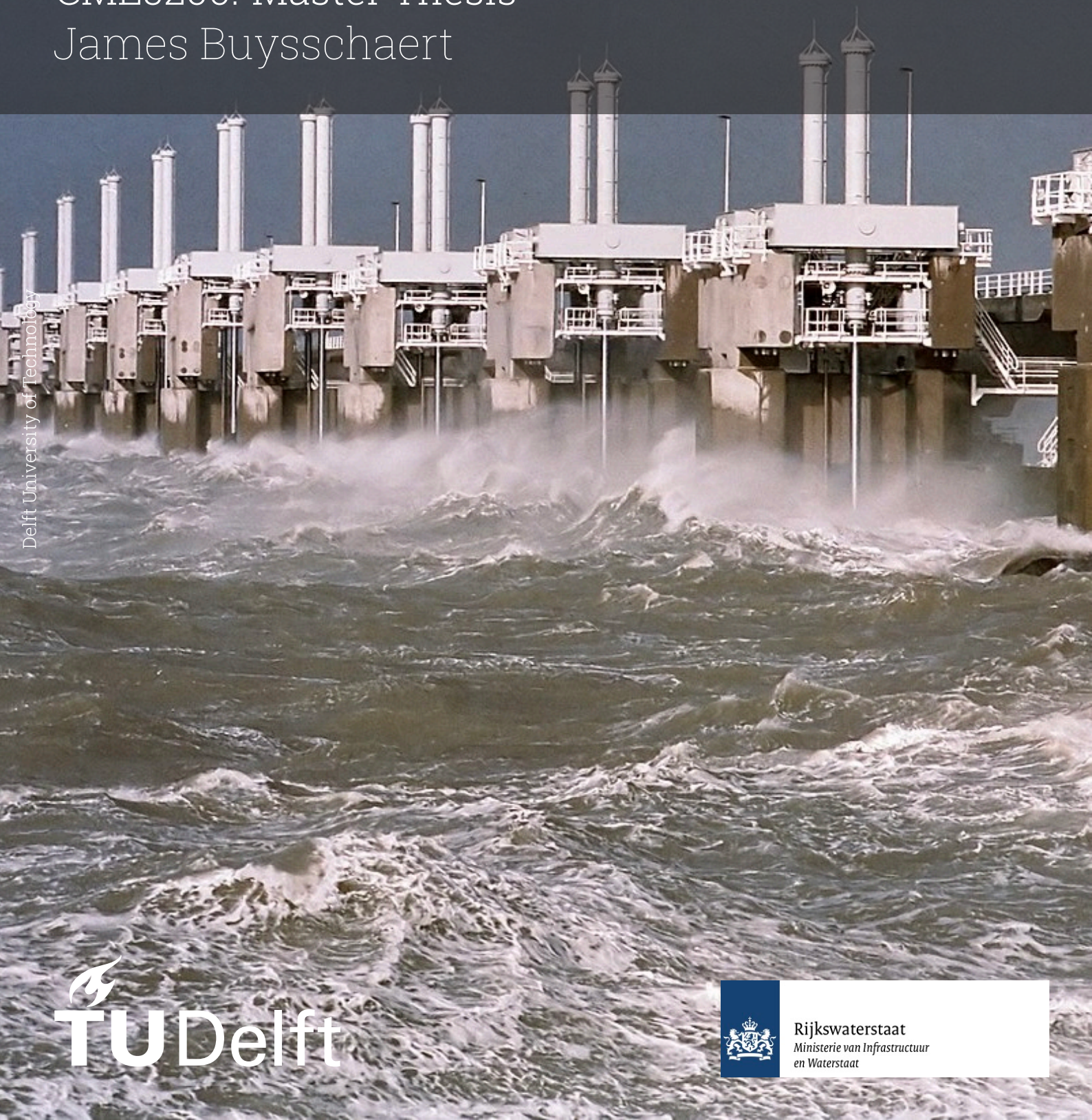
Beyond the Barrier

Assessing societal tolerance for increased closures of the Eastern Scheldt Barrier

CME5200: Master Thesis

James Buysschaert



TU Delft

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

Beyond the Barrier

Assessing societal tolerance for increased closures of the Eastern Scheldt Barrier

by

James Buysschaert

To obtain the degree of Master of Science
at the Delft University of Technology

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Preface

The end of my academic journey is approaching, and with it, the completion of this master thesis. I began my studies at TU Delft in 2018, uncertain of where my interests lay, embarking on a somewhat intimidating adventure. Looking back, despite the challenges, I would choose this path again in a heartbeat. It has been a transformative experience, one that has pushed me out of my comfort zone and contributed greatly to my personal growth.

After switching between a few study directions, I found my way to the faculty of Technology, Policy and Management in 2019. I immediately felt at home. The faculty offered a collaborative environment, less focused on pure technical engineering and more on teamwork and the human side of decision-making. Although I enjoyed the courses during this three-year bachelor's track, I gradually realised that I was seeking more practical, visual, and hands-on challenges.

This realisation led me to pursue a Master's degree in Construction Management and Engineering, in which I truly found my passion. Over the past two years, I have had the opportunity to explore and develop my skills in project and infrastructure management, two areas that have always fascinated me. In this regard, the Eastern Scheldt Barrier stands out as a unique infrastructure project. As climate change intensifies, the pressure on such systems is growing. In this context, inclusive decision-making is more important than ever, and the complexity of managing these challenges will only grow in the years ahead.

I would first like to thank my supervisors, Dr.ir. M. Nogal Macho, Dr.ir. J. Ninan, and Dr.ir. O. Kammouh, for their invaluable guidance over the past months. Maria, thank you for your support, availability, and thoughtful comments throughout the process. Johan, I am grateful that you brought this topic to my attention and for the engaging discussions during our weekly group sessions. Omar, thank you for your sharp insights, consistent feedback, and for challenging me to think more critically.

I would also like to sincerely thank M. Nagelhout and Dr.ir. A.M.R Bakker from Rijkswaterstaat for giving me the opportunity to work on such a relevant and inspiring topic. Menno, thank you for picking me up in Goes, for your valuable feedback, continued support, and for making me feel welcome at Rijkswaterstaat, it was a pleasure working for you. Alexander, thank you for your input and encouragement throughout the project.

I am especially grateful to all the interviewees who generously shared their time, perspectives, and insights. Your openness was essential to this research, and I appreciate your contributions.

Lastly, I would like to thank my family for their unwavering support over the past few years. Your encouragement, patience and reassuring presence have been a true source of strength, especially during times when I felt uncertain or overwhelmed. Knowing that I could always rely on you has not only made this journey possible, but also more meaningful. Thank you.

I wish you, the reader, a pleasant read. I hope you enjoy this thesis as much as I enjoyed working on it. I also hope that this research will contribute in some way to more inclusive and resilient barrier management, ensuring both safety and sustainability for the unique ecosystem of the Eastern Scheldt.

James Buysschaert
Delft, July 2025

Summary

The Eastern Scheldt Barrier is one of the Netherlands' most iconic flood defence structures, designed to ensure water safety while preserving tidal dynamics and ecological balance. However, climate change is expected to increase the frequency of barrier closures due to sea-level rise and more frequent storm surges. While these closures protect the hinterland from flooding, they also disrupt ecological systems, economic activities, and stakeholder routines. This shift presents a complex governance challenge: *how can societal tolerance for increased closures be assessed and incorporated into storm surge barrier management?*

Although the technical and ecological effects of storm surge barriers are relatively well understood, the societal dimension, in particularly stakeholder tolerance has received limited attention. Existing research typically examines social acceptance retrospectively, after disruptions occur, rather than offering forward-looking tools to support proactive governance. This thesis addresses this gap by applying the Social Licence to Operate (SLO) framework to infrastructure management. Originating in the extractive industries, the SLO model conceptualises public acceptance as a layered, dynamic condition rather than a binary state. This thesis adapts and extends the SLO framework to the public sector, using it to assess how legitimacy, trust, and stakeholder engagement can be actively governed in the context of increased barrier closures.

The research combines a literature review with 15 semi-structured interviews involving stakeholders from aquaculture, recreation, environmental organisations, and Rijkswaterstaat. Using the GIOIA method, the study identifies key drivers of societal tolerance, such as ecological dependency, institutional trust, risk awareness, and communicative clarity, and maps these drivers onto five stakeholder positioning levels: *ignorance*, *withdrawal*, *acceptance*, *approval*, and *identification*. Each position corresponds to a different level of social licence, with specific behavioural and perceptual indicators (as shown in Figure 1)

Findings show that aquaculture stakeholders are positioned closest to the withdrawal, ignorance, and legitimacy boundaries due to their high ecological dependency, limited adaptive alternatives, and insufficient access to strategic information. Their low tolerance is driven not only by material vulnerability, but also by a lack of awareness about long-term closure strategies and decision-making processes. Environmental NGOs demonstrated conditional acceptance, provided that closures align with transparent, ecologically grounded objectives. Recreational users expressed concern about predictability and timing but generally showed higher adaptability. Rijkswaterstaat, in turn, highlighted the importance of clarity, early engagement, and long-term planning to maintain institutional trust. These differentiated positions illustrate that societal tolerance is both sector-specific and deeply governance-dependent.

To operationalise these insights, the thesis develops a conceptual SLO-based framework for tolerance assessment and integration. It identifies four critical boundaries: *knowledge*, *credibility*, *legitimacy*, and *trust*, which stakeholders must cross for a social licence to be achieved and sustained. The framework links each boundary to specific governance strategies, such as appointing trusted intermediaries (trust-carriers), visualising closure trade-off, embedding social thresholds into operational protocols, and co-creating long-term regional visions.

Key recommendations include:

1. Developing a "tolerance dashboard" to monitor stakeholder positioning using qualitative indicators (e.g., perceived fairness, withdrawal behaviours, emotional ownership).
2. Embedding stakeholder-specific thresholds such as mussel spawning periods and peak recreational use into operational protocols and the Strategic Asset Management Plan.
3. Enhancing early-warning systems and sector-sensitive communication tailored to different stakeholder needs.

4. Strengthening social cohesion in structurally vulnerable sectors like aquaculture through collective governance mechanisms.
5. Facilitating a participatory process to co-develop a 2075–2125 vision for the Eastern Scheldt that balances safety, ecology, and legitimacy.

Beyond its practical relevance, this research makes a theoretical contribution by extending the Social Licence to Operate framework to climate-adaptive public infrastructure. This research shows that societal tolerance isn't just a public opinion, it's something that governments can actively measure and manage.

In conclusion, this thesis offers both conceptual clarity and practical tools for integrating societal tolerance into storm surge barrier management. It provides Rijkswaterstaat with a method to navigate the evolving legitimacy landscape of climate adaptation, enabling more inclusive, anticipatory, and publicly supported infrastructure governance.

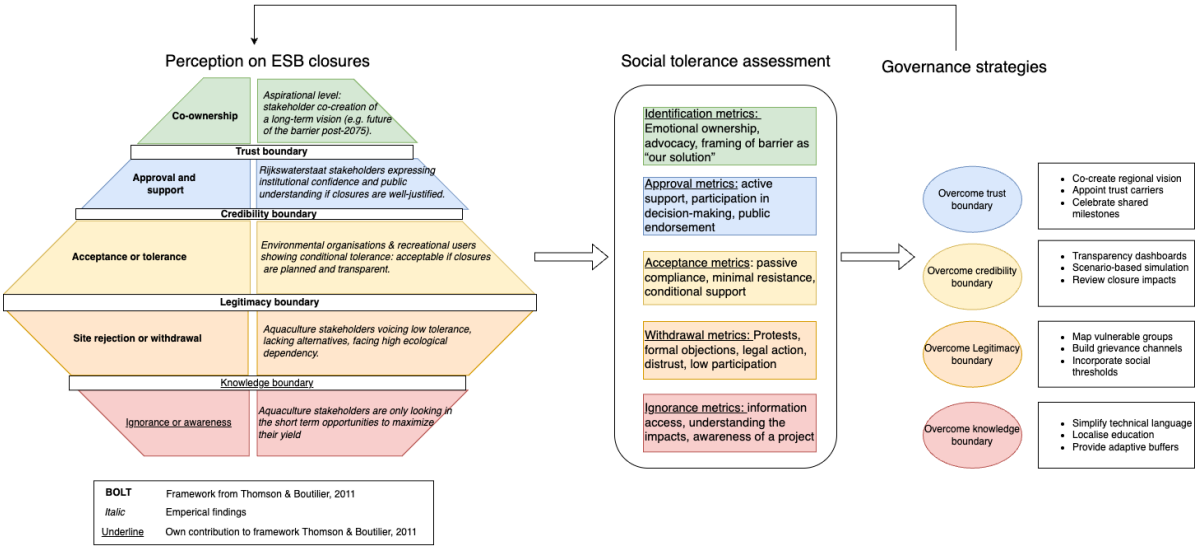

Figure 1: SLO-based conceptual framework showing how societal impact and risk perception inform stakeholder positioning and governance strategies in response to increased closures of the Eastern Scheldt Barrier. (bigger figure in 5.2)

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1

Introduction

1.1. Research background

The ”Watersnoodramp” of 1953 was one of the most catastrophic natural disasters in the history of the Netherlands. A severe north-westerly storm, combined with a spring tide, caused widespread flooding in the southern coastal provinces, leading to extensive damage to land and infrastructure, as well as devastating losses of human and animal life (Planbureau voor de Leefomgeving (PBL), n.d.).

