

To operationalize the collected indicators effectively, they must be tailored to the specific needs and priorities of decision-makers, ensuring relevance to the local context and actionable insights. An expert emphasized the need to focus on the most relevant indicators for each region: "Local relevance is crucial, even when using a standard set of vulnerability assessments."

Stakeholder involvement is key to selecting and implementing practical indicators. Collaborative input ensures the framework is comprehensive and widely accepted, as one expert noted: "Collaboration with stakeholders leads to more accepted solutions."

Additionally, the indicators must be clear and accessible. Simplifying them avoids jargon and ensures usability across diverse decision-making contexts. One expert highlighted: "Frameworks should be easy to comprehend—clear and simple."

Finally, the operational indicators rely on quality data. Decision-makers require reliable, accessible, and timely data supported by user-friendly tools and training for effective interpretation and application.

*"How can a new framework for coastal community resilience assessments be designed to effectively **integrate the needs and expectations of decision-makers**, **include essential indicators and dimensions**, **be flexible to context**, and **shift the focus from isolated system** evaluation to overall community resilience in its architecture?"*

Designing a new framework for coastal community resilience must begin with a comprehensive understanding of the factors that contribute to resilience, including social, economic, environmental, and infrastructural systems. **The framework should incorporate a multi-dimensional set of indicators that cover these five key areas (Social, economic, Organizational, Infrastructure, and Environmental).** These dimensions must be comprehensive and balanced so that no one dimension is overemphasized.

While a set of universal indicators is necessary for consistency, **the framework also needs to be adaptable to different local contexts**. Every coastal community is unique, and the framework must reflect these differences, ensuring that it remains relevant and applicable no matter where it is applied. Therefore, identifying context-specific indicators is crucial. By selecting such indicators, frameworks can become not only more operational but also more adaptable to various contexts. This flexibility allows them to serve as blueprints for a wide range of communities, enabling these communities to develop tailored frameworks without starting from scratch. Additionally, this approach ensures that frameworks can evolve over time, supporting continuous improvement in response to future changes and uncertainties.

To be useful, **the framework must be designed around the practical needs and expectations of decision-makers**. Given the level of uncertainty in the world, a framework that is only theoretically sound is not sufficient. While basing a framework solely on theory without considering current real-world conditions can be misleading, even a scientifically robust framework may fail if there is no clear pathway for its practical use. Without outlining how the framework will be applied and how each phase of its development will address the needs of different target audiences, the final product risks being underutilized, resulting in wasted resources.

When considering decision-makers, they are often the ones who will use tools such as frameworks to inform policies and investments. In the context of coastal community resilience, the decisions they face are inherently complex. Therefore, it is essential for the framework to be clear, cost-effective, and practical. Furthermore, **The framework should aim to address system thinking**. By adopting a systems theory perspective, the framework minimizes the risk of overlooking key elements that could trigger cascading effects throughout the community. This holistic view is especially important for coastal communities, where reliance on interconnected systems is high. In this context, a top-down approach that also considers other systems enables decision-makers to assess not only individual dimensions of resilience but also the broader, interconnected nature of the community that could offer a better understanding of the overall community resilience.

8.3 Future Research

To address the limitations and build upon this research, the following areas are recommended for future research:

1. Interdependency and Weighting and Temporal Dynamics: Future research should focus on developing a systematic approach to assign weights to indicators, dimensions, and categories within the framework. A matrix-based interdependency technique, like that used byKammouh et al. (2019) in the PEOPLES framework, could quantify the relationships between resilience components. This would ensure that indicators are properly weighted. Additionally, exploring the dynamic nature of resilience indicators across disaster phases (pre-, during, and post-disaster) using performance functions, as Kammouh et al. (2019) propose, would provide a more complete assessment of community resilience over time.

2. Real-World Application of the Framework: Testing the NERMI CCR framework in real-world case studies would assess its adaptability and effectiveness. As shown in Dasgupta and Shaw (2015) work in the Indian Sundarbans, future research could explore how the framework adapts to different socio-ecological systems. Additionally, a comparative analysis between Global South and Global North communities, such as Puerto Rico (Sobhaninia, 2024), The Netherlands (Zeeland), and Iran (Golestan province) would offer insights into how differing socioeconomic and environmental aspects influence resilience-building efforts and at the same time can refine the framework's global applicability.

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A Appendix A: Interview Protocol and Analysis

Position:	Date:
Person:	Interview Duration:
Interviewer(s):	Language:

Interview Questions

Greeting

Confidentiality Record Statement (Consensus)

Who you are?

- What is your background (Education, Work position, and Working Experience)?

What do you think?

- How would you define a disaster in keywords?
- We constructed the impressive Delta works and effectively prevented natural disasters. However, we must question whether we are truly safe or living in a false sense of security. What is your opinion regarding this?

How can we improve?

- Climate change is becoming an increasingly pressing issue. Despite our efforts to prevent it, it seems inevitable that its consequences will soon be upon us. This is likely to affect various structures, potentially disrupting their functions or increasing their demand. In light of this, what can we do to become more adaptable and resilient?
- As an individual with both academic and practical experience, do you believe that policies and management of climate change sufficiently prioritize the importance of people? In other words, should we shift our focus away from purely technical aspects and instead consider the role of people when assessing a region's level of resilience? Is it time to move towards a more sociotechnical approach?

What about the resilience framework?

Framework Operationalization

- Can the use of recognized global resilience frameworks assist us? Are academic frameworks addressing this need effectively?
- You can find frameworks everywhere. Is it positive for each party to view resilience from their own perspective, or do we need to combine them?
- If the combination is impossible or possible in either case, how can we benefit most from it? How can we make these frameworks work?

Decision makers' needs and expectations

- What are the specific needs and expectations of decision-makers regarding community resilience assessments that can be effectively integrated into the design of the new framework? Any Comments or recommendations? Did you like the interview?

Closing

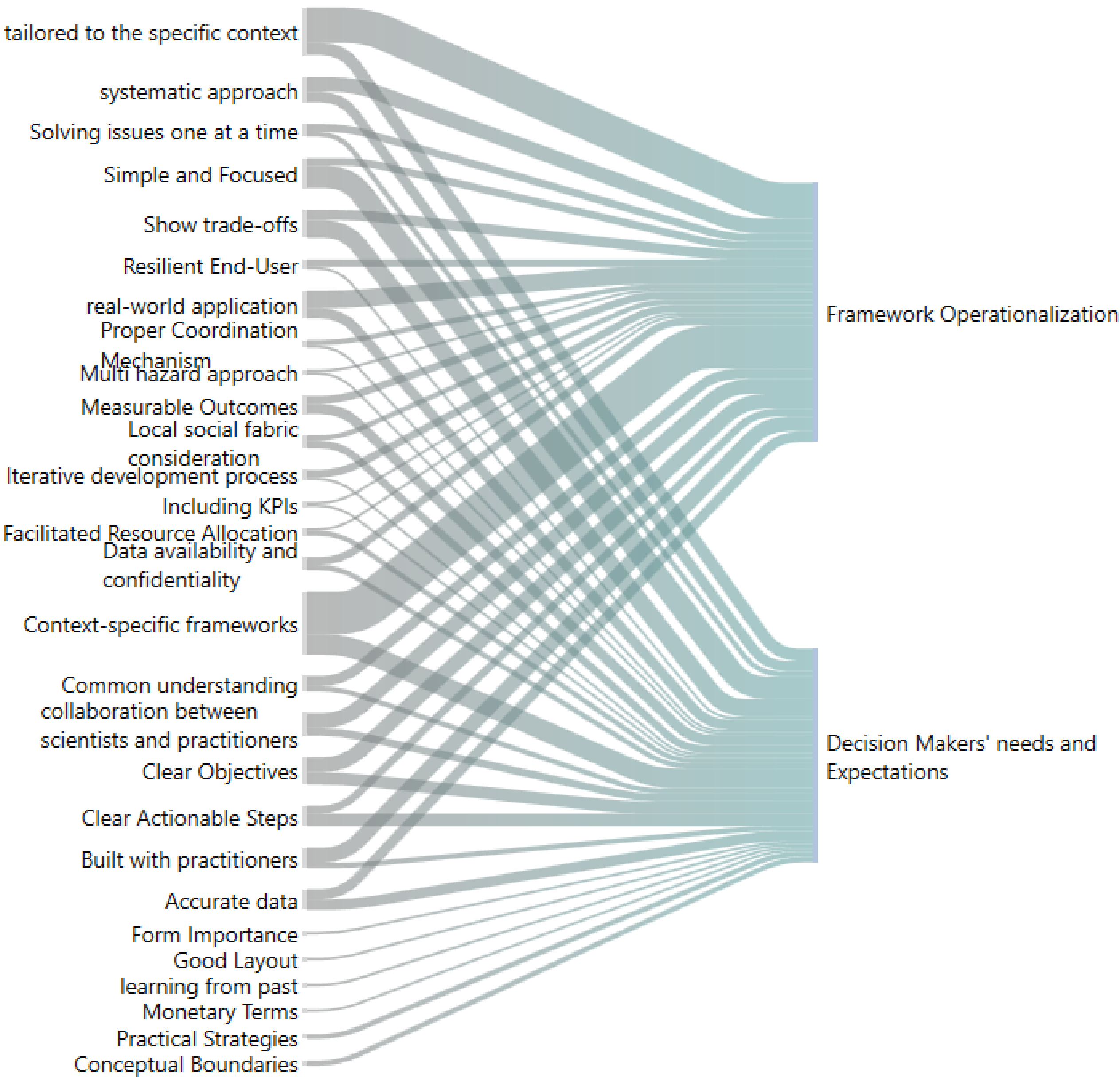

Figure A.1: The Sankey Diagram For Content Analysis (Codes)

B Appendix B: Survey Guide

READ ME AND FILL OUT!

Dear Participant,

Thank you for your invaluable contribution to my thesis research. Your feedback is crucial in assessing the relevance and significance of various indicators identified in the literature. Please take a moment to rate each indicator. Your responses will significantly enhance the accuracy and validity of this study.

Based on the provided table, here are the instructions for your participants:

1. Review the Table:

    - The table is divided into five **dimensions**: **Infrastructure, Organizational, Social, Economical, and Environmental**.
    - The table is divided into several **categories**. Each category has specific **indicators** listed under it, with corresponding **measures, units**, and **measure types**.

2. Understanding the Columns:

    - **Dimension**: The broader area under which specific categories fall.
    - **Category**: The broader area under which specific indicators fall.
    - **Indicator Name**: The specific factor you are evaluating.
    - **Measure**: The metric used to quantify the indicator.
    - **Unit**: The unit of measurement for the indicator (e.g., Number, Percent).
    - **Measure Type**: Indicates whether the measure is an integer or continuous value.
    - **Importance to coastal hazards**: This column contains five checkboxes ranging from Very Low to Very High. You need to select one that best represents the importance of each indicator to coastal hazards. **Please choose the box that is the closest to your thought.**
    - **Comment**: An optional field where you can add any additional remarks or justifications for your rating.

3. Rate the Importance:

    For **each indicator**, consider its significance and impact within its category and dimension.