In response, Rijkswaterstaat, the executive branch of the Ministry of Infrastructure and Water Management, developed the Delta Works, a comprehensive system designed to protect the Netherlands from future flooding events. The Delta Works consists of five storm surge barriers, two sluices, and six dams, forming a crucial part of the country’s critical infrastructure. An overview of the Delta Works is shown in Figure 1.1. Additionally, Rijkswaterstaat took over the management of a sixth storm surge barrier, Ramspol from the water boards on 1 July 2014 (Ministerie van Infrastructuur en Waterstaat, 2023)

Figure 1.1: Delta Works Netherlands, (Ministerie van Infrastructuur en Waterstaat, 2023)

As shown in Figure 1.2, without this critical infrastructure, two-thirds of the Netherlands would be at risk of flooding, threatening 70% of the Dutch population and 60% of its GDP (approximately €700 billion). This underlines the crucial role of the Delta Works in ensuring the survival and safety of the Dutch inland regions (Planbureau voor de Leefomgeving (PBL), n.d.).

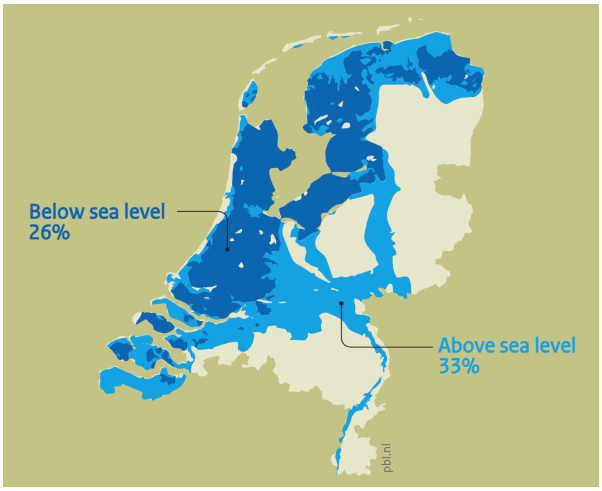

Figure 1.2: Flood prone areas in the Netherlands, (Planbureau voor de Leefomgeving (PBL), n.d.)

Among these storm surge barriers, the ”Oosterscheldekering”, also referred to as the Eastern Scheldt Barrier, is the largest and most complex. Completed in 1986, it was designed to provide flood protection while maintaining tidal movements, preserving the ecological balance of the Eastern Scheldt. Under normal conditions, the Eastern Scheldt Barrier remains open, but it closes when the predicated water level reaches +3 meters above NAP on the North Seaside of the barrier (Normaal Amsterdamse Peil, the Dutch reference for mean sea level). Historically, the barrier has closed approximately once per year on average (Ministerie van Infrastructuur en Waterstaat, 2023).

The closing regime is based on the 1-2-1 strategy. This strategy involves a dynamic, phased closure during high water events, which serves two important functions. First of all, water safety, to distribute the hydraulic load of the waves (still present in the basin) on the hinterland. secondly, to allow some tidal exchange for the quality of the ecosystem in the Eastern Scheldt. As water levels rise during a storm, the gates are first closed when the outer water level is 1 metre higher than the inner level. They are reopened once the levels equalise (as the tidal cycle continues to influence water levels during the event.). The second closure occurs when the outer level exceeds the inner by 2 metres, again reopening at equilibrium. The third closure uses a 1 metre difference. This alternating pattern continues as needed. The strategy balances safety with ecological preservation by allowing some tidal movement between closures (van Westen & Colijn, 1994).

As climate change intensifies, storm surge barriers such as the Eastern Scheldt Barrier will face increased closure frequencies due to more frequent and intense storms and sea level rise (Kharoubi et al., 2024). While these structures are designed to protect coastal areas from flooding, the increased occurrence of closures in the future will present significant economic, ecological, and societal challenges (Vader et al., 2023). Existing research has primarily focused on the technical aspects of storm surge barriers, such as their engineering resilience and structural performance. Furthermore, current literature also elaborates on the issues on the ecosystem of the Eastern Scheldt, while relatively little attention has been given to how stakeholders perceive and tolerate the closure of the barrier. Understanding societal tolerance is essential for balancing flood protection, economic stability, and community well-being (Orton et al., 2023). Appendix B provides a spatial overview of key recreational and aquaculture zones, offering important context and stakeholders for understanding the potential societal impacts of increased barrier closures.

Despite the growing knowledge of research on flood resilience, there remains a significant gap in explicitly addressing societal tolerance for storm surge barrier closures. A key challenge is understanding at what point increased closures transition from being a necessary protective measure from flooding to a socio-economic and ecological burden for stakeholders (fisheries, aquaculture, National park organisation). While some studies have examined community resilience to flooding, no studies have investigated what the tolerance levels are of society caused by (increased) storm surge barrier closures (Kirshen et al., 2020).

Furthermore, existing studies primarily rely on post-disruption surveys conducted in the aftermath of extreme weather events, such as hurricanes Michael or Harvey in the United States (Dong et al., 2020). While surveys provide large-scale quantitative data, they often lack qualitative insights, as respondents have limited opportunities to elaborate on their perspectives or provide feedback on what should have been prioritised. Additionally, previous research highlights that societal tolerance is not static. Communities and stakeholders tend to show higher acceptance levels after experiencing a disruptive event (Esmalian, Dong, et al., 2021; Rojahn et al., 2017). However, this research aims to be pre-emptive, assessing societal tolerance before increased closures occur, rather than reacting to it afterward. This proactive approach seeks to identify adaptive strategies in advance, ensuring that stakeholders can prepare for and mitigate the impacts of increased Eastern Scheldt Barrier closures, before their impacts become critically disruptive to the socio-economic and ecological functioning of the region.

By addressing these gaps, this study will contribute to a more comprehensive understanding of societal tolerance for storm surge barrier closures, integrating stakeholder perspectives into infrastructure asset management, and more inclusive decision-making practices.

1.2. Research statement

With rising sea levels and increasing storm severity, the Eastern Scheldt Barrier is expected to close more frequently, resulting in longer cumulative closure durations per time frame. While such closures are essential for ensuring flood protection, they also introduce significant ecological, economic, and societal challenges. Prolonged disruptions to tidal flow affect marine ecosystems, local fisheries, and regional economic stability. Although previous research has largely concentrated on the technical performance and ecological effects of barrier operations, limited attention has been paid to societal tolerance how communities perceive, experience, and adapt to these evolving disruptions.

This study examines the societal impact of the increasingly frequent closures of the Eastern Scheldt Barrier by assessing the societal tolerance levels. It aims to incorporate different stakeholder perspectives in order to improve Rijkswaterstaat asset management strategies. Unlike previous post-disaster studies, this research takes a pre-emptive approach by identifying the point at which closures move from necessary protective measures to socio-economic and ecological burden. The findings will provide a framework to support the management of storm surge barriers, while balancing flood safety, economic viability and ecological preservation.

1.3. Research objectives

The main objective of this study is to explore the societal tolerance for possible increased closure of the Eastern Scheldt barrier in the future and to integrate these insights into the management of the barrier. To achieve this, the study aims to:

1. Identify key factors influencing societal tolerance for Eastern Scheldt Barrier increased closures
2. Develop a framework that balances flood safety, economic sustainability, and ecological preservation in storm surge barrier management.
3. Provide policy recommendations for integrating societal tolerance levels into asset management and maintenance planning.

1.4. Research questions

Based on the formulated objectives mentioned in Section 1.3, the main questions reads as follow:

How can societal tolerance for the increased closures of the Eastern Scheldt Barrier be assessed and integrated into storm surge barrier management?

In order to achieve this goal, the main research question is supported by three sub-questions. These sub-questions focus on identifying key factors influencing societal tolerance, gathering stakeholder insights and integrating these findings into a comprehensive framework. The four sub-question go as follows:

1. What is the current knowledge on increa sed closures of the Eastern Scheldt Barrier and societal tolerance?
2. How is the perception of increased closures experienced by stakeholders?
3. How can societal tolerance for increased closures be assessed?
4. How can societal tolerance be integrated into the Eastern Scheldt barrier management?

1.5. Research relevance

For the practical side of this research, it provides policy recommendations for Rijkswaterstaat and decision-makers, supporting the development of an actionable framework to integrate societal tolerance into asset management. By doing so, it helps balance economic, ecological, and flood safety trade-off, ensuring a sustainable and publicly accepted approach to infrastructure asset management.

From a scientific perspective, this study contributes to the understanding of societal tolerance in the context of critical infrastructure management, bridging engineering and social science perspectives. Additionally, it develops a framework that links increased closures, societal tolerance, providing a structured approach to pre-emptive manage and mitigate the impacts of increasing storm surge barrier closures.

1.6. Thesis outline

This thesis is structured into seven chapters as shown in Figure 1.3. Chapter 1 introduces the research background, objectives, research questions, and the relevance of societal tolerance in the context of the Eastern Scheldt Barrier. Chapter 2 outlines the research methodology, including the sequencing of research questions, data collection methods, and the application of the GIOIA method. Chapter 3 provides the theoretical foundation by reviewing existing literature on storm surge barrier closures and the determinants of societal tolerance. Chapter 4 presents the qualitative findings from stakeholder interviews, addressing how different stakeholder groups perceive and experience increased closures. Chapter 5 synthesises these findings into a conceptual framework. Chapter 6 discusses the broader implications of the findings, offers practical recommendations, outlines research limitations, and highlights theoretical contributions. Finally, Chapter 7 answers the research questions which are formulated in the first chapter.

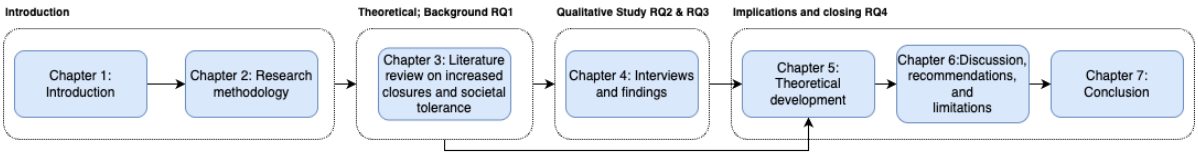

Figure 1.3: Thesis outline

2

Research methodology

This chapter outlines the research methods used to explore societal tolerance for increased closures of the Eastern Scheldt Barrier. A combination of literature review, stakeholder interviews, and qualitative analysis using the GIOIA method was employed to capture both theoretical insights and stakeholder experiences.

2.1. Research design and method integration

This study is structured around four interrelated research questions, each addressed through a combination of complementary qualitative methods. The research design was deliberately sequenced to move from theoretical grounding to empirical insight and ultimately to conceptual development.

Figure 2.1 visualises how each method contributes to one or more research questions. The process began with a targeted literature review, which informed the theoretical framing and answered RQ1 on current knowledge related to increased closures and societal tolerance. Semi-structured interviews provided rich empirical data for RQ2, focusing on stakeholder experiences and perceptions. These interviews were then analysed using the GIOIA method to address RQ3, which explores how societal tolerance can be assessed through stakeholder-specific indicators and patterns. Finally, the insights from the previous steps were synthesised into a conceptual framework, answering RQ4 on how societal tolerance can be integrated into the management of the Eastern Scheldt Barrier.

This layered design ensured that the framework was both theoretically grounded and empirically informed. Each research question builds logically upon the previous: RQ1 frames the theoretical landscape; RQ2 contextualises this with empirical stakeholder input; RQ3 translates these insights into assessable indicators; and RQ4 integrates them into a practical governance framework. This sequential structure ensures that the integration of societal tolerance into storm surge barrier management (RQ4) is deeply rooted in both conceptual understanding and stakeholder realities.

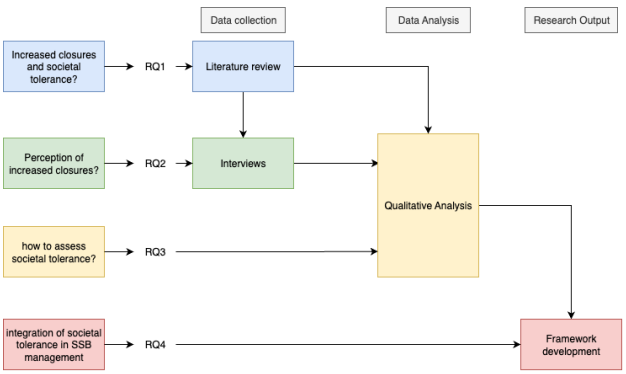

Figure 2.1: Research design

2.2. Literature review

To answer the first research question, regarding the current understanding of the impact of more frequent closures of the Eastern Scheldt Barrier and the concept of societal tolerance, a qualitatively literature review was conducted.

The literature review explores how increased barrier closures are expected to affect ecological systems, economic activities, and maintenance operations. In addition, it explores existing definitions and conceptual frameworks of societal tolerance, identifying key determinants such as demographic factors, risk awareness, preparedness, service substitutability, and crisis communication.

Academic search engines and databases such as Google Scholar, Scopus, and the TU Delft Library were used to gather relevant literature. For studies on the impact of closures, keywords included: *Eastern Scheldt Barrier, Eastern Scheldt Barrier AND closures, Storm Surge Barrier AND closures, and Storm Surge Barriers AND ecological OR economic impact*. Searches were mainly conducted in Dutch to include insights from national institutions, universities, and consultancies that may not publish in English. References from relevant papers were examined to identify further useful literature. Key contextual information was also provided by M. Nagelhout (Senior consultant asset management, Rijkswaterstaat).

For research related to societal tolerance, keywords included: societal tolerance, societal tolerance AND (critical) infrastructure, societal tolerance AND failing infrastructure, susceptibility AND infrastructure, and societal tolerance AND service disruptions. Key studies were particularly informative (Coleman et al., 2020b; Esmalian, Dong, et al., 2021; Petersen et al., 2020), and their reference lists helped to expand the literature base.

2.3. Data-collection

To gather qualitative data for the other three research questions, semi-structured, open-ended interviews were conducted with relevant stakeholders. The design of the interviews, participant selection and recruitment, and ethical procedures are outlined below.

2.3.1. Interviews

A semi-structured, open-ended interview format was adopted, providing a consistent structure across all interviews while allowing flexibility to explore participant insights. This approach enabled the collection of nuanced and in-depth responses, supporting a more comprehensive understanding of stakeholder perspectives (Hammer & Wildavsky, 2018; Knott et al., 2022).

2.3.2. Selection of participants and recruitment of respondents

The thesis focused on stakeholders with a direct economic or ecological relationship to the Eastern Scheldt, as they are most likely to be affected by increased storm surge barrier closures. To ensure relevant and balanced representation, a stakeholder identification session was held on 1 April 2025 with M. Nagelhout and the Relation Manager for Sea and Delta at the Water District Zeeuwse Delta (Rijkswaterstaat).

During this session, stakeholder groups were assessed based on three key criteria:

- Dependency on tidal flow and barrier operation
- Involvement in decision-making or regional planning
- Potential vulnerability to closure-related disruption

As a result, the following stakeholder categories were included:

- Aquaculture associations: including mussel and oyster sector representatives;
- Environmental organisations: such as nature conservation NGOs and research institutes;
- Recreational and tourism sector groups: including water sports and national park representatives;
- Government and infrastructure managers: including staff from Rijkswaterstaat Zeeland involved in water quality, morphology, and barrier operation.

While all interviews were conducted with sectoral representatives, efforts were made to ensure a diversity of perspectives within each stakeholder category. Respondents were approached through direct outreach via email and telephone, with introductions and support provided by the Rijkswaterstaat relation manager. In total, 15 interviews were carried out. Although the sample achieved broad coverage of institutional and sectoral actors, certain perspectives, such as those of individual aquaculture producers, local residents, or tourists, were not represented. This is acknowledged as a limitation and an opportunity for future research. An overview of the interviewed stakeholders is provided in Chapter 4.

In addition, a few organisations declined to participate. For example, Zeeuwse Anker (Zeeland Anchor) indicated that they had no direct interest in the topic, while Staatsbosbeheer (State Forestry Commission) explained that they do not own land around the Eastern Scheldt and are therefore not directly affected.

2.3.3. Ethics approval

To ensure compliance with ethical standards regarding data handling, a Data Management Plan was developed covering the collection, storage, use, protection, and deletion of the data. An official ethics application was submitted to the TU Delft Ethics Committee and approved prior to conducting any interviews (ID number: 5354).

Before each interview, participants were asked to sign a consent form, which can be found in Appendix C. The form outlines the study's purpose, potential risks, and how the anonymised data will be used. All signed consent forms have been shared with the first supervisor and are securely stored on the TU Delft OneDrive.

As stated in the consent form, participants were also asked for permission to record and transcribe the interviews. The interviews were conducted via Microsoft Teams, and both the recordings and transcripts were securely stored (2 steps-authentication) in the TU Delft OneDrive environment.

2.4. Qualitative data-analysis

For the qualitative data-analysis, as the automated transcription tool is not completely accurate, each transcript was manually reviewed and corrected by listening to the recordings to ensure accuracy of what participants actually said. This step was taken to ensure the consistency and integrity of the data used for qualitative analysis. In addition, all personal information was anonymised in accordance with the approved data management plan of the ethics stewards.

Once the data was collected, it was analysed qualitatively through thematic analysis. This was done mainly with the help of ATLAS.ti, a qualitative analysis tool, which helped to identify patterns and ultimately to identify patterns on societal tolerance for more frequent and prolonged closures of the Eastern Scheldt Barrier.

For this analysis, the GIOIA method was used. The GIOIA Method, is a systematic approach to qualitative data analysis. The GIOIA methodology proceeds in three structured stages (Gioia et al., 2013):

- First-order concepts: staying as close as possible to participants' own words and interpretations, enabling a rich and detailed representation of stakeholder experiences.
- Second-order themes: abstracting from the first-order terms to identify broader patterns and themes that capture how participants make sense of developments around the barrier.
- Aggregate dimensions: integrating the second-order themes into higher-level concepts that offer theoretical insights into societal tolerance mechanisms and the effects of barrier closures.

As an example, Figure 2.2 illustrates how the GIOIA method systematically links raw interview data to higher-level theoretical insights. In this example, participant quotes such as "We don't even know who we are right now" and "No consistency in labels during pre-spin-off and spin-off" are coded as first-order concepts. These concepts reflect direct experiences and language used by informants. Through the second-order coding process, these quotes are grouped under the theme of "Identity Ambiguity", which captures a broader underlying issue present across multiple interviews. Finally, this second-order theme is synthesised into the aggregate dimension "Change Context", representing a core dynamic affecting stakeholder understanding and behaviour. This structure exemplifies how the GIOIA method

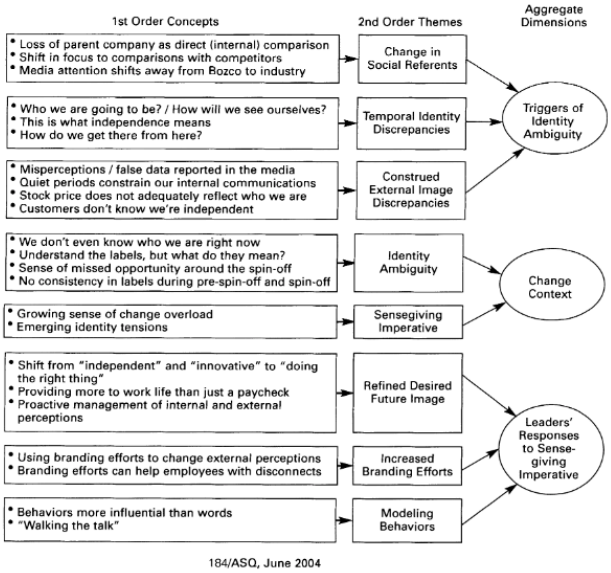

Figure 2.2: Example GIOIA-method from (Corley & Gioia, 2004)

transitions from rich qualitative detail to theoretical abstraction, while maintaining a clear audit trail from data to concept (Corley & Gioia, 2004).

Applying the GIOIA Method provided several advantages for this research. Firstly, it allowed for a systematic but flexible way of capturing the complexity and diversity of stakeholder views. Secondly, it ensures transparency by clearly showing the steps from raw data to final interpretations. Thirdly, the method emphasises iteration between data and theory-building, which is critical for developing a conceptual framework that is both empirically grounded and theoretically meaningful.

The practical steps of the qualitative analysis are summarised below:

- Data import: by importing and categorising the data into ATLAS.ti, the programme acted as a data manager.
- Coding: coding the data provided initial insights into the data. The codes are organised into families or groups, providing a structure to the data.
- Categorising data in instances: after coding, the data was reviewed again to extract key insights and quotations. These were compiled and linked directly to the second research question. Relevant findings were organised in a table under emerging thematic categories.
- Interpretation of findings: themes and patterns were interpreted through a combination of data analysis, insights from existing literature, and reflective observations. This interpretation formed the basis for drawing conclusions.
- Incorporation in framework: based on the findings, a conceptual framework was developed to represent societal tolerance levels for increased closures. This framework illustrates the relationships between key factors influencing tolerance and offers guidance on how these insights can inform policy and infrastructure planning.

This chapter has outlined the methodological approach used to explore how stakeholders in the Eastern Scheldt region perceive and tolerate more frequent and longer storm surge barrier closures. Through a combination of literature review, stakeholder interviews, and qualitative analysis using the GIOIA method, the study captures both theoretical and empirical dimensions of societal tolerance. These methods were carefully chosen to ensure a systematic and transparent research process. They made it possible to account for the complexity of stakeholder experiences and the context-dependent nature of societal tolerance. The next chapter examines the existing literature on the effects of increased closure and the concept of societal tolerance in the context of critical infrastructure.

3

Literature review on increased closures and societal tolerance

This literature review focuses on two key themes: 1) the increased closures of storm surge barriers and the consequences, and 2) societal tolerance and its determinants. 1) It examines how future increased closure of storm surge barriers, in particular the Eastern Scheldt Barrier, will likely affect ecological systems, economic activities and infrastructure management. 2) It also examines societal tolerance by analysing the factors that influence the ability of communities to adapt to future disruptions, including risk perception, preparedness, service expectations and socio-demographic characteristics.

3.1. Increased closures of the Eastern Scheldt Barrier

As climate change progresses, more frequent and severe storms, combined with rising sea levels, are expected to increase the closure frequency of storm surge barriers such as the Eastern Scheldt Barrier. While the structure remains mechanically and structurally sound, repeated closures increasingly disrupt natural tidal exchanges. This disruption has significant ecological, economic, and societal implications. Restricted tidal flow affects marine ecosystems, local fisheries, aquaculture, and presents challenges for coastal zone management and long-term asset maintenance.

A scenario study by Rijkswaterstaat projects closure frequencies under various sea-level rise conditions. With a 0.5 metre sea-level rise, the barrier would need to close approximately five times per year to maintain the current safety threshold of +3.00 metres above NAP. However, as sea levels continue to rise, the number of closures increases exponentially. At 1.0 metre of sea-level rise, up to 85 closures could be required annually; at 1.5 metres, as many as 418 closures per year may be necessary. Beyond 2.25 metres of sea-level rise, the barrier could remain closed through multiple consecutive tidal cycles, effectively eliminating natural tidal exchange (Zandvoort et al., 2019). These scenarios point to profound consequences for ecology, the economy, and maintenance planning.

Figure 3.1 presents a conceptual model that illustrates how the ecosystem is affected by the increased frequency of closures for the Eastern Scheldt Barrier. The following subsections elaborate on these interactions.

3.1.1. Ecological consequences of increased closures

Increased Eastern Scheldt Barrier closures due to more and intensified storms and sea-level rise create a complex set of morphological and hydrodynamic changes (De Vet et al., 2024; Orton et al., 2023). Sand starvation refers to the gradual disappearance of intertidal flats, salt marshes, and shoals along the coast due to disrupted sediment supply. Storm surge barriers, such as the Eastern Scheldt Barrier, hinder the natural tidal movement that typically transports sand from the sea to the coast. Meanwhile, wave action continues to erode sand, which is then lost to deeper channels. This process leads to the loss of feeding grounds for birds and reduces the protective capacity of dunes and dikes.

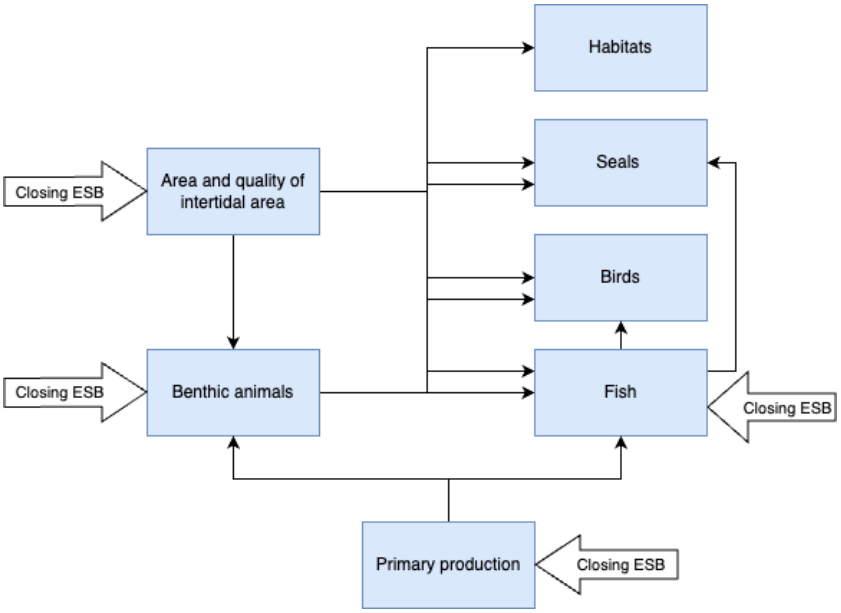

Figure 3.1: Impact chain showing how the Eastern Scheldt Barrier closure regime affects the morphological system (area and quality of the intertidal zone) and the ecological system (primary production, benthic animals, fish, birds, marine mammals, and habitats). Adapted and translated from (Zandvoort et al., 2019).

Sea-level rise and sand starvation reduce both the area and quality of the intertidal zone. These losses directly impact benthic species, which in turn affect higher trophic levels such as fish, birds, and marine mammals. Although the Eastern Scheldt Barrier was originally designed to allow partial tidal exchange, more frequent closures increase water residence time within the estuary, which alters sediment transport and deposition patterns. Erosion accelerates in intertidal zones due to the sediment deficit, while deeper areas experience increased sedimentation. These morphological changes reduce water clarity, alter salinity gradients, and deplete oxygen levels, contributing to widespread ecological degradation (Chen et al., 2020).