    Select the checkbox that corresponds to your assessment of the indicator's importance (**Choose one box only**):

    - Very Low
    - Low
    - Medium
    - High
    - Very High

4. Add Comments:

    Please **Motivate** your answer and note them in the "**Comment**" column.

Infrastructure											
Code	Category	Indicator Name	Measure	Unit	Measure Type	Importance to coastal hazards					Comment
						Very Low	Low	Medium	High	Very High	
1	Infrastrcuture Establishments	Building construction establishments	Number of Building Construction establishments	Number of estalblishments	Integer	☐	☑	☐	☐	☐	Reason
2		Highway, street, and bridge construction establishments	Highway, street, and bridge construction establishments	Number of estalblishments	Integer	☐	☐	☑	☐	☐	Reason
3		Hotels and motels	Number of Hotels and motels	Number	Integer	☐	☐	☑	☐	☐	Reason
4		Land subdivision establishments	Number of Land subdivision establishments	Number of estalblishments	Integer	☐	☐	☐	☐	☑	Reason

If you need further clarification or assistance, please let us know so we can arrange a face-to-face meeting and fill out the survey together. You have **one week** from receiving these instructions to complete and return the Excel sheet. Please rename the file to include the **first letter of your first name and the first letter of your surname**. If you have any questions regarding the survey, feel free to reach out to me. Your participation and insights are greatly appreciated.

Best Regards,

Shayan

C Appendix C: Survey Questionnaires

The full set of questionnaires used in this study is available online. Interested readers can access them through the following link: Link.

D Appendix D: Survey Analysis

Table D.1: Descriptive Statistics Questionnaire 1

Q1	Number of values	Minimum	25% Percentile	Median	75% Percentile	Maximum	Range	Mean	Std. Deviation	Std. Error of Mean
A1	6	0	0.375	0.625	1	1	1	0.625	0.379	0.155
A2	6	0.5	0.688	1	1	1	0.5	0.875	0.209	0.0854
A3	6	0.75	0.75	1	1	1	0.25	0.917	0.129	0.0527
A4	6	0.25	0.25	0.5	0.563	0.75	0.5	0.458	0.188	0.0768
A5	6	0	0.188	0.375	0.5	0.5	0.5	0.333	0.204	0.0833
A6	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
A7	6	0.25	0.625	0.75	0.813	1	0.75	0.708	0.246	0.1
A8	6	0.5	0.5	0.5	0.75	0.75	0.25	0.583	0.129	0.0527
A9	6	0.5	0.688	0.75	1	1	0.5	0.792	0.188	0.0768
A10	6	0	0.375	0.625	0.75	0.75	0.75	0.542	0.292	0.119
A11	6	0.75	0.75	1	1	1	0.25	0.917	0.129	0.0527
A12	6	0	0.375	0.75	1	1	1	0.667	0.376	0.154
A13	6	0	0.563	0.75	1	1	1	0.708	0.368	0.15
A14	6	0.5	0.5	0.625	0.75	0.75	0.25	0.625	0.137	0.0559
A15	6	0.75	0.75	1	1	1	0.25	0.917	0.129	0.0527
A16	6	0	0.375	0.5	0.75	0.75	0.75	0.5	0.274	0.112
A17	6	0.5	0.688	0.75	1	1	0.5	0.792	0.188	0.0768
A18	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
A19	6	0.75	0.938	1	1	1	0.25	0.958	0.102	0.0417
A20	6	0.25	0.625	0.75	1	1	0.75	0.75	0.274	0.112
A21	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
A22	6	0.25	0.438	0.75	1	1	0.75	0.708	0.292	0.119
A23	6	0.75	0.938	1	1	1	0.25	0.958	0.102	0.0417
A24	6	0.75	0.938	1	1	1	0.25	0.958	0.102	0.0417
A25	6	1	1	1	1	1	0	1	0	0
A26	6	0	0	0.5	0.625	1	1	0.417	0.376	0.154
A27	6	0.5	0.5	0.625	0.75	0.75	0.25	0.625	0.137	0.0559
A28	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
A29	6	0	0.188	0.625	0.813	1	1	0.542	0.368	0.15
A30	6	0	0.375	0.5	0.813	1	1	0.542	0.332	0.136
A31	6	0.25	0.438	0.75	1	1	0.75	0.708	0.292	0.119
A32	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
A33	6	0	0.375	0.625	0.813	1	1	0.583	0.342	0.139
A34	6	0.25	0.25	0.5	0.75	0.75	0.5	0.5	0.224	0.0913
A35	6	0.25	0.25	0.5	0.5	0.5	0.25	0.417	0.129	0.0527
A36	6	0.25	0.438	0.5	0.563	0.75	0.5	0.5	0.158	0.0645
A37	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
A38	6	0.25	0.25	0.5	0.563	0.75	0.5	0.458	0.188	0.0768
A39	6	0.25	0.25	0.375	0.75	0.75	0.5	0.458	0.246	0.1
A40	6	0	0.188	0.625	1	1	1	0.583	0.408	0.167
A41	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
A42	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
A43	6	0.5	0.5	0.5	0.813	1	0.5	0.625	0.209	0.0854
A44	6	0.75	0.75	0.75	0.813	1	0.25	0.792	0.102	0.0417
A45	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
A46	6	0.25	0.438	0.5	1	1	0.75	0.625	0.306	0.125
A47	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
A48	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
A49	6	0.25	0.438	0.75	1	1	0.75	0.708	0.292	0.119
A50	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
A51	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
A52	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
A53	6	0.25	0.438	0.625	0.813	1	0.75	0.625	0.262	0.107
A54	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
A55	6	0.5	0.875	1	1	1	0.5	0.917	0.204	0.0833
A56	6	0.5	0.5	0.75	0.75	0.75	0.25	0.667	0.129	0.0527
A57	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913

Table D.2: Descriptive Statistics Questionnaire 2

Q2	Number of values	Minimum	25% Percentile	Median	75% Percentile	Maximum	Range	Mean	Std. Deviation	Std. Error of Mean
B1	6	0.25	0.25	0.5	0.813	1	0.75	0.542	0.292	0.119
B2	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
B3	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
B4	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
B5	6	0	0	0.375	0.5	0.5	0.5	0.292	0.246	0.1
B6	6	0	0	0.125	0.5	0.5	0.5	0.208	0.246	0.1
B7	6	0.25	0.813	1	1	1	0.75	0.875	0.306	0.125
B8	6	0.25	0.438	0.625	0.75	0.75	0.5	0.583	0.204	0.0833
B9	6	0	0.375	0.5	0.75	0.75	0.75	0.5	0.274	0.112
B10	6	0	0	0.25	0.5	0.5	0.5	0.25	0.224	0.0913
B11	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
B12	6	0.5	0.688	0.75	1	1	0.5	0.792	0.188	0.0768
B13	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
B14	6	0.25	0.438	0.5	0.563	0.75	0.5	0.5	0.158	0.0645
B15	6	0	0.188	0.5	0.813	1	1	0.5	0.354	0.144
B16	6	0.5	0.5	0.625	0.813	1	0.5	0.667	0.204	0.0833
B17	6	0.25	0.25	0.75	1	1	0.75	0.667	0.376	0.154
B18	6	0.25	0.25	0.75	1	1	0.75	0.667	0.342	0.139
B19	6	0.5	0.688	1	1	1	0.5	0.875	0.209	0.0854
B20	6	0	0.188	0.25	0.313	0.5	0.5	0.25	0.158	0.0645
B21	6	0.5	0.688	0.75	1	1	0.5	0.792	0.188	0.0768
B22	6	0	0.188	0.5	1	1	1	0.542	0.401	0.164
B23	6	1	1	1	1	1	0	1	0	0
B24	6	0.25	0.438	0.625	0.813	1	0.75	0.625	0.262	0.107
B25	6	0.25	0.25	0.5	0.75	0.75	0.5	0.5	0.274	0.112
B26	6	0	0	0	0.25	0.25	0.25	0.0833	0.129	0.0527
B27	6	0.25	0.25	0.5	0.75	0.75	0.5	0.5	0.224	0.0913
B28	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
B29	6	0	0.188	0.5	1	1	1	0.542	0.431	0.176
B30	6	0.25	0.25	0.75	0.75	0.75	0.5	0.583	0.258	0.105
B31	6	0.25	0.438	0.75	0.813	1	0.75	0.667	0.258	0.105
B32	6	0	0	0.125	0.375	0.75	0.75	0.208	0.292	0.119
B33	6	0.25	0.25	0.25	0.563	0.75	0.5	0.375	0.209	0.0854
B34	6	0	0	0.125	0.375	0.75	0.75	0.208	0.292	0.119
B35	6	0.25	0.25	0.75	1	1	0.75	0.667	0.342	0.139
B36	6	0.25	0.25	0.375	0.813	1	0.75	0.5	0.316	0.129
B37	6	0	0.188	0.375	0.563	0.75	0.75	0.375	0.262	0.107
B38	6	0	0	0.125	0.25	0.25	0.25	0.125	0.137	0.0559
B39	6	0	0.188	0.625	0.75	0.75	0.75	0.5	0.316	0.129
B40	6	0	0.188	0.375	0.813	1	1	0.458	0.368	0.15
B41	6	0	0.188	0.5	0.563	0.75	0.75	0.417	0.258	0.105
B42	6	0	0.188	0.625	0.75	0.75	0.75	0.5	0.316	0.129
B43	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
B44	6	0.5	0.688	0.75	0.813	1	0.5	0.75	0.158	0.0645
B45	6	0.5	0.5	0.625	1	1	0.5	0.708	0.246	0.1
B46	6	0.5	0.688	0.75	0.813	1	0.5	0.75	0.158	0.0645
B47	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
B48	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
B49	6	0.5	0.688	0.75	1	1	0.5	0.792	0.188	0.0768
B50	6	0.5	0.688	1	1	1	0.5	0.875	0.209	0.0854
B51	6	0.25	0.438	0.875	1	1	0.75	0.75	0.316	0.129
B52	6	0	0	0.5	1	1	1	0.5	0.474	0.194
B53	6	0	0.375	0.875	1	1	1	0.708	0.401	0.164
B54	6	0.25	0.438	0.625	1	1	0.75	0.667	0.303	0.124
B55	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105

Table D.3: Descriptive Statistics Questionnaire 3

Var	Number of values	Minimum	25% Percentile	Median	75% Percentile	Maximum	Range	Mean	Std. Deviation	Std. Error of Mean
C1	6	0	0.375	0.5	0.625	1	1	0.5	0.316	0.129
C2	6	0.5	0.688	0.75	0.813	1	0.5	0.75	0.158	0.0645
C3	6	0.25	0.625	0.75	0.813	1	0.75	0.708	0.246	0.1
C4	6	0.25	0.25	0.25	0.563	0.75	0.5	0.375	0.209	0.0854
C5	6	0.25	0.438	0.5	0.625	1	0.75	0.542	0.246	0.1
C6	6	0.25	0.438	0.5	0.5	0.5	0.25	0.458	0.102	0.0417
C7	6	0	0.188	0.5	0.75	0.75	0.75	0.458	0.292	0.119
C8	6	0.75	0.75	1	1	1	0.25	0.917	0.129	0.0527
C9	6	0.75	0.938	1	1	1	0.25	0.958	0.102	0.0417
C10	6	0.5	0.688	1	1	1	0.5	0.875	0.209	0.0854
C11	6	0.25	0.438	0.625	0.813	1	0.75	0.625	0.262	0.107
C12	6	0.25	0.625	0.75	0.75	0.75	0.5	0.667	0.204	0.0833
C13	6	0.5	0.688	0.875	1	1	0.5	0.833	0.204	0.0833
C14	6	0.75	0.938	1	1	1	0.25	0.958	0.102	0.0417
C15	6	0	0.375	0.5	0.75	0.75	0.75	0.5	0.274	0.112
C16	6	0.75	0.75	1	1	1	0.25	0.917	C	0.0527
C17	6	0.75	0.75	0.75	1	1	0.25	0.833	0.129	0.0527
C18	6	0.25	0.625	1	1	1	0.75	0.833	0.303	0.124
C19	6	0.25	0.438	0.75	1	1	0.75	0.708	0.292	0.119
C20	6	0.75	0.75	0.75	0.813	1	0.25	0.792	0.102	0.0417
C21	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
C22	6	0	0.375	0.625	0.813	1	1	0.583	0.342	0.139
C23	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
C24	6	0.5	0.5	0.875	1	1	0.5	0.792	0.246	0.1
C25	6	0.25	0.438	0.625	0.813	1	0.75	0.625	0.262	0.107
C26	6	0.5	0.5	0.625	0.75	0.75	0.25	0.625	0.137	0.0559
C27	6	0.5	0.688	0.75	0.75	0.75	0.25	0.708	0.102	0.0417
C28	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
C29	6	0.25	0.25	0.375	0.563	0.75	0.5	0.417	0.204	0.0833
C30	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
C31	6	0.25	0.25	0.75	0.75	0.75	0.5	0.583	0.258	0.105
C32	6	0	0.188	0.25	0.313	0.5	0.5	0.25	0.158	0.0645
C33	6	0	0.188	0.25	0.313	0.5	0.5	0.25	0.158	0.0645
C34	6	0	0.188	0.25	0.5	0.5	0.5	0.292	0.188	0.0768
C35	6	0.25	0.25	0.25	0.5	0.5	0.25	0.333	0.129	0.0527
C36	6	0.25	0.625	0.75	0.813	1	0.75	0.708	0.246	0.1
C37	6	0	0.188	0.375	0.563	0.75	0.75	0.375	0.262	0.107
C38	6	0	0.188	0.375	0.813	1	1	0.458	0.368	0.15
C39	6	0.5	0.5	0.625	0.813	1	0.5	0.667	0.204	0.0833
C40	6	0.25	0.438	0.75	0.813	1	0.75	0.667	0.258	0.105
C41	6	0	0.188	0.375	1	1	1	0.5	0.418	0.171
C42	6	0.5	0.688	0.75	1	1	0.5	0.792	0.188	0.0768
C43	6	0.25	0.25	0.75	0.75	0.75	0.5	0.583	0.258	0.105
C44	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
C45	6	0	0.188	0.625	0.75	0.75	0.75	0.5	0.316	0.129
C46	6	0.75	0.75	0.75	1	1	0.25	0.833	0.129	0.0527
C47	6	0.25	0.438	0.625	0.813	1	0.75	0.625	0.262	0.107
C48	6	0.25	0.438	0.75	0.813	1	0.75	0.667	0.258	0.105
C49	6	0.25	0.438	0.625	1	1	0.75	0.667	0.303	0.124
C50	6	0.5	0.688	0.875	1	1	0.5	0.833	0.204	0.0833
C51	6	0.75	0.75	0.75	1	1	0.25	0.833	0.129	0.0527
C52	6	0.5	0.688	0.875	1	1	0.5	0.833	0.204	0.0833
C53	6	0.75	0.938	1	1	1	0.25	0.958	0.102	0.0417
C54	6	0.5	0.5	0.75	1	1	0.5	0.75	0.224	0.0913
C55	6	0.25	0.438	0.625	0.75	0.75	0.5	0.583	0.204	0.0833
C56	6	0.25	0.25	0.5	0.75	0.75	0.5	0.5	0.224	0.0913

Table D.4: Descriptive Statistics Questionnaire 4

Var	Number of values	Minimum	25% Percentile	Median	75% Percentile	Maximum	Range	Mean	Std. Deviation	Std. Error of Mean
D1	6	0.25	0.25	0.5	0.563	0.75	0.5	0.458	0.188	0.0768
D2	6	0.25	0.438	0.5	0.75	0.75	0.5	0.542	0.188	0.0768
D3	6	0.5	0.5	0.875	1	1	0.5	0.792	0.246	0.1
D4	6	0.75	0.75	0.75	0.813	1	0.25	0.792	0.102	0.0417
D5	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
D6	6	0	0	0.25	0.5	0.5	0.5	0.25	0.224	0.0913
D7	6	0.25	0.25	0.375	0.5	0.5	0.25	0.375	0.137	0.0559
D8	6	0.25	0.438	0.5	0.563	0.75	0.5	0.5	0.158	0.0645
D9	6	0.5	0.688	0.875	1	1	0.5	0.833	0.204	0.0833
D10	6	0.25	0.625	0.875	1	1	0.75	0.792	0.292	0.119
D11	6	0	0	0.75	0.75	0.75	0.75	0.5	0.387	0.158
D12	6	0	0.188	0.625	0.75	0.75	0.75	0.5	0.316	0.129
D13	6	0.25	0.25	0.75	0.813	1	0.75	0.625	0.306	0.125
D14	6	0	0.188	0.25	0.5	0.5	0.5	0.292	0.188	0.0768
D15	6	0.25	0.25	0.5	0.563	0.75	0.5	0.458	0.188	0.0768
D16	6	0.75	0.75	1	1	1	0.25	0.917	0.129	0.0527
D17	6	0.5	0.5	0.75	0.75	0.75	0.25	0.667	0.129	0.0527
D18	6	0.25	0.438	0.5	0.625	1	0.75	0.542	0.246	0.1
D19	6	0	0.188	0.5	0.563	0.75	0.75	0.417	0.258	0.105
D20	6	0.25	0.25	0.25	0.5	0.5	0.25	0.333	0.129	0.0527
D21	6	0.75	0.75	0.875	1	1	0.25	0.875	0.137	0.0559
D22	6	0.5	0.5	0.75	0.75	0.75	0.25	0.667	0.129	0.0527
D23	6	0.5	0.5	0.625	0.75	0.75	0.25	0.625	0.137	0.0559
D24	6	0.25	0.25	0.75	0.75	0.75	0.5	0.583	0.258	0.105
D25	6	0	0.188	0.375	0.75	0.75	0.75	0.417	0.303	0.124
D26	6	0.25	0.25	0.25	0.5	0.5	0.25	0.333	0.129	0.0527
D27	6	0	0.188	0.5	0.75	0.75	0.75	0.458	0.292	0.119
D28	6	0	0.188	0.25	0.5	0.5	0.5	0.292	0.188	0.0768
D29	6	0.5	0.5	0.5	0.75	0.75	0.25	0.583	0.129	0.0527
D30	6	0	0.375	0.5	0.563	0.75	0.75	0.458	0.246	0.1
D31	6	0	0.375	0.75	0.813	1	1	0.625	0.345	0.141
D32	6	0.5	0.5	0.75	0.813	1	0.5	0.708	0.188	0.0768
D33	6	0	0	0.375	0.813	1	1	0.417	0.408	0.167
D34	6	0	0.188	0.375	0.5	0.5	0.5	0.333	0.204	0.0833
D35	6	0.25	0.438	0.5	0.563	0.75	0.5	0.5	0.158	0.0645
D36	6	0.5	0.5	0.5	0.563	0.75	0.25	0.542	0.102	0.0417
D37	6	0	0	0.25	0.313	0.5	0.5	0.208	0.188	0.0768
D38	6	0	0.188	0.25	0.5	0.5	0.5	0.292	0.188	0.0768
D39	6	0.25	0.25	0.375	0.563	0.75	0.5	0.417	0.204	0.0833
D40	6	0	0.188	0.375	0.563	0.75	0.75	0.375	0.262	0.107
D41	6	0.25	0.438	0.625	0.75	0.75	0.5	0.583	0.204	0.0833
D42	6	0.25	0.438	0.5	0.75	0.75	0.5	0.542	0.188	0.0768
D43	6	0.75	0.75	0.75	1	1	0.25	0.833	0.129	0.0527
D44	6	0.5	0.688	0.75	0.813	1	0.5	0.75	0.158	0.0645
D45	6	0.5	0.5	0.5	0.75	0.75	0.25	0.583	0.129	0.0527
D46	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
D47	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
D48	6	0.25	0.438	0.75	1	1	0.75	0.708	0.332	0.136
D49	6	0.25	0.438	0.5	0.813	1	0.75	0.583	0.258	0.105
D50	6	0.25	0.625	0.75	1	1	0.75	0.75	0.274	0.112
D51	6	0.25	0.25	0.5	0.625	1	0.75	0.5	0.274	0.112
D52	6	0.25	0.25	0.25	0.5	0.5	0.25	0.333	0.129	0.0527
D53	6	0.25	0.25	0.5	0.563	0.75	0.5	0.458	0.188	0.0768
D54	6	0.25	0.25	0.5	0.563	0.75	0.5	0.458	0.188	0.0768
D55	6	0.25	0.25	0.625	0.813	1	0.75	0.583	0.303	0.124

Table D.5: Eigenvectors in Matrix Format (A1 to A57)

Var	PC1	PC2	PC3	PC4	PC5
A1	0.1912	0.2082	−0.2304	0.0270	−0.3798
A2	0.0910	−0.0735	0.0793	−0.2216	−0.1062
A3	0.0623	−0.0124	−0.1375	−0.0123	0.0499
A4	0.1531	−0.0858	0.0116	0.0446	−0.1127
A5	0.1449	−0.0490	0.0074	−0.1434	−0.1552
A6	0.0513	0.1812	0.2059	0.1784	−0.0242
A7	−0.0560	−0.2607	0.0124	0.1443	−0.0433
A8	0.0030	0.0599	0.0712	−0.1343	0.0901
A9	0.0542	0.0244	−0.1417	−0.2003	0.0074
A10	−0.1111	0.2635	−0.1706	−0.1083	−0.0666
A11	0.0651	0.0476	0.0035	0.1318	0.0836
A12	−0.2603	0.2329	−0.0993	−0.1990	0.1340
A13	−0.1704	0.3358	0.0381	−0.2303	−0.0264
A14	−0.0081	0.0368	−0.0042	−0.1880	−0.0425
A15	0.0497	−0.0551	0.0069	−0.1560	−0.0037
A16	−0.0698	0.2452	−0.0982	−0.1738	−0.1691
A17	−0.0548	0.1519	0.0602	−0.1663	0.0512
A18	0.0608	−0.0320	0.0823	−0.1023	0.1289
A19	0.0413	−0.0183	0.0725	−0.0656	−0.1026
A20	0.1973	−0.0442	0.1553	−0.1553	−0.1252
A21	−0.0007	−0.1960	0.2315	−0.0019	0.0767
A22	0.2084	−0.0211	0.2307	−0.1016	0.0073
A23	0.0111	0.0231	0.0754	0.0537	0.1325
A24	0.0540	0.0244	−0.0719	0.0781	−0.0490
A25	0	0	0	0	0
A26	0.2440	0.2639	0.0056	0.1513	0.2493
A27	−0.0375	−0.0981	0.0105	0.0194	0.1904
A28	0.0422	−0.1947	0.0842	0.0226	−0.1048