Another critical factor illustrated in the figure is rising water temperatures, which influence both primary production and species distribution (Chen et al., 2020). Temperature rise contributes to changes across multiple levels of the food chain, favouring some species while pushing others toward local extinction. Fish, for example, may suffer physiological stress from warming waters, while warm-water or invasive species may gain a competitive edge. This growing stress, combined with habitat loss and tidal flow reductions, further weakens the ecosystem (Zandvoort et al., 2019).

The figure also shows that more frequent barrier closures have serious ecological consequences by limiting water exchange. It is leading to the disappearance of intertidal flats and mudflats (Ysebaert et al., 2015), which serve as important foraging and resting habitats for birds and marine species. An older study by Van Kessel and Van der Zee (2004) mentions that construction of the Delta Works has resulted in sand starvation in the channels of the Eastern Scheldt amounting to 400 to 600 million m^3. Because intertidal flats cannot accumulate sediment at the same rate as sea-level rise, their disappearance threatens species that depend on these habitats, such as seals and shorebirds (Van Zanten & Adriaanse, 2008). If high water levels persist for more than one tidal cycle, these species will lose access to essential feeding and resting areas, leading to population declines (Haigh et al., 2024).

Research by Orton et al. (2023) and De Vet et al. (2024) has shown that hydrodynamic changes caused by storm surge barrier closures alter sediment transport, salinity gradients, and nutrient flows. These changes disrupt the entire food chain, from primary production to bottom-dwelling (benthic) organisms, fish, and higher predators such as seabirds and marine mammals. Studies show that estuarine ecosystems continue to adjust even decades after the construction of storm surge barriers. The Eastern Scheldt has not reached a new ecological equilibrium since the completion of the Eastern Scheldt Barrier in 1986. With continued sea-level rise, more storms, and increased closure frequency, an equilibrium may never be reached again (Zhou et al., 2017).

The closure of the Eastern Scheldt Barrier reduces water flow by approximately 93%, sharply limiting nutrient inflow and the transport of organic matter. This directly impacts water quality and primary production, which serve as the main food source for filter-feeding benthic organisms like mussels. De Vries (2015) note that mussel cultivation near the barrier benefits from nutrient-rich, dynamic water flow. More frequent closures would significantly reduce food availability, by up to 93%, and pose serious risks to shellfish farming, especially during the critical spawning and growth periods in spring and summer (Zandvoort et al., 2019). However, it remains unclear at what point this ecological disruption becomes intolerable for stakeholders. This study aims to explore that threshold by assessing societal tolerance to increased closures.

3.1.2. Economic consequences of increased closures

Frequent and prolonged closures will pose significant economic risks, particularly for the fishing and shellfish farming industries that depend on stable tidal flows for production and harvesting. Unpredictable closures will reduce access to marine resources, threatening the livelihoods of communities engaged in aquaculture within the Eastern Scheldt region. The shellfish industry, including mussel farming, is especially vulnerable to changes of water flow and nutrient availability (Zandvoort et al., 2019). As closures limit water exchange between the Eastern Scheldt and the voordelta, the transport of primary production and nutrients decreases, directly impacting the growth conditions for fishes, mussels, and oysters. Since mussels, fishes and oysters growth depends on food availability carried by tidal currents, the long-term reduction in water movement could significantly affect production levels. Additionally, reduced flow dynamics may result in increased sedimentation, altering seabed conditions and further complicating aquaculture activities.

The projection of closures in Section 3.1 indicates that as closures become more frequent in the future, the disruptions to economic activities such as fisheries and aquaculture will intensify, potentially reaching a tipping point where these industries are no longer viable and threatens the livelihoods of communities.

3.1.3. Maintenance challenges

Besides that frequent closures put constraints on the ecological and economical side, it presents operational and maintenance challenges. The Eastern Scheldt Barrier was designed for intermittent use during extreme storm events (on average once a year), but with increased closure frequencies, the wear and tear on some mechanical components may intensify. More frequent operations place stress on some moving parts, requiring more inspections and possible repairs leading to higher maintenance costs. Currently, maintenance is scheduled outside the storm season (April 1 to October 1) to minimise the risk of compromising flood protection (Ministerie van Infrastructuur en Waterstaat, 2023; Van Alphen et al., 2022). However, unpredictable closures during the storm season may necessitate adaptive maintenance strategies, which could be logistically and financially demanding (Trace-Kleeberg et al., 2023).

In addition, a shortage of skilled personnel further complicates maintenance planning. As infrastructure ages, specialised expertise is required for continued operation, but the shortage of engineering and maintenance staff (at Rijkswaterstaat), contractors and engineering firms poses a challenge to maintaining long-term functionality (Redactie Engineersonline, 2023). This issue becomes even more pressing as climate change increases the vulnerability of infrastructure, requiring continuous monitoring and adaptive management approaches.

3.1.4. Linking increased closures to societal tolerance

The societal impact of more frequent Eastern Scheldt Barrier closures can be understood through a chain of disruptions, adapted from the theoretical framework by (Yang et al., 2021), as shown in Figure 3.2. In this adapted version, as sea-level rise and more intense storms lead to increased closures, the resulting interruption in tidal exchange affects essential ecosystem services. This then impacts daily economic activities such as aquaculture, fisheries, and tourism. When these disruptions reach a point where basic physiological or economic needs can no longer be met, societal tolerance begins to decline. Identifying where this tipping point lies is essential for decision-makers to manage the trade-off between flood protection and the ecological and socio-economic functioning of the Eastern Scheldt region.

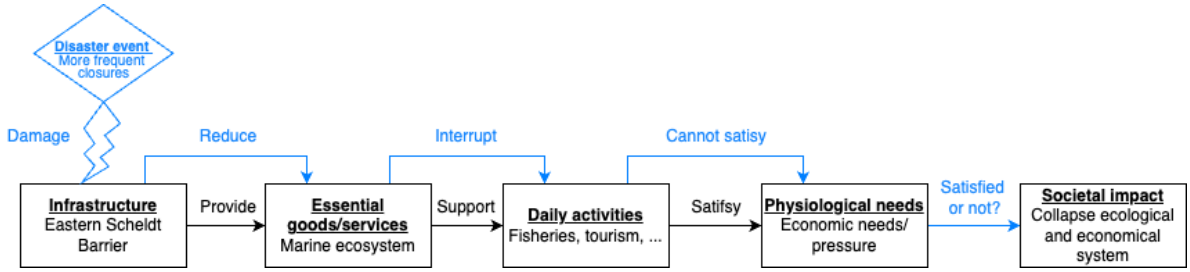

Figure 3.2: Adapted framework for analysing societal impact from infrastructure disruption, based on (Yang et al., 2021), contextualised for the Eastern Scheldt Barrier

3.2. Societal tolerance in critical infrastructure

Societal tolerance refers to the ability of communities to endure and adapt to disruptions in essential services before experiencing significant hardship or demanding intervention (Coleman et al., 2020a).

In the case of the Eastern Scheldt Barrier, societal tolerance is determined by how frequently future closures will occur, before they become a significant burden on communities and industries in the Eastern Scheldt region. If the frequency of closures increases from once per year to multiple times per year, different stakeholders will have varying levels of tolerance.

Understanding societal tolerance is essential for policymakers to determine whether infrastructure can be considered ”safe-to-fail”, meaning that failure or reduced functionality of the Eastern Scheldt would have manageable consequences. By integrating societal tolerance and expectations into infrastructure performance assessments, decision-makers can minimise disruptions and develop more adaptive management strategies (Kim et al., 2019).

A study by Esmalian, Coleman, et al. (2021) on household susceptibility to infrastructure service disruptions during disasters highlights a critical knowledge gap in research. It emphasises the importance of incorporating the needs of more vulnerable populations to the negative impact of disruption into decision-making processes when evaluating the societal impact of infrastructure failures. Furthermore, effectively integrating insights on disaster impacts, service disruptions, and social vulnerability into policy frameworks is crucial to ensuring more equitable and informed infrastructure (Koks et al., 2014; McLaughlin & Cooper, 2010).

In the context of storm surge management, this means identifying the different tolerance levels of all relevant stakeholders. Stakeholders should be segmented according to their ability to cope with closures and disruptions, with priority given to those most affected, those with the lowest tolerance levels. Tailored, stakeholder-specific strategies will need to be developed to address their specific vulnerabilities. Clear and targeted communication will be essential to maintain trust, ensure transparency and improve public support for adaptive management strategies.

3.2.1. Determinants of societal tolerance

A study of Esmalian, Dong, et al. (2021) proposes a conceptual framework for the determinants of the zone of tolerance (Figure 3.3). The ”Household Service Gap Model” explains how individuals perceive and tolerate infrastructure service disruptions. The model was evaluated and validated using survey data collected from residents of Harris County (Texas, USA) following the power outages caused by Hurricane Harvey in 2017.

The zone of tolerance refers to the range between a household’s desired and adequate service levels, indicating how much disruption can be endured before it negatively impacts the well-being of individuals and society. Several factors influence this tolerance, as shown in Figure 3.3.

The desired level of service is influenced by two key factors: 1) pre-disaster service function and 2) service utilisation. 1) Pre-disaster service levels shape expectations. For instance, after the Nepal earthquake in 2015, areas with historically limited water access reported lower hardship despite prolonged disruptions, as residents were already accustomed to scarcity (Mostafavi et al., 2017). Generally, the better the infrastructure before a disaster, the higher the expected service level post-disruption. In the

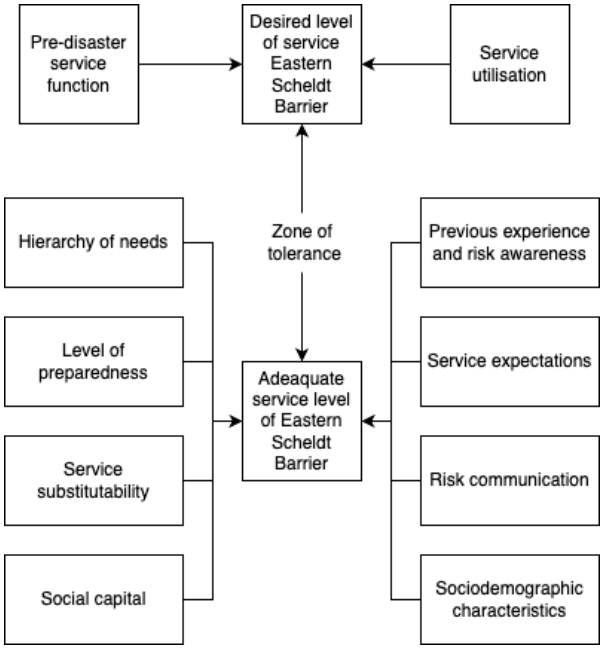

Figure 3.3: Adapted from (Esmalian, Dong, et al., 2021), this framework contextualises the determinants of the zone of tolerance for the Eastern Scheldt Barrier.

context of the Eastern Scheldt Barrier, this can be understood through its historical operation: since its completion, the barrier has typically closed only once per year on average. This low closure frequency has established a baseline expectation of high service continuity, particularly among stakeholders who rely on regular tidal exchange.

2) Service utilisation also affects household expectations. Households that use a service more frequently demand a higher level of reliability. Conversely, those with minimal dependence often experience little hardship during interruptions. Applied to the barrier, stakeholders such as mussel and oyster farmers, recreational boat operators, and environmental organisations engage intensively with the tidal system and are therefore more sensitive to changes in barrier operation. Their frequent use of and dependence on the estuarine dynamics creates a higher expected level of service continuity.

Additional research emphasises the importance of establishing a clear definition of normal performance before gathering data. Defining baseline service conditions ensures that disruptions can be accurately assessed in relation to what is typically expected (Petersen et al., 2020). In the case of storm surge barriers, a historical norm of approximately one closure per year could serve as a reference point for defining the expected or desired level of service against which stakeholder tolerance may be evaluated.

The adequate service level, which determines how much disruption a household can tolerate, and which primarily defines the zone of tolerance, is influenced by the following factors, according to the study by Esmalian, Dong, et al. (2021):

Hierarchy of needs
The first important factor that plays a fundamental role is the hierarchy of needs. It states that some needs are more important than others (Maslow, 1943). In the research of Coleman et al. (2020a), which investigated household susceptibility after Hurricane Harvey (2017, Texas, USA), Hurricane Florence (2018, East Coast, USA), and Hurricane Michael (2018, Florida, USA), it was found that essential services such as water and sewer are defined as extremely important. Furthermore, healthcare facilities like hospitals, electricity, and communication were defined as very important. Lastly, transportation, supermarkets, and solid waste were considered important to moderately important.

The hierarchy of needs is crucial to this thesis as it helps explain why some stakeholders have lower societal tolerance for the increased closures of the Eastern Scheldt Barrier. Stakeholders whose basic needs, such as access to clean water, food from aquaculture, or income from fisheries, are directly

impacted by closures are more likely to reach their tolerance threshold sooner. Understanding which needs are most essential enables policymakers to prioritise actions and tailor communication strategies towards the most affected groups.