Var	PC1	PC2	PC3	PC4	PC5
A29	0.0497	0.1615	0.4257	0.0884	0.0548
A30	0.2134	0.2545	−0.0796	0.1344	−0.1147
A31	0.2057	−0.0810	0.0897	−0.2457	−0.0263
A32	0.1342	−0.0213	0.0202	−0.0610	0.3114
A33	−0.2412	−0.2040	0.1354	−0.0072	−0.2156
A34	0.1010	0.1260	0.2128	0.0224	−0.0279
A35	−0.0156	−0.1027	0.0731	−0.0094	−0.1436
A36	−0.0653	−0.0476	0.0663	0.1466	−0.1400
A37	0.1036	−0.0307	−0.0650	−0.0779	−0.0527
A38	−0.0597	−0.1443	−0.1403	−0.0879	−0.0747
A39	−0.1659	0.0431	0.2025	0.0902	0.0027
A40	0.2739	0.2225	0.0724	0.3105	−0.0423
A41	0.1644	−0.0627	0.0172	−0.1802	0.0762
A42	0.2183	−0.0383	−0.0547	−0.1020	0.0272
A43	0.1725	−0.0995	0.0214	0.0078	0.1187
A44	−0.0084	0.0368	0.0656	0.0904	−0.0989
A45	0.0321	0.1948	0.1263	−0.0633	−0.1992
A46	−0.0833	0.0064	0.3475	−0.0410	−0.2024
A47	−0.1007	0.0906	0.1363	−0.0565	0.1427
A48	0.0554	0.0648	0.2191	−0.1462	0.1200
A49	0.2639	0.0230	−0.0610	0.0666	−0.1206
A50	0.2265	−0.0751	−0.0505	0.0860	0.0697
A51	0.1036	−0.0307	−0.0650	−0.0779	−0.0527
A52	0.1503	−0.1458	−0.1294	−0.0995	−0.1464
A53	0.1260	0.0156	0.0160	−0.2489	0.2689
A54	0.1066	0.0293	0.0062	−0.2122	0.0374
A55	0.0826	−0.0366	0.1449	−0.1311	−0.2051
A56	0.0497	−0.0551	0.0069	−0.1560	−0.0037
A57	−0.0788	0.0860	0.1989	−0.0852	−0.1913

Table D.6: Contribution of Variables in Matrix Format (A1 to A57)

Var	PC1	PC2	PC3	PC4	PC5
A30	0.0455	0.0648	0.0063	0.0181	0.0132
A31	0.0423	0.0066	0.0080	0.0604	0.0007
A32	0.0180	0.0005	0.0004	0.0037	0.0969
A33	0.0582	0.0416	0.0183	0.0001	0.0465
A34	0.0102	0.0159	0.0453	0.0005	0.0008
A35	0.0002	0.0105	0.0054	0.0001	0.0206
A36	0.0043	0.0023	0.0044	0.0215	0.0196
A37	0.0107	0.0009	0.0042	0.0061	0.0028
A38	0.0036	0.0208	0.0197	0.0077	0.0056
A39	0.0275	0.0019	0.0410	0.0081	0.0000
A40	0.0750	0.0495	0.0052	0.0964	0.0018
A41	0.0270	0.0039	0.0003	0.0325	0.0058
A42	0.0477	0.0015	0.0030	0.0104	0.0007
A43	0.0298	0.0099	0.0005	0.0001	0.0141
A44	0.0001	0.0014	0.0043	0.0082	0.0098
A45	0.0010	0.0380	0.0160	0.0040	0.0397
A46	0.0069	0.0000	0.1207	0.0017	0.0410
A47	0.0101	0.0082	0.0186	0.0032	0.0204
A48	0.0031	0.0042	0.0480	0.0214	0.0144
A49	0.0697	0.0005	0.0037	0.0044	0.0146
A50	0.0513	0.0056	0.0026	0.0074	0.0049
A51	0.0107	0.0009	0.0042	0.0061	0.0028
A52	0.0226	0.0212	0.0167	0.0099	0.0214
A53	0.0159	0.0002	0.0003	0.0620	0.0723
A54	0.0114	0.0009	0.0000	0.0450	0.0014
A55	0.0068	0.0013	0.0210	0.0172	0.0421
A56	0.0025	0.0030	0.0000	0.0243	0.0000
A57	0.0062	0.0074	0.0396	0.0073	0.0366

Var	PC1	PC2	PC3	PC4	PC5
A1	0.0366	0.0434	0.0531	0.0007	0.1443
A2	0.0083	0.0054	0.0063	0.0491	0.0113
A3	0.0039	0.0002	0.0189	0.0002	0.0025
A4	0.0234	0.0074	0.0001	0.0020	0.0127
A5	0.0210	0.0024	0.0001	0.0206	0.0241
A6	0.0026	0.0328	0.0424	0.0318	0.0006
A7	0.0031	0.0680	0.0002	0.0208	0.0019
A8	0.0000	0.0036	0.0051	0.0180	0.0081
A9	0.0029	0.0006	0.0201	0.0401	0.0001
A10	0.0123	0.0694	0.0291	0.0117	0.0044
A11	0.0042	0.0023	0.0000	0.0174	0.0070
A12	0.0678	0.0542	0.0099	0.0396	0.0179
A13	0.0290	0.1128	0.0015	0.0530	0.0007
A14	0.0001	0.0014	0.0000	0.0353	0.0018
A15	0.0025	0.0030	0.0000	0.0243	0.0000
A16	0.0049	0.0601	0.0096	0.0302	0.0286
A17	0.0030	0.0231	0.0036	0.0277	0.0026
A18	0.0037	0.0010	0.0068	0.0105	0.0166
A19	0.0017	0.0003	0.0053	0.0043	0.0105
A20	0.0389	0.0020	0.0241	0.0241	0.0157
A21	0.0000	0.0384	0.0536	0.0000	0.0059
A22	0.0434	0.0004	0.0532	0.0103	0.0001
A23	0.0001	0.0005	0.0057	0.0029	0.0176
A24	0.0029	0.0006	0.0052	0.0061	0.0024
A25	0	0	0	0	0
A26	0.0595	0.0697	0.0000	0.0229	0.0621
A27	0.0014	0.0096	0.0001	0.0004	0.0362
A28	0.0018	0.0379	0.0071	0.0005	0.0110
A29	0.0025	0.0261	0.1812	0.0078	0.0030

Table D.7: PC Scores in Matrix Format Questionnaire 1

PC1	PC2	PC3	PC4	PC5
−0.24349595	−0.31418991	−0.91809978	−0.52324906	−0.76236501
−1.18422268	−0.33211766	0.87568172	−0.76181149	0.28173637
−0.18351121	0.50027502	0.79847989	0.88172766	−0.56886218
1.26844044	−1.24935320	0.13449696	0.31189974	0.22332487
0.90644729	0.24884729	−0.88227028	0.63905678	0.58994635
1.24923669	1.14653846	−0.00828851	−0.54762363	0.23621960

Table D.8: Eigenvectors in Matrix Format (B1 to B55)

Var	PC1	PC2	PC3	PC4	PC5
B1	0.0299	0.2963	−0.0375	0.0156	0.0236
B2	−0.1565	−0.0639	−0.1072	0.0098	−0.1771
B3	−0.0468	−0.0624	0.0992	0.2418	−0.2302
B4	0.1052	−0.0412	−0.1112	0.2260	−0.2117
B5	−0.0632	0.1122	0.1816	0.1489	−0.1359
B6	0.0806	0.2207	0.0124	0.0866	−0.0703
B7	0.0246	−0.2619	−0.1236	0.1394	−0.1414
B8	0.0790	−0.0958	0.1645	−0.0328	−0.0743
B9	0.0958	−0.2458	−0.0583	0.0704	−0.0197
B10	0.0185	−0.1655	0.1466	0.0909	−0.0894
B11	−0.0166	−0.0654	−0.0652	−0.1365	−0.0875
B12	0.0684	−0.0421	0.1171	−0.0874	−0.1809
B13	0.0436	−0.0203	0.0931	−0.2704	−0.2212
B14	−0.1115	−0.0186	0.0725	0.0424	−0.0701
B15	−0.2266	−0.1228	0.2158	0.0111	0.0327
B16	0.0664	0.1888	0.0358	−0.0418	−0.0040
B17	−0.2663	0.1501	−0.0256	−0.1890	−0.0911
B18	0.0214	−0.0964	−0.2917	−0.1180	−0.2928
B19	−0.0389	−0.0100	−0.0007	−0.3113	0.0259
B20	−0.0343	−0.0989	−0.1324	0.0219	−0.0004
B21	−0.0617	0.1048	0.0431	−0.1358	−0.1616
B22	−0.2501	0.1910	0.1801	−0.0627	−0.1525
B23	0	0	0	0	0
B24	−0.1478	0.1134	−0.1412	0.1100	0.1063
B25	−0.1493	−0.2031	0.0109	−0.0094	0.1023
B26	0.0024	0.0336	0.0886	0.0081	0.1537
B27	−0.0924	−0.1351	−0.0617	0.1537	0.1382
B28	−0.1437	−0.1085	0.1691	0.0623	−0.0656
B29	−0.3033	−0.2334	−0.0078	0.0085	0.0789

Var	PC1	PC2	PC3	PC4	PC5
B30	−0.1211	−0.1394	−0.0358	0.2473	−0.0302
B31	−0.0817	−0.0462	0.0485	−0.3461	−0.0762
B32	−0.1037	−0.1305	0.1717	0.0787	−0.2660
B33	−0.0931	0.0640	−0.1412	−0.0956	0.1405
B34	−0.1215	0.0842	−0.2557	0.0082	0.1210
B35	0.0144	−0.2675	−0.1502	−0.2655	0.0529
B36	−0.1873	0.0543	0.1389	−0.2218	−0.1654
B37	−0.1173	0.1023	0.2023	0.0041	0.1308
B38	−0.0366	0.1075	−0.0733	0.0573	0.0276
B39	−0.2262	−0.0982	0.0754	0.0213	0.1815
B40	−0.2903	−0.0271	0.0298	−0.1227	−0.1338
B41	−0.1940	−0.0083	−0.0212	0.0014	0.1770
B42	−0.2262	−0.0982	0.0754	0.0213	0.1815
B43	−0.0484	−0.1308	−0.1091	−0.1064	0.0658
B44	0.0769	−0.1049	−0.0645	−0.0307	−0.0792
B45	0.0666	−0.0266	−0.2523	−0.0751	−0.0370
B46	−0.0531	0.0420	−0.1386	−0.0791	−0.0599
B47	−0.1384	−0.0058	−0.1805	−0.1385	−0.1153
B48	−0.1300	0.1469	−0.0741	−0.0484	0.0193
B49	0.0345	−0.1165	−0.1557	−0.0553	−0.0325
B50	0.0750	0.1261	−0.1459	0.0149	0.0977
B51	0.1489	0.1786	0.1296	−0.0008	−0.2511
B52	−0.2501	0.0594	−0.2692	0.2645	−0.3375
B53	−0.2534	0.2139	−0.0508	0.2343	0.0171
B54	−0.0979	0.2368	−0.1707	−0.0683	0.0148
B55	−0.0815	0.0622	−0.2531	0.0247	−0.0795