Level of preparedness
The second factor that is considered is households that implemented protective actions and preparedness measures had significantly lower susceptibility (or higher tolerance levels) to disruptions. This reduction in vulnerability was influenced by greater preparedness perception, stronger belief in infrastructure capability, increased forewarning time, and the availability of emergency supplies (Coleman et al., 2020a).

Preparedness directly influences how communities respond to increased closures of the Eastern Scheldt Barrier. Households and stakeholders with higher levels of preparedness through awareness, planning and resources are more resilient to the environmental and economic disruptions caused by frequent closures. Identifying gaps in preparedness can help Rijkswaterstaat to develop targeted strategies to support vulnerable groups and increase overall societal tolerance.

Service substitutability
The availability of alternative services influences a household's tolerance zone for disruptions (Zeithaml et al., 1993). When substitutes are available, households are better able to cope with service disruptions. However, where substitutes are not available and reliance on the service is high, societal dependence on the infrastructure becomes more pronounced. While some substitutes exist, such as generators, not all households are aware of them or can afford them (Baker, 2011). As a result, household characteristics play a crucial role in determining access to alternative resources. Overall, households with viable substitutes tend to be more tolerant of service interruptions than those without alternatives.

Service substitutability influences how different stakeholders cope with the reduced tidal flow caused by increased barrier closures. Where alternatives, such as nutrient supplements or alternative aquaculture strategies are lacking or inaccessible, reliance on the regular functioning of the Eastern Scheldt Barrier becomes critical. Understanding where substitutes are limited can help identify stakeholders with low tolerance and guide more targeted support.

Social capital
Social capital also plays a role in shaping a household's tolerance. Strong community networks and social ties can provide additional support during disruptions, increasing tolerance (Aldrich, 2011). In addition, Coleman et al. (2020b) finds that higher levels of social capital, including stronger links with family, friends and community organisations, can provide individuals with greater resources and alternatives during disruptions. For example, access to power generators can help mitigate the impact of infrastructure failures. In addition, renters who stay temporarily or lack financial resources for ownership tend to be less informed about the situation and receive less (financial) support. Renters also have fewer ties within the community, a key factor for societal tolerance (Coleman et al., 2020b), worsening this situation (Kunreuther, 2000).

Social capital affects how well individuals and communities can cope with increased barrier closures and the resulting disruptions. Stakeholders with strong local networks may share resources, information, or coping strategies, increasing their tolerance levels. In contrast, those with weaker social ties, such as renters, may experience greater vulnerability, making social capital a key determinant in identifying low-tolerance groups.

Previous experience and risk awareness
Previous disaster experience can influence societal tolerance by expanding an individual's zone of tolerance, as those who have experienced similar disruptions tend to be better prepared and less affected by future events (Knuth et al., 2014). However, research by Coleman et al. (2020a) suggests that experiencing damage from a previous disruption does not necessarily contribute to a higher level of tolerance, suggesting that exposure alone is not a sufficient predictor of adaptive capacity.

The role of risk awareness and disaster experience in shaping societal tolerance has been explored in several studies. Petersen et al. (2020) examined the societal tolerance of the Barreiro municipal water network (Lisbon, Portugal) using a scenario-based earthquake simulation that led to water out-

ages. The study found that risk perception has a significant impact on public trust in authorities and the perceived legitimacy of crisis communication efforts. Samaddar et al. (2012) further supports this by demonstrating that building trust through effective communication increases risk awareness and tolerance. A prior study by Petersen et al. (2018) on the Barreiro network also observes that individuals with prior disaster experience are more accepting of temporary disruptions to critical infrastructure.

However, Petersen et al. (2020) presents conflicting findings that contradict previous studies, including Lindell and Hwang (2008) and even Petersen et al. (2018), by suggesting that prior disaster experience does not significantly affect societal tolerance. Instead, the study highlights the importance of trust in infrastructure operators, showing that water users in Barreiro reported high levels of satisfaction and confidence in the operator's ability to manage disruptions. This finding reinforces the idea that trust, especially when built through pre-disaster communication, increases risk awareness and contributes to overall tolerance.

This factor reveals that risk awareness and trust in authorities may be more influential than disaster experience alone in shaping societal tolerance. As closures of the Eastern Scheldt Barrier become more frequent, building trust through proactive communication may strengthen public tolerance and acceptance. Understanding this dynamic helps identify which stakeholders may tolerate more frequent disruptions and which require targeted engagement.

Service expectations
Households expect services to be restored after disruptions caused by natural hazards. The higher their expectations of service restoration, the lower their threshold for acceptable disruption, leading to a wider zone of tolerance (Zeithaml et al., 1993). However, these expectations vary between households and are influenced by factors such as risk perception and communication of service restoration estimates. Households adjust their preparedness efforts based on their expectations and available resources (Lindell and Perry, 2000). As a result, service expectations play an important role in shaping a household's tolerance for potential disruptions.

Risk and crisis communication during infrastructure disruptions
Effective risk communication plays a crucial role in enhancing public adaptability during infrastructure disruptions. Clear and reliable information from authorities helps communities understand the severity of disruptions, their expected duration, and the precautions required (Fan et al., 2018).

During crises, crisis communication becomes particularly important as it directly influences the public's perceived ability to cope. Petersen et al. (2018) highlights a positive feedback loop in which effective crisis communication increases societal tolerance for disruptions to critical infrastructure services. When the public receives timely and transparent information, their ability to tolerate and adapt to service disruptions increases. Conversely, inadequate or inconsistent communication can lead to frustration, misinformation, and reduced confidence in infrastructure operators.

The mode of communication also plays an important role in determining public reaction. Fallou et al. (2019) emphasises that infrastructure operators need to understand what information to share and how to communicate it effectively, particularly when societal tolerance drops below acceptable levels. Studies show that younger generations are more likely to seek information about disruptions online, while older people are more likely to rely on traditional media and official government sources. Furthermore, Serafinelli et al. (2017) found that trust in information sources is more important than the choice of communication channel itself (otherwise conspiracy theories can arise). When a source is perceived as credible and reliable, it builds public trust, ensuring that crisis messaging is effective and that expectations are aligned with the operational capabilities of infrastructure providers.

This factor is crucial for the Eastern Scheldt storm surge barrier, as the increasing frequency of closures is likely to lead to greater public concern and criticism. Rijkswaterstaat must communicate transparently and proactively in order to maintain social tolerance, especially among stakeholders directly affected by ecological and economic disruptions. Effective crisis communication can build trust, manage expectations, and prevent resistance to necessary closures.

Socio-demographic characteristics
Socio-demographic characteristics have a significant impact on how households cope with infrastructure disruptions, shaping their ability to prepare for, withstand and recover from service disruptions.

Factors such as income level, age, minority status, gender, culture, religion, nationality and education level determine the extent to which individuals and communities experience hardship during these disruptions.

Vulnerability is frequently discussed in the literature as the increased susceptibility of certain populations, such as low-income groups, the elderly, or racial minorities, to infrastructure disruptions, due to limited resources, restricted mobility, and systemic inequalities (Baker, 2011). However, such demographic definitions may not always directly apply in every context. In regions like the Eastern Scheldt Basin, vulnerability must also be understood in terms of functional dependence on the barrier's operation. Literature suggests that economically or ecologically dependent sectors, such as aquaculture or nature conservation, can also be vulnerable when their exposure to environmental or operational disruptions is high and their capacity to adapt is limited. This calls for a more nuanced, sector-specific framing of vulnerability, particularly in complex socio-ecological systems like the Eastern Scheldt Barrier.

Research by Peacock et al. (2014) highlights that infrastructure disruptions do not affect all communities equally. While some households can absorb temporary disruptions with minimal impact, others in marginalised or economically disadvantaged communities face severe hardship. The exclusion of vulnerable populations from decision-making processes further exacerbates social and economic inequalities, leading to disproportionate impacts on those with fewer resources.

Despite being among the most affected, low-income and minority communities are often overlooked in infrastructure planning (Baker, 2010; Morrow, 1999). Ensuring their representation in strategies is essential to avoid biased policies that disproportionately disadvantage those with fewer resources. Policies should be designed to address inequalities and ensure equitable disaster preparedness and recovery.

The study by Coleman et al. (2020a) integrates contextual and community factors by examining levels of urbanisation (population density) and previous disaster experience (previous disaster declarations). It finds that metropolitan areas generally have greater access to resources, whereas rural areas tend to rely more on strong community ties for support during disruptions. Similarly, Coleman et al. (2020b) examines the impact of urbanisation on household vulnerability to infrastructure failure, emphasising that while urban areas benefit from greater institutional resources, rural areas foster stronger social cohesion, which can provide an alternative support system during crises.

Beyond socio-economic factors, political power and influence, social safety nets, and entitlement programmes for recovery also play a crucial role in determining tolerance levels (Cutter et al., 2000; G. Peacock et al., 1997). Research also mentions the importance of insurance. The level of insurance coverage an individual has can significantly reduce economic strain, provide financial support during recovery, and result in higher tolerance levels (Contento et al., 2017).

This factor is particularly relevant in the context of storm surge barrier management, where increased closures may have uneven effects across stakeholder groups. For example, sectors with limited operational flexibility or high dependency on ecological conditions, such as aquaculture, may face greater challenges in adapting to more frequent closures. Understanding the socio-economic diversity and varying degrees of dependency among affected stakeholders is essential for developing equitable and inclusive adaptation strategies.

To summarise the study by Esmalian, Dong, et al. (2021) using the "Household Service Gap Model", the ability to tolerate infrastructure disruption varies between households. Those with higher levels of preparedness, access to alternative services, and strong social support tend to have a wider zone of tolerance, making them more resilient (Murphy & Gardoni, 2007). In contrast, vulnerable groups often have fewer coping mechanisms, leading to greater hardship when disruptions occur. Understanding these determinants is essential for improving risk communication, infrastructure planning, and disaster strategies to reduce social inequalities in coping with service disruptions.

For the study by Petersen et al. (2020) on the Barreiro water network (Lisbon, Portugal), there are some limitations as the questionnaire was scenario-based. It mentions that it is difficult to generalise the results because societal tolerance consists of many variables that differ across contexts. For example,

demographic factors play a key role in determining tolerances, so the study recommends that similar research be conducted for each critical infrastructure operator (Petersen et al., 2020).

3.2.2. Integrating social and physical vulnerability

In another study by Coleman et al. (2020b), it emphasises the importance of integrating both physical infrastructure characteristics and socio-demographic factors to better understand the disparities in risk experienced by households (Figure 3.4). Similarly, Dong et al. (2020) incorporates both social and physical vulnerabilities when assessing tolerance levels. Considering both dimensions provides a more comprehensive understanding of the relationship between people and their surrounding environment, aiding decision-making for planners, government authorities, infrastructure managers, and emergency management agencies (Mayaud et al., 2018).

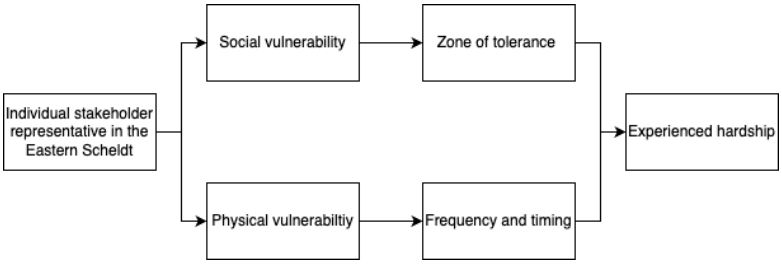

Figure 3.4: Framework linking stakeholder vulnerabilities and closure traits to disruption tolerance, adapted from Coleman et al. (2020b) for the Eastern Scheldt Barrier.

The conceptual framework in evaluates how households experience hardship during infrastructure service disruptions through three key factors:

- Zone of tolerance: the ability to withstand disruptions, shaped by social vulnerabilities. A higher tolerance reduces perceived hardship. Social vulnerability refers to factors such as income level, education, social networks.
- Extent of exposure: the duration or frequency of service disruptions a stakeholder faces, influenced by physical vulnerabilities. Longer exposure generally leads to greater hardship. Physical vulnerability relates to the exposure and resilience of the infrastructure itself.
- Experienced hardship: the primary measure of the negative impact caused by disruptions.

The framework highlights the disparities in societal risk, demonstrating that hardship is not only determined by the length of service loss but also by a stakeholders ability to cope. Socially vulnerable populations typically have lower tolerance, making them more susceptible to prolonged disruptions.

3.3. Conclusion

This chapter has shown that while the Eastern Scheldt Barrier remains technically functional, its increased use under future climate scenarios introduces a new type of vulnerability: non-technical, societal vulnerability. It shows that closures cannot be assessed solely through an engineering lens, as their frequency begins to challenge the ecological balance, economic viability and societal acceptability of the surrounding region. This insight reshapes the definition of functionality: not just whether the infrastructure works, but whether it works for the society.

The reviewed literature makes two important contributions to the main research question. First, it establishes that societal tolerance is a measurable and dynamic variable that is shaped by a wide range of contextual, infrastructural and societal factors. Second, it shows that tolerance thresholds vary across stakeholder groups and are strongly influenced by service dependency, communication practices and vulnerability characteristics. This means that tolerance is not uniform and needs to be approached with granularity.