Table D.9: Contribution of Variables in Matrix Format (B1 to B55)

Var	PC1	PC2	PC3	PC4	PC5
B1	0.0009	0.0878	0.0014	0.0002	0.0006
B2	0.0245	0.0041	0.0115	0.0001	0.0314
B3	0.0022	0.0039	0.0098	0.0585	0.0530
B4	0.0111	0.0017	0.0124	0.0511	0.0448
B5	0.0040	0.0126	0.0330	0.0222	0.0185
B6	0.0065	0.0487	0.0002	0.0075	0.0049
B7	0.0006	0.0686	0.0153	0.0194	0.0200
B8	0.0062	0.0092	0.0271	0.0011	0.0055
B9	0.0092	0.0604	0.0034	0.0050	0.0004
B10	0.0003	0.0274	0.0215	0.0083	0.0080
B11	0.0003	0.0043	0.0043	0.0186	0.0077
B12	0.0047	0.0018	0.0137	0.0076	0.0327
B13	0.0019	0.0004	0.0087	0.0731	0.0489
B14	0.0124	0.0003	0.0053	0.0018	0.0049
B15	0.0513	0.0151	0.0466	0.0001	0.0011
B16	0.0044	0.0357	0.0013	0.0017	0.0000
B17	0.0709	0.0225	0.0007	0.0357	0.0083
B18	0.0005	0.0093	0.0851	0.0139	0.0857
B19	0.0015	0.0001	0.0000	0.0969	0.0007
B20	0.0012	0.0098	0.0175	0.0005	0.0000
B21	0.0038	0.0110	0.0019	0.0185	0.0261
B22	0.0626	0.0365	0.0324	0.0039	0.0232
B23	0.0000	0.0000	0.0000	0.0000	0.0000
B24	0.0218	0.0129	0.0199	0.0121	0.0113
B25	0.0223	0.0413	0.0001	0.0001	0.0105
B26	0.0000	0.0011	0.0078	0.0001	0.0236
B27	0.0085	0.0182	0.0038	0.0236	0.0191
B28	0.0207	0.0118	0.0286	0.0039	0.0043
B29	0.0920	0.0545	0.0001	0.0001	0.0062

Var	PC1	PC2	PC3	PC4	PC5
B30	0.0147	0.0194	0.0013	0.0612	0.0009
B31	0.0067	0.0021	0.0024	0.1198	0.0058
B32	0.0108	0.0170	0.0295	0.0062	0.0708
B33	0.0087	0.0041	0.0199	0.0091	0.0197
B34	0.0148	0.0071	0.0654	0.0001	0.0146
B35	0.0002	0.0716	0.0226	0.0705	0.0028
B36	0.0351	0.0029	0.0193	0.0492	0.0274
B37	0.0138	0.0105	0.0409	0.0000	0.0171
B38	0.0013	0.0116	0.0054	0.0033	0.0008
B39	0.0512	0.0097	0.0057	0.0005	0.0329
B40	0.0843	0.0007	0.0009	0.0150	0.0179
B41	0.0377	0.0001	0.0005	0.0000	0.0313
B42	0.0512	0.0097	0.0057	0.0005	0.0329
B43	0.0023	0.0171	0.0119	0.0113	0.0043
B44	0.0059	0.0110	0.0042	0.0009	0.0063
B45	0.0044	0.0007	0.0637	0.0056	0.0014
B46	0.0028	0.0018	0.0192	0.0063	0.0036
B47	0.0192	0.0000	0.0326	0.0192	0.0133
B48	0.0169	0.0216	0.0055	0.0023	0.0004
B49	0.0012	0.0136	0.0242	0.0031	0.0011
B50	0.0056	0.0159	0.0213	0.0002	0.0095
B51	0.0222	0.0319	0.0168	0.0000	0.0631
B52	0.0625	0.0035	0.0725	0.0700	0.1139
B53	0.0642	0.0457	0.0026	0.0549	0.0003
B54	0.0096	0.0561	0.0291	0.0047	0.0002
B55	0.0066	0.0039	0.0641	0.0006	0.0063

Table D.10: PC Scores in Matrix Format Questionnaire 2

PC1	PC2	PC3	PC4	PC5
−0.2345	1.6443	0.6533	−0.3954	0.3728
−1.2247	−0.6821	0.7805	−0.2956	−0.8077
−1.2147	−0.2196	−1.4456	−0.2089	0.3693
1.9659	−0.3311	−0.3693	−0.6566	−0.2535
0.3044	−1.0113	0.7511	0.4644	0.8430
0.4037	0.5998	−0.3701	1.0920	−0.5240

Table D.11: Tabular Result Questionnaire 2

Tabular Result					
Table Analyzed	Q2				
PC summary	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	1.43	0.942	0.793	0.425	0.395
Proportion of variance	35.88%	23.63%	19.89%	10.67%	9.92%
Cumulative proportion of variance	35.88%	59.52%	79.41%	90.08%	100.00%
Component selection	Selected	Selected			

Data summary	
Total number of variables	55
Total number of components	5
Component selection method	All PCs
Number of selected components	2
Rows in table	6
Rows skipped (missing data)	0
Rows analyzed (#cases)	6

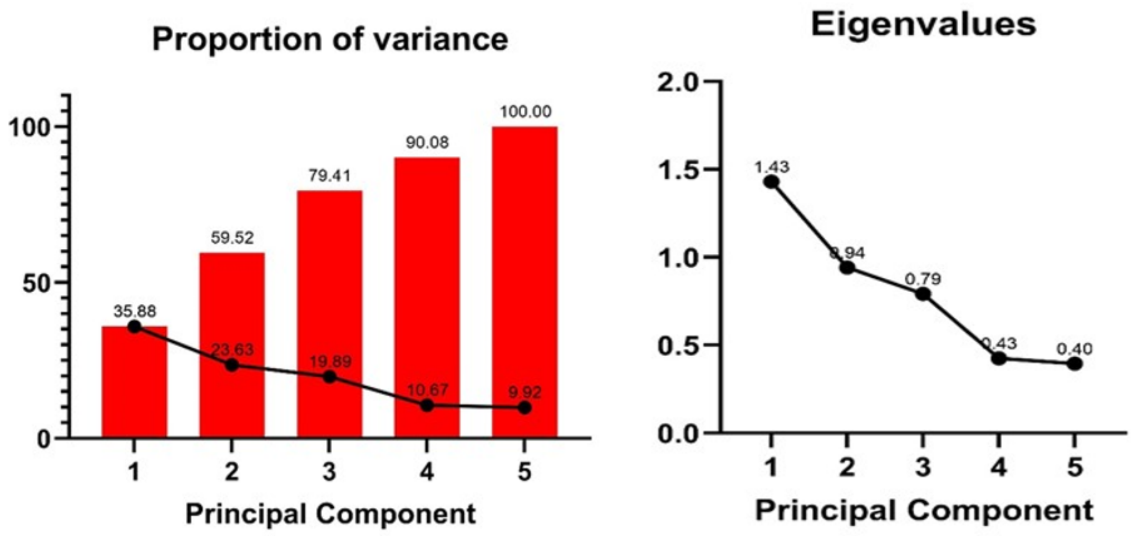

Figure D.1: Proportion of Variance Questionnaire 2 and Eigenvalues of Principal Components Questionnaire 2

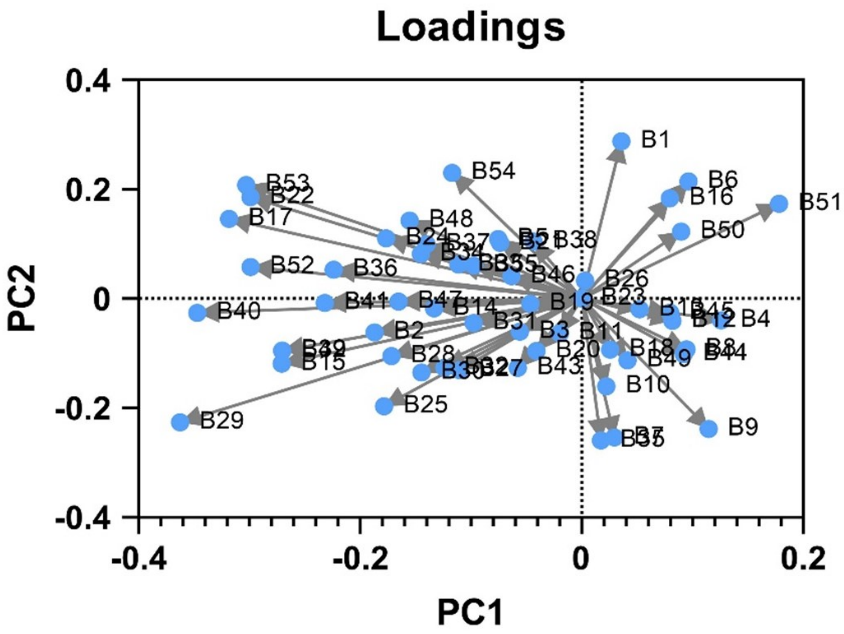

Figure D.2: Loadings Diagram Questionnaire 2

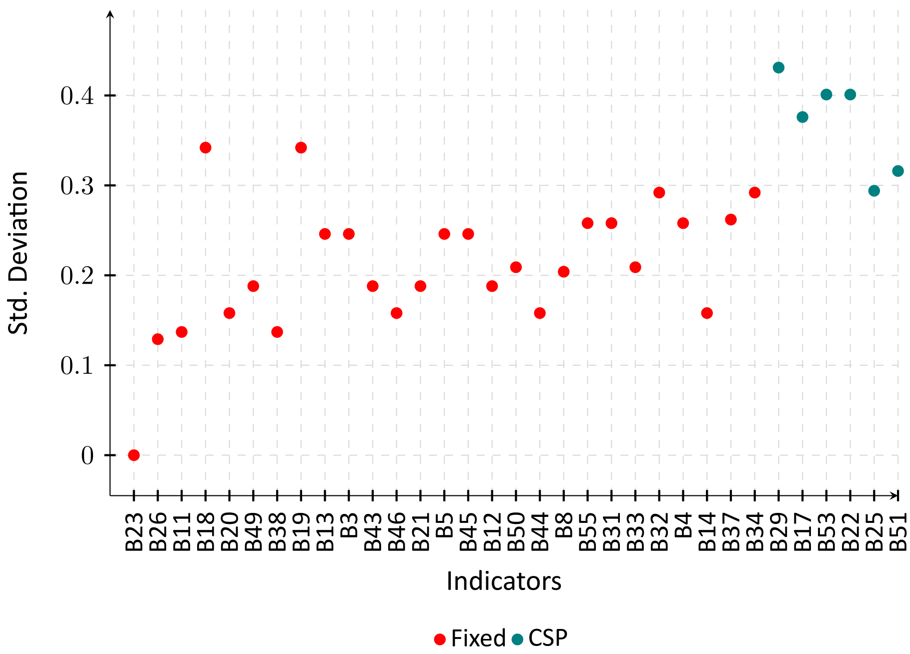

Figure D.3: Fixed vs Potential Context-Specific Indicators Questionnaire 2

Table D.12: Eigenvectors in Matrix Format (C1 to C56)