Critically, this chapter helps to answer the first sub-question: *what is the current state of knowledge on increasing closures and societal tolerance?* By providing an overview of the ecological, economic, and societal consequences of more frequent barrier closures. It does not aim to pinpoint specific tipping

points of intolerance, as these are highly context- and stakeholder-dependent, but instead highlights the need to shift focus from technical functionality toward societal acceptability. The literature makes it clear that disruptions affect stakeholders differently depending on their vulnerability, preparedness, and access to alternatives. This chapter therefore lays the groundwork for understanding how societal tolerance can be meaningfully assessed and integrated into storm surge barrier management. The following chapter will elaborate on the interviews and its findings.

4

Interviews and findings

This chapter presents the main findings from the stakeholder interviews. Using the GIOIA method, key themes were identified to explore how different groups perceive and respond to more frequent closures of the Eastern Scheldt Barrier. The results offer insight into the factors that shape societal tolerance and its implications for future management.

4.1. Interview setup

Following the literature review, a set of semi-structured, open-ended interview questions was developed. These questions were subsequently refined in consultation with M. Nagelhout and Dr. J. Ninan and received final approval. As outlined in Section 2.3, the interviews served as the primary method for data collection. Participant selection was carried out during a meeting with the relation manager from Rijkswaterstaat, who also facilitated initial contact and communication with the identified stakeholders. This research was conducted in accordance with the approved Data Management Plan, as reviewed by the TU Delft Ethics Committee. The complete list of interview questions is provided in Appendix A. The questions are translated to English as the interviews were in Dutch.

To collect the data, interviews were conducted with the following stakeholder representatives:

Participant	Organisation	Duration
1	Fisheries, Province of Zeeland	55 min
2	Mussel Culture Producers Organisation (PO Mossel)	50 min
3	Watersport Association	15 min
4	Dutch Oyster Association (NOV)	55 min
5	HISWA-RECRON (organisation for recreation and watersports companies)	55 min
6	Preservation of Nature Monuments (Natuurmonumenten)	55 min
7	Zeeland Environmental Federation (ZMf)	1h 05 min
8	National Park Eastern Scheldt (NPO)	55 min
9	Wageningen Marine Research (WMR)	1h
10	Het zeeuwse Landschap (Environmental organisation in Zeeland)	30 min
11	Rijkswaterstaat: Asset Manager	40 min
12	Rijkswaterstaat: Asset Manager	50 min
13	Rijkswaterstaat: Asset Manager	60 min
14	Rijkswaterstaat: Asset Manager	45 min
15	Rijkswaterstaat: Asset Manager	30 min

Table 4.1: Overview of interview participants and duration

4.2. Stakeholder perspectives on the Eastern Scheldt Barrier

This chapter presents the findings from the stakeholder interviews conducted for this study. The quotes and accompanying context illustrate the diverse perspectives surrounding the Eastern Scheldt Barrier, its increasing closure frequency, and the broader ecological, economic, and societal consequences.

4.2.1 Historical perspective and changing awareness

Since its completion in 1986, the Eastern Scheldt Barrier has played a crucial role in protecting the hinterland from flooding, while maintaining a tidal exchange which is vital for the estuarine ecosystem. In the first five years of its operation, the barrier closed based on a threshold of +2.75 m above NAP, as part of an evaluation phase (1987-1992) supported by the Barrier Control research project in 1986-1987 (BARCON). This extensive study aimed to assess and optimise the barrier's closure regime. As a result of these early experiences, the threshold was formally adjusted to +3.00 m above NAP in 1992.

The Eastern Scheldt Barrier has closed 27 times since its completion in 1986, including seven closures in 1990 alone. However, historical awareness among stakeholders appears to have been limited. Stakeholders who were ecologically and economically active in the Eastern Scheldt admitted to being unaware of these past closure frequencies, suggesting a societal memory gap regarding the earlier barrier closures and their effects. While today every closure draws considerable media attention and public debate, in the early years closures largely passed unnoticed. One respondent reflected on this shift in perception:

"Well, I think I would start getting a bit irritated if, say, in the next storm season the barrier has to close three or four times and the newspapers will go full of dramatic headlines claiming everything is going wrong. Back in 1990 it closed seven times, and no one even talked about it." (Participant 12, Question 6b)

Other respondents also elaborated on the fact that, if the barrier closes, there is a "call-list" of people that must be called, to let them now the barrier is going to close.

This comparison not only shows how societal sensitivities have changed over time, but also highlights how media and communication have become increasingly important in shaping public opinion. Stakeholders emphasised that after 1992, decisions to close the barrier were made strictly according to legal regulations, showing that flood protection remained the top institutional priority.

"Water safety is written into law and exists for the benefit of the people. It is our duty and responsibility to uphold it." (Participant 12, Question 7b)

When stakeholders were specifically asked about their recollections of the 1990 closures, many expressed genuine surprise at the number of events and the apparent lack of public concern at the time. For instance:

"Quite interesting that you tell me that the barrier closed 7 times in 1990. I have never heard anybody complaining about this." (Participant 7, Question 6b)

and

"I have been a mussel breeder in those years and even now I never heard somebody talking about the 7 closures in 1990." (Participant 4, Question 6b)

These remarks were further reinforced by reflections from stakeholders active in more recent years:

"Stories about major problems usually stick with people. But in the past ten years, since taking this position, I haven't heard anyone mention that the barrier closed so often in 1990, or that it caused specific issues back then." (Participant 2, Question 6b)

The broader implication of these reflections is that, historically, societal tolerance for closures may have been higher, or perhaps, more realistically, that the closures were less visible to the public. Changes in communication methods, increased media coverage, and new bureaucratic requirements appear to have amplified the public's sensitivity to closures today. As one stakeholder noted:

"The problem now is, if you want to do something, you need to write so much. In the past you were just able to do things." (Participant 4, Question 6a)

Another stakeholder reinforced that even if closures did occur, they were largely operational events without significant disruption to daily life or business:

"I do not know if in the past it was communicated to us when the barrier closed. But in any case, I do not recall that it impacted me because my production levels were not affected" (Participant 4, Question 6a & 9a)

Thus, the historical perspective shows that while the barrier's role in flood safety has remained unchanged, societal perception and expectations regarding its functioning have evolved over time. Today, even a few closures can or may trigger public anxiety, whereas in the early years, a much higher frequency was largely absorbed without major societal reaction. These reflections indicate that closure events historically operated under a general societal ignorance and minimal visibility, with little awareness or discussion among stakeholders and the broader public.

4.2.2 Stakeholder sentiments on the current functioning of the barrier

Despite changes in public attention and expectations over time, the majority of stakeholders interviewed expressed continued appreciation for the Eastern Scheldt Barrier's role in flood protection. Its strategic importance for safeguarding the Dutch hinterland remains largely undisputed, even as its ecological side-effects and future viability are increasingly questioned.

Several stakeholders emphasised the necessity of the barrier, pointing to the fact that, even with emerging challenges, no better alternative has yet been found:

"I still believe the Eastern Scheldt Barrier is the next best solution. I don't see a better alternative for the Scheldt region. Above all, safety remains the top priority, the safety of the population always comes first." (Participant 7, Question 2a & 2b)

and

"I still notice that the principle of 'safety comes first' is deeply rooted—especially among the people of Zeeland. Other issues matter too, but safety is non-negotiable. That's a strong sentiment here, and it plays a major role in how people view these decisions: we shouldn't take risks with our safety." (Participant 8, Question 2a & 2b)

Yet, even among those supportive of the barrier, there was recognition that it is not without its drawbacks. Some respondents highlighted that maintaining the delicate balance between safety, ecology, and economy involves inevitable trade-off:

"Of course, it affects the daily situation, that's the price you pay. But I still believe a beautiful Eastern Scheldt environment remains. There are certainly some drawbacks, but in my view, the benefits outweigh the disadvantages." (Participant 12, Question 2a & 2b)

and,

"The barrier not only provides safety, but also certain ecological benefits—some of which we may not even fully understand yet. So, alongside the drawbacks, there are definitely advantages too." (Participant 8, Question 2e)

Interestingly, despite concerns over future impacts, several interviewees stressed that the direct operational impact of the barrier closures remains limited today, especially in sectors like aquaculture. For many stakeholders, the barrier's infrequent closures (only during extreme conditions) mean that its day-to-day influence is minimal compared to broader water management strategies like the Delta Plan:

"At this moment, the barrier has no real impact on us. The broader Delta Plan is more relevant—we'd like to see more freshwater in the Eastern Scheldt. But as for the barrier itself, I can't say it has had a positive or negative impact on the oyster sector, since it only closes a few hours a year." (Participant 4, Question 2a)

However, stakeholders are increasingly forward-looking. Some expressed serious concern about the financial and technical sustainability of the barrier in the long term. Visible signs of ageing infrastructure, rising maintenance costs, and broader ecological shifts were cited as reasons to start questioning whether the current system will remain fit for purpose:

"The barrier will not survive another 50 years. Whenever I pass by on my bike, I notice that maintenance work is constantly being carried out. I don't even want to imagine how much it costs, probably a fortune, year after year. Personally, I would prefer to create a dune area in the Voordelta as a buffer." (Participant 4, Question 9b)

Other respondents were even more radical, suggesting that future planning should at least consider the possibility of removing the barrier altogether, although they acknowledged that such an idea would require extensive preparation and societal debate:

"Could removing the barrier be an option? I find the idea fascinating. I work closely with researchers who argue that, in theory, the barrier could be removed. It sounds shocking at first, but if you explore what that would mean for our inland systems, it might actually be manageable. Given the ecological issues in the Delta, it's not such a far-fetched idea. I'm not saying it should be removed tomorrow, but it's a conversation worth having, so we can mentally prepare and explore how we might redesign our landscape, especially considering the growing negative effects we see today." (Participant 7, Question 9b)

Thus, while immediate operational satisfaction with the barrier remains high, a clear concern has emerged among stakeholders about how to ensure future-proof protection of Zeeland in a changing climate and shifting ecological landscape.

4.2.3 Temporal dimension: Short term pressures vs long term risks

Throughout the interviews, a striking contrast emerged between the short-term concerns that currently preoccupy stakeholders and the long-term systemic risks associated with more frequent closures of the Eastern Scheldt Barrier. While long-term planning is recognised as important, most immediate worries revolve around short-term pressures affecting livelihoods, ecosystems, and operational certainty. Although stakeholders acknowledged broader systemic risks, such as ecosystem decline and sea-level rise, the interviews revealed that attention remains heavily skewed toward more immediate challenges. This persistent short-term focus appears to be rooted in a limited societal awareness of long-term risks and the gradual nature of environmental change.

Short-term pressures

In conversations surrounding financial setbacks within the aquaculture sector, stakeholders highlighted their economic vulnerability. Mussel farmers, for example, are entirely self-reliant, without public financial safety nets to cushion years of poor harvests or price fluctuations:

"We are completely financially independent—there's no safety net. Mussel farmers are used to fluctuating yields, both in price and volume, depending on the year." (Participant 2, Question 1h)

Similarly, multiple participants stressed that today's Ecological stressors, such as sand starvation, steel slag deposits, and oyster diseases, poses far more immediate and tangible challenges than the prospect of more frequent barrier closures:

"We're currently more concerned with short-term threats like sand suppletion and steel slag, it is bad for our reputation. These are more immediate worries than the closures." (Participant 2, Question 2d)

One aquaculture sector representative elaborated on the variety of pressing environmental threats. Issues like unexplained species mortality, viral outbreaks, and deteriorating water conditions in key production areas are causing severe economic distress:

"In the mussel sector, we've experienced significant mortality, but the cause is still unknown. The lobster and oyster sectors are also struggling, particularly with two major plagues: oyster herpes virus and the oyster drill, which have caused losses of 70–80% on some plots. The oyster sector is further impacted by the extremely poor farming conditions in the Grevelingenmeer, their second main production area alongside the Eastern Scheldt. Conditions there are now so bad that no oyster production is possible any more. Meanwhile, the shrimp and cutter fisheries face spatial constraints. Shrimp fisheries are also under pressure due to nitrogen emissions, although there's some optimism thanks to a proposed 20-year permit by the state secretary." (Participant 1, Question 2d)

Recognising these short issues, stakeholders are happy with initiatives like the ongoing multi-stakeholder

research project led by Wageningen Marine Research. They expressed hope that scientific insights will soon lead to concrete, future-proof interventions:

"Agriculture, fisheries, and nature organisations are all involved, and Wageningen Marine Research is leading the effort. Over the next four years, they will investigate the causes behind the high mortality rates among mussels and lobsters (one million euro fund). I really hope something will come out of this research so we can take the necessary steps." (Participant 1, Question 1h & 5b)

Another concern was the limited capacity for adaptation when barrier closures do happen. Mussel farmers and aquaculture producers explained that closures are often decided only a few hours in advance, leaving almost no time to prepare or mitigate the impacts:

"I really wouldn't know what to do, apart from calling Rijkswaterstaat every half an hour to open the gates. That's all you can do. If there's no water renewal, you can't just place a few buckets onshore and throw them in the water. What else can you do?" (Participant 4, Question 3a & 3b & 7e)

Long-term risks and future thinking

One of the most recurrent long-term concerns raised was sand starvation, an ongoing process where intertidal flats subside due to insufficient sediment supply, threatening biodiversity, shellfish habitats, and the broader ecological sustainability of the Delta region. To counteract this subsidence, Rijkswaterstaat plans to apply sand suppletion in selected intertidal areas, aiming to stabilise the system and preserve its ecological functions.