Var	PC1	PC2	PC3	PC4	PC5
C1	−0.2832	0.1198	0.0282	0.0075	−0.2885
C2	0.0306	0.0698	−0.1015	0.1779	−0.0397
C3	0.0216	0.0568	−0.1286	0.3214	−0.0211
C4	−0.0307	−0.1231	−0.1433	0.0225	0.3025
C5	0.0079	0.2559	−0.1445	0.0426	−0.1146
C6	−0.0014	−0.0409	−0.1116	−0.0551	−0.0729
C7	0.0084	−0.2016	−0.3240	0.0577	0.0240
C8	−0.0104	−0.0540	−0.1386	0.0885	−0.0543
C9	−0.0090	−0.0131	−0.0271	0.1435	0.0186
C10	0.0330	−0.0096	0.0153	0.2888	−0.1150
C11	−0.1599	−0.2500	0.0200	0.0497	−0.0839
C12	−0.0792	−0.1657	0.1489	−0.0687	0.1166
C13	0.1033	0.0206	0.0056	0.2590	0.0312
C14	0.0510	0.0165	0.0694	0.0018	−0.1522
C15	−0.2639	0.1336	−0.0509	−0.0241	0.0100
C16	−0.0803	0.0771	−0.0226	0.1174	0.0206
C17	0.0410	0.1238	0.0371	0.0894	0.0146
C18	−0.0756	−0.0327	−0.3303	−0.1913	−0.2168
C19	0.0560	0.0147	−0.3767	−0.1074	0.0943
C20	−0.0510	−0.0165	−0.0694	−0.0018	0.1522
C21	−0.1237	0.0327	−0.1766	−0.0829	0.0813
C22	−0.2610	0.2155	0.1722	0.0860	0.1558
C23	0.1123	0.0337	0.0327	0.1155	0.0126
C24	−0.0911	−0.2607	−0.1012	−0.0352	−0.0106
C25	0.0122	−0.2401	−0.0956	0.2238	0.0206
C26	0.0599	−0.0238	−0.1483	0.0586	0.0919
C27	−0.0090	−0.0131	−0.0271	0.1435	0.0186
C28	0.1009	0.1001	−0.1112	0.1480	0.1065
C29	−0.0534	0.0629	−0.1863	−0.1128	0.2275

Var	PC1	PC2	PC3	PC4	PC5
C30	0.0599	−0.0238	−0.1483	0.0586	0.0919
C31	0.0614	−0.1053	0.1296	−0.1283	0.4091
C32	−0.0524	−0.0574	−0.1810	−0.0568	0.0793
C33	−0.0524	−0.0574	−0.1810	−0.0568	0.0793
C34	−0.1227	−0.0877	−0.1713	−0.0270	−0.0669
C35	0.0203	−0.1066	−0.0738	0.0243	0.1502
C36	0.0216	0.0568	−0.1286	0.3214	−0.0211
C37	−0.2422	0.0679	−0.0132	0.0552	0.2332
C38	−0.3828	0.0074	0.0062	0.1149	−0.0593
C39	−0.1203	−0.1671	−0.0545	0.0840	−0.1422
C40	−0.1585	−0.2090	0.1316	0.1047	−0.0110
C41	−0.4338	−0.0091	−0.0632	0.1131	0.0929
C42	0.1019	−0.0203	−0.1060	0.2039	−0.0417
C43	−0.1606	0.1542	−0.0453	0.2349	0.0412
C44	0.1722	0.0099	−0.1156	0.1741	0.1045
C45	−0.0665	−0.2445	0.1596	0.1542	0.3584
C46	0.1109	−0.0073	−0.0789	0.0604	−0.0603
C47	−0.0341	0.2525	−0.1869	−0.1027	0.0190
C48	−0.0327	0.2934	−0.0753	−0.0477	0.0919
C49	−0.0402	0.3213	0.0092	0.1509	0.1834
C50	0.1203	0.1671	0.0545	−0.0840	0.1422
C51	0.0410	0.1238	0.0371	0.0894	0.0146
C52	0.1203	0.1671	0.0545	−0.0840	0.1422
C53	0.0510	0.0165	0.0694	0.0018	−0.1522
C54	0.1797	−0.0180	−0.2001	−0.0245	0.0130
C55	−0.1836	0.0565	−0.0283	−0.1416	−0.0106
C56	−0.1147	0.0458	−0.1495	−0.2265	0.0627

Table D.13: Contribution of Variables in Matrix Format (C1 to C56)

Var	PC1	PC2	PC3	PC4	PC5
C1	0.0802	0.0144	0.0008	0.0001	0.0832
C2	0.0009	0.0049	0.0103	0.0316	0.0016
C3	0.0005	0.0032	0.0165	0.1033	0.0004
C4	0.0009	0.0152	0.0205	0.0005	0.0915
C5	0.0001	0.0655	0.0209	0.0018	0.0131
C6	0.0000	0.0017	0.0124	0.0030	0.0053
C7	0.0001	0.0406	0.1050	0.0033	0.0005
C8	0.0001	0.0029	0.0192	0.0078	0.0029
C9	0.0001	0.0002	0.0007	0.0206	0.0003
C10	0.0011	0.0001	0.0002	0.0834	0.0132
C11	0.0256	0.0625	0.0004	0.0025	0.0070
C12	0.0063	0.0275	0.0222	0.0047	0.0136
C13	0.0107	0.0004	0.0000	0.0671	0.0010
C14	0.0026	0.0003	0.0048	0.0000	0.0232
C15	0.0696	0.0178	0.0026	0.0006	0.0001
C16	0.0064	0.0059	0.0005	0.0138	0.0004
C17	0.0017	0.0153	0.0014	0.0080	0.0002
C18	0.0057	0.0011	0.1091	0.0366	0.0470
C19	0.0031	0.0002	0.1419	0.0115	0.0089
C20	0.0026	0.0003	0.0048	0.0000	0.0232
C21	0.0153	0.0011	0.0312	0.0069	0.0066
C22	0.0681	0.0464	0.0297	0.0074	0.0243
C23	0.0126	0.0011	0.0011	0.0133	0.0002
C24	0.0083	0.0680	0.0103	0.0012	0.0001
C25	0.0001	0.0576	0.0091	0.0501	0.0004
C26	0.0036	0.0006	0.0220	0.0034	0.0084
C27	0.0001	0.0002	0.0007	0.0206	0.0003
C28	0.0102	0.0100	0.0124	0.0219	0.0113
C29	0.0029	0.0040	0.0347	0.0127	0.0518

Var	PC1	PC2	PC3	PC4	PC5
C30	0.0036	0.0006	0.0220	0.0034	0.0084
C31	0.0038	0.0111	0.0168	0.0165	0.1673
C32	0.0028	0.0033	0.0328	0.0032	0.0063
C33	0.0028	0.0033	0.0328	0.0032	0.0063
C34	0.0151	0.0077	0.0293	0.0007	0.0045
C35	0.0004	0.0114	0.0055	0.0006	0.0226
C36	0.0005	0.0032	0.0165	0.1033	0.0004
C37	0.0586	0.0046	0.0002	0.0031	0.0544
C38	0.1465	0.0001	0.0000	0.0132	0.0035
C39	0.0145	0.0279	0.0030	0.0071	0.0202
C40	0.0251	0.0437	0.0173	0.0110	0.0001
C41	0.1882	0.0001	0.0040	0.0128	0.0086
C42	0.0104	0.0004	0.0112	0.0416	0.0017
C43	0.0258	0.0238	0.0021	0.0552	0.0017
C44	0.0296	0.0001	0.0134	0.0303	0.0109
C45	0.0044	0.0598	0.0255	0.0238	0.1285
C46	0.0123	0.0001	0.0062	0.0037	0.0036
C47	0.0012	0.0637	0.0349	0.0106	0.0004
C48	0.0011	0.0861	0.0057	0.0023	0.0084
C49	0.0016	0.1032	0.0001	0.0228	0.0337
C50	0.0145	0.0279	0.0030	0.0071	0.0202
C51	0.0017	0.0153	0.0014	0.0080	0.0002
C52	0.0145	0.0279	0.0030	0.0071	0.0202
C53	0.0026	0.0003	0.0048	0.0000	0.0232
C54	0.0323	0.0003	0.0401	0.0006	0.0002
C55	0.0337	0.0032	0.0008	0.0200	0.0001
C56	0.0132	0.0021	0.0224	0.0513	0.0039

Table D.14: PC Scores in Matrix Format Questionnaire 3

PC1	PC2	PC3	PC4	PC5
0.6935	1.1492	−0.7869	0.3253	−0.2719
0.0251	0.5678	1.1789	0.5217	0.3400
0.1576	0.1811	0.2859	−1.3600	−0.0868
−0.8933	−0.2287	−0.7336	−0.0169	0.7097
−1.2311	−0.4193	0.1023	0.2827	−0.6817
1.2482	−1.2501	−0.0466	0.2472	−0.0093

Table D.15: Tabular Result Questionnaire 3

Tabular Result					
Table Analyzed	Q3				
PC summary	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	0.8756	0.6934	0.5284	0.4738	0.2331
Proportion of variance	31.22%	24.73%	18.84%	16.90%	8.31%
Cumulative proportion of variance	31.22%	55.95%	74.79%	91.69%	100.00%
Component selection	Selected	Selected			

Data summary	
Total number of variables	56
Total number of components	5
Component selection method	All PCs
Number of selected components	2
Rows in table	6
Rows skipped (missing data)	0
Rows analyzed (#cases)	6