"Yes, the negative effects have become increasingly visible in recent years. Take sand starvation, for example, that doesn't only apply to the Eastern Scheldt Barrier, but to all Delta Works." (Participant 5, Question 9a)

On a more strategic level, stakeholders acknowledged the slow but inevitable pressure of sea-level rise. One interviewee noted that its gradual nature still offers time for adaptive planning, if action is taken early:

"The good thing about sea-level rise is that it doesn't happen overnight, it's gradual. So we can plan ahead. With the current closure regime, we might still manage for another 20 years." (Participant 12, Question 3a)

However, when asked how frequent closures would need to become before societal tolerance might be breached, responses varied. While some participants offered concrete estimates, others admitted they had never reflected on it:

"If I had to give a ballpark estimate, I'd say maybe 20 to 30 closures per year." (Participant 7, Question 7a)

and,

"Yes, that's a good one—it's a difficult question. I saw it coming, but it's not an easy one to answer." (Participant 1, Question 7a)

Some stakeholders took this thinking a step further, reflecting on the need for long-term vision and structural adaptation. This included speculation about the possible removal or redesign of the barrier:

"A decision has to be made soon about the future of the barrier, especially with sea-level rise. I can even imagine a scenario where the barrier is removed—something I think could actually work." (Participant 7, Question 9b)

Others warned that without a clear and timely roadmap, more sustainable options may no longer be feasible:

"Especially in the long term—we believe far too little attention is currently being paid to future risks. Our concern is that if decisions are postponed, society will default to technical solutions under time pressure, whereas nature-based alternatives require decades to develop. Without early planning, the opportunity for these slower, but more sustainable, solutions may be lost."(Participant 6, Question 2c)

and,

"It would be helpful to view barrier closures as part of a long-term sea-level rise strategy. If there's a clear vision—say for 2150—and no major changes planned before 2075, then we can align our expectations. That clarity would help nature organisations understand the steps being taken and suggest appropriate countermeasures when needed." (Participant 6, Question, 9b)

Yet others, particularly from a technical background, noted that long-term planning remains difficult due to systemic uncertainty:

"It's difficult to say how they can prepare or what the conditions are going to be, because there's so much uncertainty about how the system will evolve." (Participant 11, Question 3a & 3b)

These reflections show a clear contrast: some stakeholders are already thinking in long-term scenarios, while others feel limited by the uncertainty surrounding future developments. Although not everyone agrees on what action is needed now, most recognise that future decisions will become more difficult if planning is delayed. Without a shared long-term vision, it may become harder to maintain societal tolerance, leaving decision-makers with fewer viable options down the line.

4.2.4 Ecosystem sensitivities and biodiversity concerns

Beyond the direct economic impacts, many stakeholders voiced concerns about how the increasing frequency of barrier closures could exacerbate vulnerabilities in the ecosystem of the Eastern Scheldt. The intricate relationship between tidal patterns, ecosystem health, and biodiversity was a recurring theme throughout the interviews.

One area of concern raised was the ecological role of the tides. Tidal dynamics provide essential habitat and feeding conditions for numerous species. Disruptions to this natural rhythm, through closures that limit tidal exchange, could destabilise critical ecological processes:

"The tide serves different functions—high tide is important for some species, while low tide benefits others. And then there's the question of water safety: how does this affect the safety of the dikes?" (Participant 9, Question 2b & 2c)

Seasonal vulnerabilities were also highlighted. During the summer, extreme heat in combination with limited tidal flow could increase mortality among bottom-dwelling animals. In the winter, bird populations become particularly dependent on accessible intertidal areas for foraging:

"In summer, it becomes too warm for bottom-dwelling animals, which can lead to mortality. In winter, birds are more at risk since most of them are present then and rely on the intertidal area to forage." (Participant 9, Question 2c & 2d)

and,

"Three closure days of the barrier throughout the year. Birds are more vulnerable during winter due to lower temperatures and higher population density, while the breeding season is also a sensitive period, as their need for food increases. As for benthic organisms, their sensitivity depends on both species and location. In general, species living in sandy areas are more vulnerable than those in silty environments." (Participant 9, Question 7a & 7b & 7c)

Moreover, while some resilience exists within ecosystems allowing certain species to withstand occasional disruptions, prolonged or repeated closures were identified as a significant ecological threat:

"Birds might be able to skip a tide once in a while, but not too often. Bottom-dwelling animals, especially shellfish, can handle drying out briefly, but not for too long. Maybe we can interactively manage the barrier to account for this." (Participant 9, Question 7a & 7b & 7c)

However, stakeholders also recognised the logistical and biological challenges of directly mitigating ecological impacts on a large scale. Given the scale of the Eastern Scheldt system, direct interventions such as supplemental feeding of birds or artificial habitat restoration were viewed with scepticism:

"We're dealing with huge surface areas here, so helping the birds directly like feeding them isn't realistic. Maybe we can be more flexible with how we manage the barrier, but I'm not sure it can really be mitigated." (Participant 9, Question 3a & 4a)

This nuanced view recognising both the need for more adaptive barrier management and the limitations of intervention reflects a growing awareness among stakeholders of the delicate ecological balance that the Eastern Scheldt system depends upon.

4.2.5 Governance, trust and collaboration dynamics

Stakeholders' perspectives on governance and institutional relationships revealed a mixture of trust, scepticism, and calls for more proactive collaboration regarding the future management of the Eastern Scheldt Barrier.

On a positive note, many respondents expressed confidence in Rijkswaterstaat proactive engagement practices. Past experience had shown that when major changes were expected, Rijkswaterstaat actively initiated stakeholder dialogues to gather input and assess societal acceptance:

"I can imagine that if closures become more frequent, Rijkswaterstaat will likely initiate a series of stakeholder consultations—asking how we experience it and what our thoughts are. If they continue being as proactive as I know them to be, it will naturally appear on their radar. And if not, I'll be the one to ring the bell to make sure it does." (Participant 7, Question 8a)

Nonetheless, several participants voiced frustration with broader government decision-making processes. They described a bureaucratic environment where civil servants, insulated from operational or commercial risks, often delayed crucial decisions:

"In general, civil servants don't like to make decisions. Even those in higher positions often avoid responsibility. It's easy to clock out at 4 p.m. without making tough calls, but that's not how things work in business, we need to make decisions." (Participant 4, Question 8c)

Participants also noted that, while platforms for stakeholder input exist, their influence on final policy outcomes can be limited. Stakeholder arguments are often filtered and weighted differently depending on broader political or institutional priorities:

"Yes, we can give input, but it doesn't mean they act on it. Arguments are weighed differently based on interests. Everyone evaluates things based on what fits their agenda." (Participant 2, Question 8d)

Nevertheless, good practices around maintenance and transparent communication were appreciated by many stakeholders. Particularly, the structured and early communication regarding maintenance schedules by Rijkswaterstaat helped local stakeholders to better plan their activities and disseminate the message to the customers in the summer:

"He's a great guy because, even when delivering bad news, he does it well and on time. That's why regular maintenance is so important—it gives us a preview of what's coming 18 months down the line." (Participant 5, Question 8a)

Flexibility and a pragmatic attitude were often emphasised as critical factors for successful collaboration, especially when disruptions such as summer maintenance on recreational waterways, required temporary sacrifices:

"The great thing is that we always aim for the optimal solution. Sometimes we have to acknowledge that it doesn't exist, so we settle for the second or third best—but always through good coordination and alignment." (Participant 5, Question 8e)

Overall, while there are some tensions and criticisms, there remains a strong foundation of trust in the technical expertise and engagement capabilities of Rijkswaterstaat. Stakeholders widely recognised that adaptive, transparent, and inclusive management will be crucial as closures potentially increase in the future.

4.2.6 Local identity, community and reflection

Beyond environmental and economic concerns, the interviews revealed a strong attachment to the Eastern Scheldt as a living landscape deeply intertwined with local identity, family businesses, and traditional livelihoods. Several stakeholders described the close social fabric of the aquaculture and coastal sectors in Zeeland.

"Everyone knows each other, since we all come from the same small towns and background. But on the other hand there's also a kind of informal oversight because everything happens in the open. People do keep an eye on each other." (Participant 2, Question 5a)

A key characteristic of the aquaculture sector in the Eastern Scheldt is its deeply rooted family structure. Many mussel and oyster businesses are family-owned and have been passed down over three, four, or even five generations. However, the sector faces mounting pressures, both financial and demographic, that increasingly challenge this continuity:

"Officially, there are 89 companies with permits, each a separate legal entity. But the actual number of owners is probably around 35 to 40. Most are family businesses, often passed down through three, four, or even five generations. But when a company cannot pass the business on to the next generation (their children have less or no interest) or has financial issues and the bank would not lent them, another company (already active in the Eastern Scheldt) is likely to buy it." (Participant 2, Question 5a)

The local economy and community cohesion are therefore highly sensitive not only to environmental changes but also to subtle shifts in sector viability and succession opportunities.

Some respondents also reflected thoughtfully on the process of participating in the interviews themselves. Several mentioned how the dialogue helped them think more consciously about future challenges and highlighted the value of structured societal reflection. The interviews themselves served as a catalyst for raising stakeholder awareness, demonstrating how structured dialogue can help overcome habitual ignorance and improve a more proactive mindset towards future uncertainties.

"This conversation helps me better prepare for the 'what-if' scenarios. Maybe it's even worth researching the potential impacts more thoroughly, let's map it out!" (Participant 7, Question 3a & 3b)

In addition, the participant shared that they had recently contributed to an independent journal, encouraging a broader perspective on the Eastern Scheldt future. Next time the respondent would like to incorporate this new knowledge in order to gather new perspectives from others.

However, the vulnerability of traditional livelihoods was made starkly clear when stakeholders spoke about the drastic economic downturns they had faced, particularly in the mussel sector. Fluctuating yields, increasingly harsh environmental conditions, and shrinking margins were recurrent themes:

"Well, back when I was active in the sector, there was money to be made—real profits. But now, honestly, it's like working with mushy wood. Especially last year, the mussel industry was hit hard. I've never seen anything like it. Back then, we used to produce between 800,000 and over 1 million kilos of mussels, and now it's down to just 200,000." (Participant 4, Question 6a)

This reflection on past and present hardships underscored a broader sentiment: reliance on nature remains absolute, and small changes in environmental or regulatory conditions can have cascading effects.

"Yes, it's simply nature, you're 200% dependent on it." (Participant 4, Question 3a & 3b)

and,

"A mussel farmer is limited in his options —the animals are underwater and rely entirely on natural food passing through the water. There are no antibiotics, no feed, no pesticides—nothing at all." (Participant 2, Question 3b & 3d)

The interviews revealed growing anxiety over the sectors future that is shaped by environmental volatility, and demographic shifts.

4.3. Overview of Instances

Tables 4.2 to 4.4 provide an overview of all findings and examples drawn from the interviews. The results are organised by aggregate dimension, with each dimension further structured into second-order themes, following the GIOIA methodology outlined in Chapter 2.

Table 4.2: Quotes related to the aggregated dimension *Perception of increased closures* 1

Aggregated dimension: Perception of increased closures		
#	**1st Order Quote**	**2nd Order Theme**
1	The problem now is, if you want to do something, you need to write so much. In the past you were just able to do things.	Barrier function
2	Of course, it affects the daily situation, that's the price you pay. But I still believe a beautiful Eastern Scheldt environment remains. There are certainly some drawbacks, but in my view, the benefits outweigh the disadvantages.	Barrier function
3	The barrier not only provides safety, but also certain ecological benefits—some of which we may not even fully understand yet. So, alongside the drawbacks, there are definitely advantages too.	Barrier function
4	The barrier will not survive another 50 years. [...] I would prefer to create a dune area in the Voordelta as a buffer.	Barrier function
5	In the mussel sector, we've experienced significant mortality, [...] two major plagues: oyster herpes virus and the oyster drill.	Ecological sensitivity
6	Officially, there are 89 companies with permits, [...] actual number of owners is probably around 35 to 40.	Ecological sensitivity
7	Back when I was active in the sector, [...] now it's down to just 200,000.	Ecological sensitivity
8	Yes, it's simply nature, you're 200% dependent on it.	Ecological sensitivity
9	A mussel farmer is limited in his options [...] There are no antibiotics, no feed, no pesticides—nothing at all.	Ecological sensitivity
10	The negative effects have become increasingly visible in recent years. Take sand starvation [...]	Ecological sensitivity
11	We're currently more concerned with short-term threats like sand suppletion and steel slag [...]	Ecological stressors
12	Agriculture, fisheries, and nature organisations [...] investigating the causes behind the high mortality rates [...]	Ecological stressors
13	Everyone knows each other [...] informal oversight because everything happens in the open.	Ecological stressors
14	This conversation helps me better prepare for the 'what-if' scenarios. [...]	Ecological stressors
15	We're dealing with huge surface areas [...] I'm not sure it can really be mitigated.	Ecological stressors
16	I would start getting a bit irritated if the barrier has to close 3–4 times [...] back in 1990 it closed seven times [...]	Historical perception & memory
17	Water safety is written into law [...] It is our duty and responsibility to uphold it.	Historical perception & memory
18	Quite interesting that you tell me the barrier closed 7 times in 1990 [...]	Historical perception & memory
19	I have been a mussel breeder [...] I never heard somebody talking about the 7 closures in 1990.	Historical perception & memory
20	Stories about major problems usually stick with people [...] no one ever mentioned the closures.	Historical perception & memory