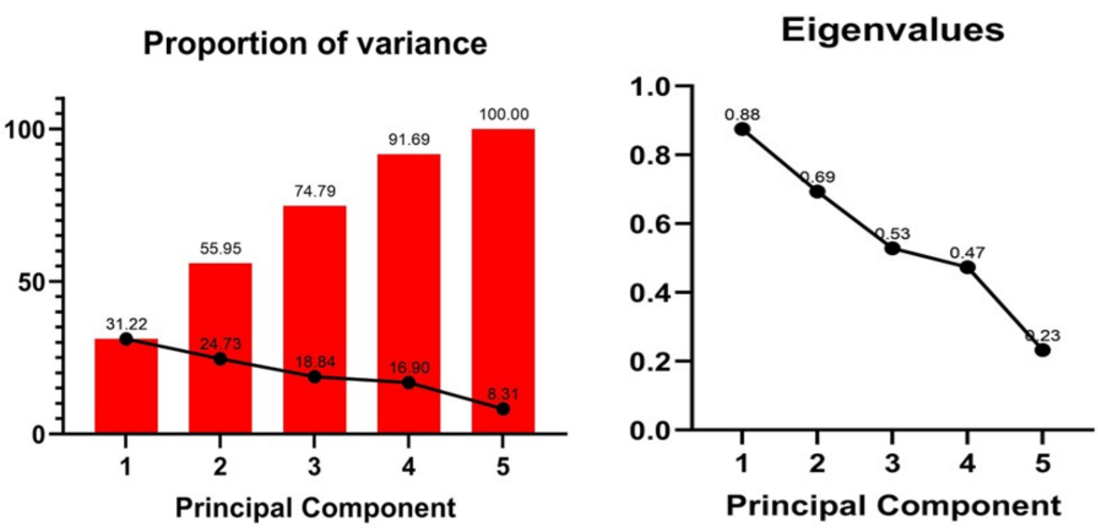

Figure D.4: Proportion of Variance Questionnaire 3 and Eigenvalues of Principal Components Questionnaire 3

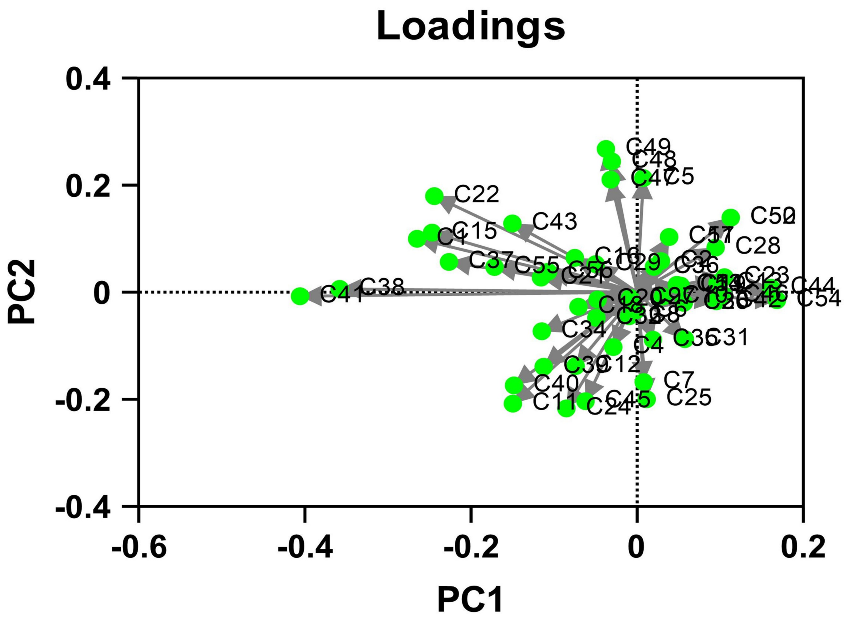

Figure D.5: Loadings Diagram Questionnaire 3

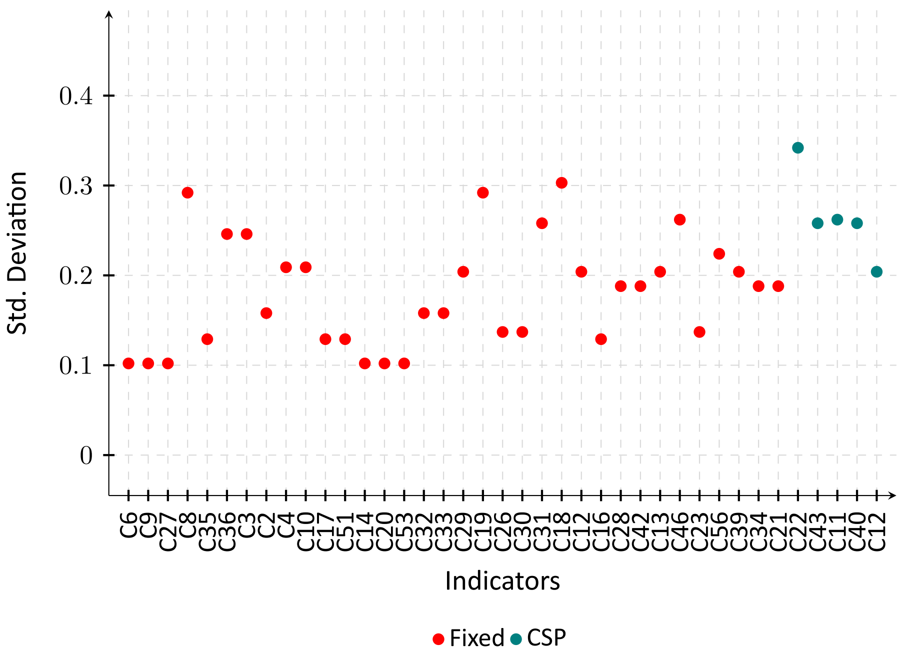

Figure D.6: Fixed vs Potential Context-Specific Indicators Questionnaire 3

Table D.16: Eigenvectors in Matrix Format (D1 to D55)

Var	PC1	PC2	PC3	PC4	PC5
D1	−0.0164	0.2362	0.0271	−0.0752	−0.0358
D2	−0.1004	0.1485	0.0404	−0.1042	−0.1557
D3	0.1383	0.0911	0.2603	−0.0617	0.0455
D4	0.0583	−0.0731	0.0252	−0.0477	0.0931
D5	0.0943	0.0757	0.2301	0.1937	0.2281
D6	0.0680	0.2109	−0.0250	0.1583	−0.1866
D7	−0.0042	−0.0489	0.1692	0.0272	0.1083
D8	−0.0235	0.1612	−0.0294	−0.0417	−0.1711
D9	0.1146	0.1268	0.1518	−0.0331	0.1504
D10	0.2615	0.0773	−0.0442	0.1255	−0.0156
D11	−0.1538	0.4442	0.0938	0.0425	0.1264
D12	−0.1754	0.3323	−0.0369	−0.0614	−0.0087
D13	0.0199	0.1640	−0.0394	−0.4313	0.1930
D14	0.1497	−0.0235	0.0297	0.1523	0.0776
D15	0.0603	0.1234	−0.1218	0.0576	0.2248
D16	0.0092	−0.0727	0.0344	−0.1661	−0.1047
D17	−0.0493	−0.1251	−0.0700	−0.0481	0.0781
D18	−0.1469	0.0495	0.1960	−0.1586	0.1660
D19	0.1157	0.0242	−0.3222	0.0162	0.0743
D20	0.0728	−0.0362	0.0994	0.0898	0.0930
D21	0.0162	0.0022	0.0909	−0.1996	0.0306
D22	0.0092	−0.0727	0.0344	−0.1661	−0.1047
D23	0.0162	0.0022	0.0909	−0.1996	0.0306
D24	−0.1026	0.2961	0.0625	0.0283	0.0843
D25	−0.1083	−0.0622	0.3399	0.1548	−0.2097
D26	−0.0625	0.0242	0.1439	0.0749	0.0152
D27	0.2540	0.1153	−0.0619	−0.0455	0.1198
D28	0.1497	−0.0235	0.0297	0.1523	0.0776
D29	−0.0625	0.0242	0.1439	0.0749	0.0152

Var	PC1	PC2	PC3	PC4	PC5
D30	0.1056	−0.1446	0.2423	−0.1049	−0.1165
D31	0.2727	0.2012	−0.1569	0.0647	0.0113
D32	0.0508	−0.0352	0.0076	−0.2187	0.2286
D33	0.3597	−0.0293	0.1804	−0.1504	0.0033
D34	0.1098	−0.0957	0.0731	−0.1321	−0.2249
D35	−0.0699	0.0622	0.1263	−0.0961	0.1506
D36	0.0583	−0.0731	0.0252	−0.0477	0.0931
D37	−0.1701	−0.0277	0.0486	0.0745	0.0001
D38	−0.0440	−0.0154	−0.0302	0.2554	0.1826
D39	−0.1026	−0.1735	0.1082	−0.1392	−0.0114
D40	0.0105	0.1136	0.3225	0.0944	−0.1677
D41	0.0232	0.0772	0.1474	−0.2331	0.1659
D42	−0.1355	−0.0651	−0.0346	0.0554	0.1981
D43	0.0513	−0.1481	−0.0313	−0.0142	−0.0421
D44	0.0653	0.0018	0.0818	−0.0812	0.2284
D45	−0.0092	0.0727	−0.0344	0.1661	0.1047
D46	0.2284	−0.0455	−0.0234	−0.1222	0.0930
D47	0.2080	−0.0966	0.0549	0.1046	0.1708
D48	0.2922	0.1165	0.1208	0.0634	0.0148
D49	0.1865	−0.2085	−0.0758	0.0007	0.0357
D50	0.2032	0.1505	−0.0695	0.1732	−0.1088
D51	0.1703	0.1532	0.0305	−0.1448	−0.2760
D52	0.0493	0.1251	0.0700	0.0481	−0.0781
D53	0.1355	0.0651	0.0346	−0.0554	−0.1981
D54	0.1355	0.0651	0.0346	−0.0554	−0.1981
D55	−0.0008	−0.1358	0.3560	0.2254	0.0812

Table D.17: Contribution of Variables in Matrix Format (D1 to D55)

Var	PC1	PC2	PC3	PC4	PC5
D1	0.0003	0.0558	0.0007	0.0057	0.0013
D2	0.0101	0.0221	0.0016	0.0109	0.0242
D3	0.0191	0.0083	0.0678	0.0038	0.0021
D4	0.0034	0.0053	0.0006	0.0023	0.0087
D5	0.0089	0.0057	0.0529	0.0375	0.0520
D6	0.0046	0.0445	0.0006	0.0251	0.0348
D7	0.0000	0.0024	0.0286	0.0007	0.0117
D8	0.0006	0.0260	0.0009	0.0017	0.0293
D9	0.0131	0.0161	0.0230	0.0011	0.0226
D10	0.0684	0.0060	0.0020	0.0157	0.0002
D11	0.0237	0.1973	0.0088	0.0018	0.0160
D12	0.0307	0.1104	0.0014	0.0038	0.0001
D13	0.0004	0.0269	0.0016	0.1860	0.0372
D14	0.0224	0.0006	0.0009	0.0232	0.0060
D15	0.0036	0.0152	0.0148	0.0033	0.0505
D16	0.0001	0.0053	0.0012	0.0276	0.0110
D17	0.0024	0.0156	0.0049	0.0023	0.0061
D18	0.0216	0.0024	0.0384	0.0252	0.0276
D19	0.0134	0.0006	0.1038	0.0003	0.0055
D20	0.0053	0.0013	0.0099	0.0081	0.0086
D21	0.0003	0.0000	0.0083	0.0398	0.0009
D22	0.0001	0.0053	0.0012	0.0276	0.0110
D23	0.0003	0.0000	0.0083	0.0398	0.0009
D24	0.0105	0.0877	0.0039	0.0008	0.0071
D25	0.0117	0.0039	0.1155	0.0240	0.0440
D26	0.0039	0.0006	0.0207	0.0056	0.0002
D27	0.0645	0.0133	0.0038	0.0021	0.0144
D28	0.0224	0.0006	0.0009	0.0232	0.0060
D29	0.0039	0.0006	0.0207	0.0056	0.0002

Var	PC1	PC2	PC3	PC4	PC5
D30	0.0112	0.0209	0.0587	0.0110	0.0136
D31	0.0744	0.0405	0.0246	0.0042	0.0001
D32	0.0026	0.0012	0.0001	0.0478	0.0523
D33	0.1294	0.0009	0.0325	0.0226	0.0000
D34	0.0121	0.0092	0.0053	0.0175	0.0506
D35	0.0049	0.0039	0.0159	0.0092	0.0227
D36	0.0034	0.0053	0.0006	0.0023	0.0087
D37	0.0289	0.0008	0.0024	0.0056	0.0000
D38	0.0019	0.0002	0.0009	0.0652	0.0333
D39	0.0105	0.0301	0.0117	0.0194	0.0001
D40	0.0001	0.0129	0.1040	0.0089	0.0281
D41	0.0005	0.0060	0.0217	0.0543	0.0275
D42	0.0183	0.0042	0.0012	0.0031	0.0392
D43	0.0026	0.0219	0.0010	0.0002	0.0018
D44	0.0043	0.0000	0.0067	0.0066	0.0522
D45	0.0001	0.0053	0.0012	0.0276	0.0110
D46	0.0522	0.0021	0.0005	0.0149	0.0087
D47	0.0433	0.0093	0.0030	0.0109	0.0292
D48	0.0854	0.0136	0.0146	0.0040	0.0002
D49	0.0348	0.0435	0.0057	0.0000	0.0013
D50	0.0413	0.0226	0.0048	0.0300	0.0118
D51	0.0290	0.0235	0.0009	0.0210	0.0762
D52	0.0024	0.0156	0.0049	0.0023	0.0061
D53	0.0183	0.0042	0.0012	0.0031	0.0392
D54	0.0183	0.0042	0.0012	0.0031	0.0392
D55	0.0000	0.0184	0.1267	0.0508	0.0066

Table D.18: PC Scores in Matrix Format Questionnaire 4

PC1	PC2	PC3	PC4	PC5
−1.6945	−0.1477	0.6709	−0.4466	0.0867
1.2838	−0.8494	0.2428	−0.3406	0.5260
−0.1545	−0.8700	−0.5436	0.2394	−0.7639
−0.5211	0.4148	−1.0438	0.2042	0.5920
0.7672	1.0232	−0.0397	−0.6382	−0.4399
0.3192	0.4291	0.7134	0.9817	−0.0009

Table D.19: Tabular Result Questionnaire 4

Tabular Result					
Table Analyzed	Q4				
PC summary	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	1.1	0.581	0.481	0.357	0.282
Proportion of variance	39.29%	20.72%	17.16%	12.74%	10.08%
Cumulative proportion of variance	39.29%	60.02%	77.18%	89.92%	100.00%
Component selection	Selected	Selected			

Data summary	
Total number of variables	55
Total number of components	5
Component selection method	All PCs
Number of selected components	2
Rows in table	6
Rows skipped (missing data)	0
Rows analyzed (#cases)	6

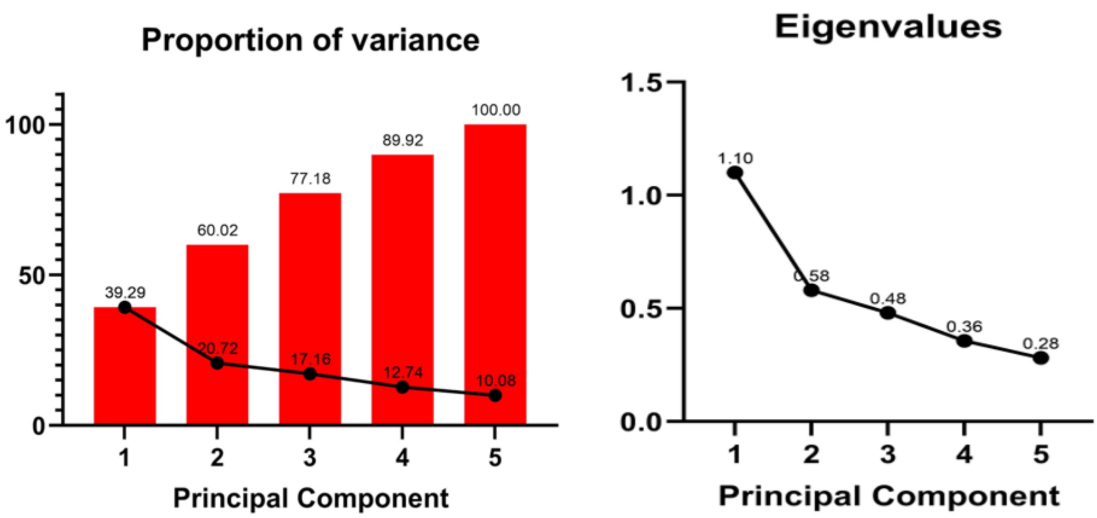

Figure D.7: Proportion of Variance Questionnaire 4 and Eigenvalues of Principal Components Questionnaire 4

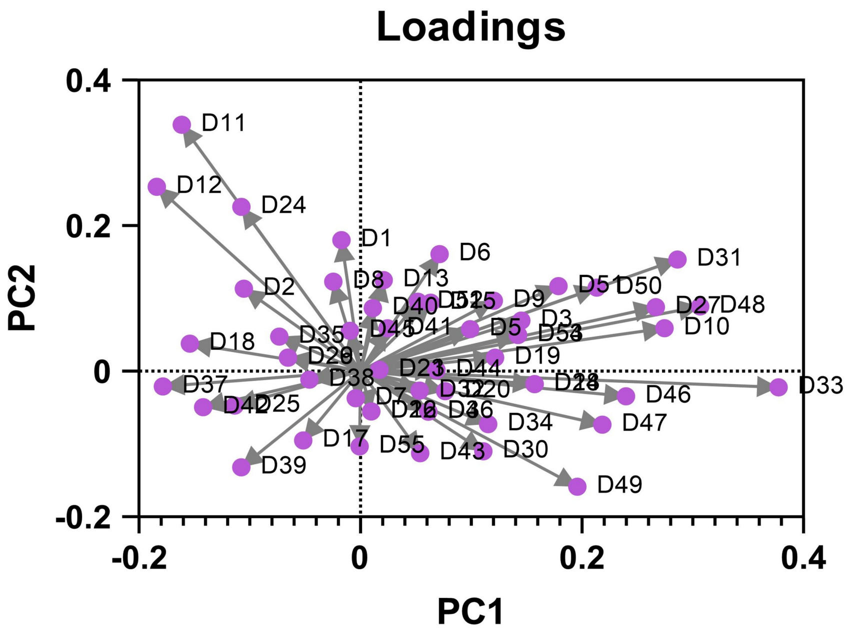

Figure D.8: Loadings Diagram Questionnaire 4

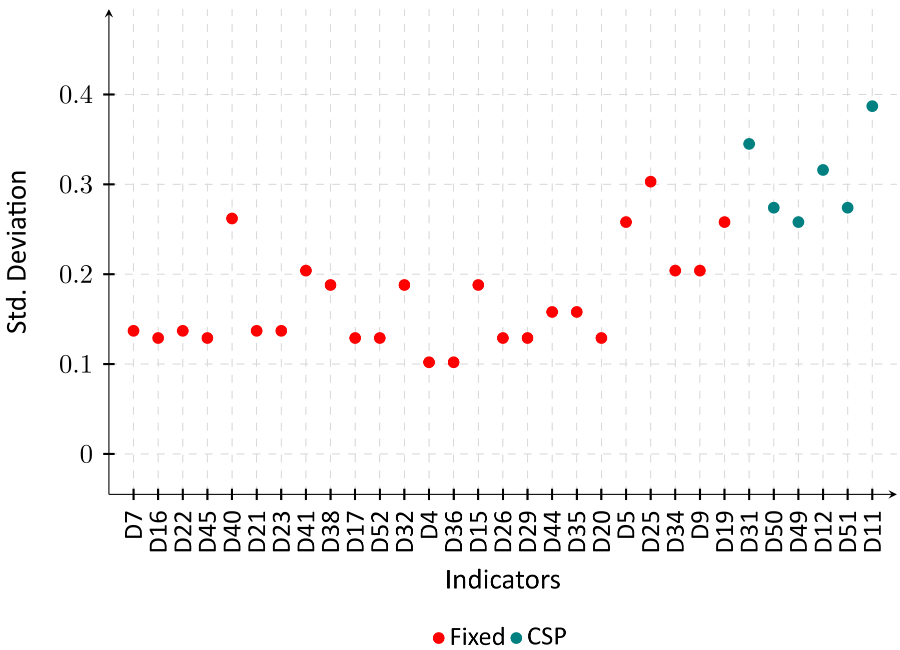

Figure D.9: Fixed vs Potential Context-Specific Indicators Questionnaire 4

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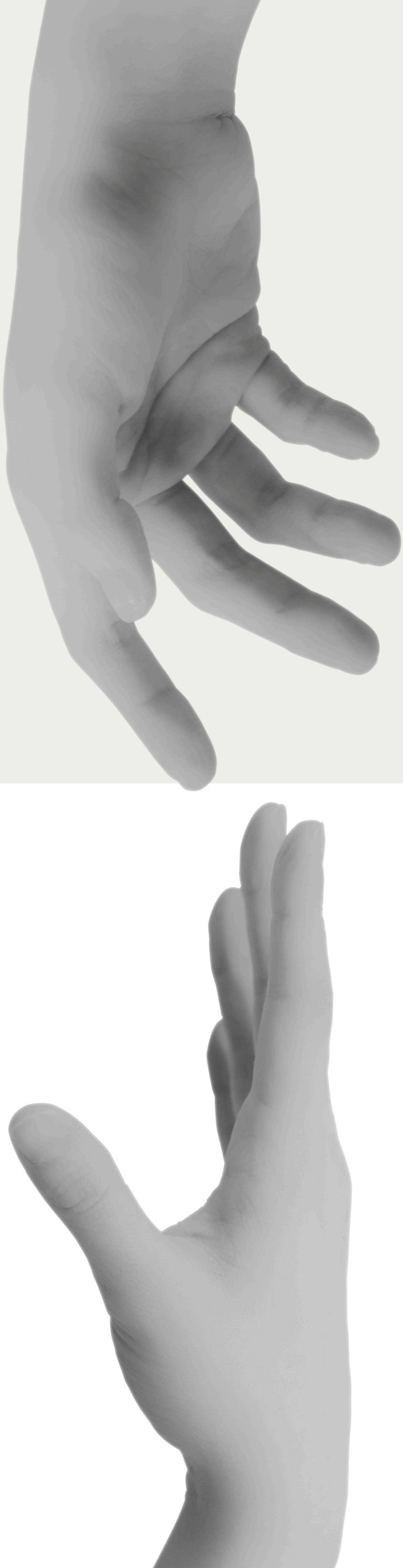

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