Table 4.3: Quotes related to the aggregated dimension *Perception of increased closures* 2

Aggregated dimension: Perception of increased closures		
#	**1st Order Quote**	**2nd Order Theme**
21	I do not know if in the past it was communicated [...] but my production levels were not affected.	Historical perception & memory
22	If I had to give a ballpark estimate, I'd say maybe 20 to 30 closures per year.	Historical perception & memory
23	Yes, that's a good one—it's a difficult question. I saw it coming [...]	Historical perception & memory
24	I still believe the Eastern Scheldt Barrier is the next best solution [...] safety remains the top priority.	Risk awareness
25	Safety comes first is deeply rooted—especially among the people of Zeeland [...]	Risk awareness
26	At this moment, the barrier has no real impact on us [...] the broader Delta Plan is more relevant.	Risk awareness
27	Could removing the barrier be an option? [...] not such a far-fetched idea.	Risk awareness

Table 4.4: Quotes related to the aggregated dimension *KPI for assessing societal tolerance*

Aggregated dimension: KPI for assessing societal tolerance		
#	**1st Order Quote**	**2nd Order Theme**
1	I really wouldn't know what to do, apart from calling Rijkswaterstaat every half an hour to open the gates. That's all you can do. If there's no water renewal, you can't just place a few buckets onshore and throw them in the water. What else can you do?	Adaptation & preparedness
2	The good thing about sea-level rise is that it doesn't happen overnight, it's gradual. So we can plan ahead. With the current closure regime, we might still manage for another 20 years.	Adaptation & preparedness
3	In general, civil servants don't like to make decisions. Even those in higher positions often avoid responsibility. It's easy to clock out at 4 p.m. without making tough calls, but that's not how things work in business, we need to make decisions.	Adaptation & preparedness
4	We are completely financially independent—there's no safety net. Mussel farmers are used to fluctuating yields, both in price and volume, depending on the year.	Economic resilience & risk
5	Yes, we can give input, but it doesn't mean they act on it. Arguments are weighed differently based on interests. Everyone evaluates things based on what fits their agenda.	Economic resilience & risk
6	He's a great guy because, even when delivering bad news, he does it well and on time. That's why regular maintenance is so important—it gives us a preview of what's coming 18 months down the line.	Economic resilience & risk
7	The great thing is that we always aim for the optimal solution. Sometimes we have to acknowledge that it doesn't exist, so we settle for the second or third best—but always through good coordination and alignment.	Economic resilience & risk

Table 4.5: Quotes related to the aggregated dimension *Strategies for integrating societal tolerance into SSB management*

Aggregated dimension: Strategies for integrating societal tolerance into SSB management		
#	**1st Order Quote**	**2nd Order Theme**
1	The tide serves different functions—high tide is important for some species, while low tide benefits others. And then there's the question of water safety: how does this affect the safety of the dikes?	Barrier function
2	In summer, it becomes too warm for bottom-dwelling animals, which can lead to mortality. In winter, birds are more at risk since most of them are present then and rely on the intertidal area to forage.	Barrier function
3	Three closure days of the barrier throughout the year. Birds are more vulnerable during winter due to lower temperatures and higher population density, while the breeding season is also a sensitive period, as their need for food increases. [...]	Barrier function
4	It would be helpful to view barrier closures as part of a long-term sea-level rise strategy. If there's a clear vision—say for 2150—and no major changes planned before 2075, then we can align our expectations. That clarity would help nature organisations understand the steps being taken and suggest appropriate countermeasures when needed.	Long-term visioning
5	A decision has to be made soon about the future of the barrier, especially with sea-level rise. I can even imagine a scenario where the barrier is removed—something I think could actually work.	Long-term visioning
6	Especially in the long term—we believe far too little attention is currently being paid to future risks. Our concern is that if decisions are postponed, society will default to technical solutions...	Long-term visioning
7	It's difficult to say how they can prepare or what the conditions are going to be, because there's so much uncertainty about how the system will evolve.	Stakeholder dynamics
8	Birds might be able to skip a tide once in a while, but not too often. Bottom-dwelling animals, especially shellfish, can handle drying out briefly, but not for too long. Maybe we can interactively manage the barrier to account for this.	Stakeholder dynamics
9	I can imagine that if closures become more frequent, Rijkswaterstaat will likely initiate a series of stakeholder consultations—asking how we experience it and what our thoughts are. [...]	Stakeholder dynamics

5

Theoretical development

This chapter introduces a conceptual framework that translates the empirical findings into a structured approach for assessing and managing societal tolerance. It adapts the Social Licence to Operate (SLO) model to the context of the Eastern Scheldt Barrier, providing a practical tool for governance and policy.

5.1. Framework development

Figure 5.1 illustrates a causal structure based on five linkages (L1–L5), tracing the pathway from increased closures of the Eastern Scheldt Barrier to shifts in societal tolerance and the strategic responses required to manage these shifts. The framework addresses the dual challenge faced by Rijkswaterstaat: minimising the physical, ecological, and economic impacts of closures ("know it"), and managing how these impacts are understood and experienced by stakeholders ("feel it"). However, the goal is not to maximise perception or emotional response. Instead, the framework aims to increase risk awareness, defined as the informed ability of stakeholders to recognise, contextualise, and respond to closure-related disruptions. This distinction is important: while perception may include emotional, inaccurate, or reactive responses, awareness supports preparedness, trust, and institutional legitimacy. In the context of Figure 5.1, this distinction is particularly relevant in linkages L2 and L3, where the aim is to translate disruption into constructive awareness, not merely visibility or public concern.

While grounded in the Eastern Scheldt context, the framework is designed to be modular and adaptive, making it applicable to other critical infrastructure systems where public acceptance is vital. It captures concrete disruptions, such as biodiversity loss or economic damage, and more diffuse indicators of awareness, including media sentiment, public trust and political pressure. This integrated approach enables decision-makers to detect early warning signs and intervene before tolerance thresholds are breached. Importantly, the framework incorporates feedback loops to enable iterative learning and dynamic adjustment, supporting reactive management and proactive governance based on stakeholder engagement and transparent communication.

By linking technical operations to the social dynamics of legitimacy and acceptance, the framework addresses a significant shortcoming in infrastructure governance. It provides Rijkswaterstaat with the means to anticipate resistance, communicate trade-off more clearly and develop closure regimes that are socially inclusive. By integrating impact minimisation with awareness building, the framework fosters a more comprehensive, flexible and socially grounded approach to storm surge barrier governance. Crucially, it also recognises that if societal tolerance drops below a critical threshold, a tipping point may be reached beyond which trust erodes, stakeholder cooperation breaks down and institutional legitimacy falters, potentially resulting in societal collapse in the affected region.

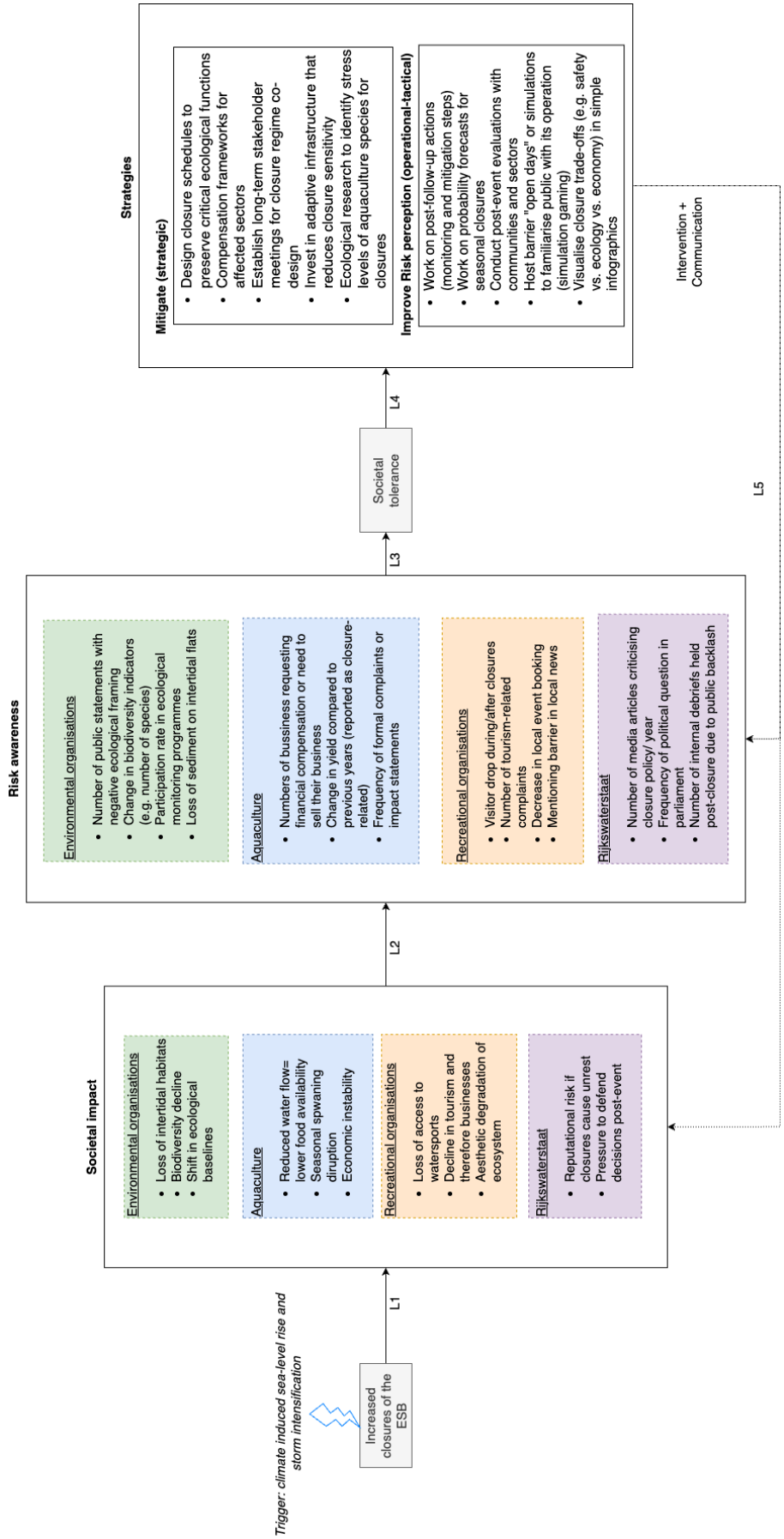

Figure 5.1: Framework linking societal impact, risk awareness, and tolerance strategies for Eastern Scheldt closures

The five linkages (L1–L5) are elaborated below. Each one represents a step in the causal chain from operational disruption to societal response. Ultimately, they guide how Rijkswaterstaat can intervene to maintain or restore societal tolerance.

- L1: represents the connection between climate-induced increases in Eastern Scheldt Barrier closures and stakeholder-specific disruptions. Drawing on Yang et al. (2021), the framework expands this by linking disruption in Eastern Scheldt Barrier operations to sector specific domains, ecological (e.g., biodiversity loss), economic (e.g., yield decline), recreational (e.g., reduced tourism access), and governance related (e.g., reputational risks). This offers a contextualised application of broader disruption theory to the specific socio-environmental dynamics of the Eastern Scheldt.
- L2: captures the translation of societal impact into stakeholder risk awareness. Following Coleman et al. (2020b), who highlights the need to integrate infrastructure conditions with socio-demographic vulnerability, this framework operationalises risk awareness using measurable proxies such as formal complaints, loss estimates, biodiversity indicators, and media sentiment. Communication plays a key role at this stage by determining whether and how stakeholders become aware of the disruption. Poor or delayed communication may suppress early warning signals, while effective communication can enable informed responses.
- L3: links elevated risk awareness to declining societal tolerance. Tolerance is framed here as a dynamic and context-dependent threshold (Esmalian, Dong, et al., 2021). By proposing behavioural indicators, such as stakeholder disengagement, protest, or increased demands, the framework makes societal tolerance empirically accessible, moving beyond abstract attitudinal models.
- L4: defines societal tolerance as an actionable decision point. When tolerance erodes, interventions must be triggered. These may be strategic (e.g., long-term ecological investment) or operational-tactical (e.g., improved communication or early-warning systems). Crucially, this part of the framework reinforces that effective adaptation must not only reduce impact but also manage its awareness, through targeted, tiered responses. Communication at this stage can prevent escalation by providing clarity, justification, and reassurance.
- L5: closes the feedback loop. It acknowledges that even when appropriate interventions are designed (e.g., ecological compensation, schedule adjustments), their effectiveness depends on how they are communicated and understood by stakeholders. At this stage, communication becomes a separate, strategic activity: not only informing, but rebuilding trust, clarifying intent, and aligning expectations. While interventions address the substance of stakeholder concerns, communication addresses the perception and legitimacy of those actions. L5 therefore highlights the importance of treating communication and intervention as parallel, equally necessary responses for working together to restore societal tolerance and reinforce institutional credibility.

To illustrate its practical application, each linkage *(L1–L5)* can be anchored in real-world examples. For instance, *L1* may involve disruption to the mussel spawning period due to increased closures. *L2* could then manifest as heightened media coverage and stakeholder complaints. *L3* may be evidenced by protests or formal objections submitted to Rijkswaterstaat. *L4* could trigger operational adjustments such as altered closure timings or ecological compensation in response to the decline in tolerance. Finally, *L5* highlights the importance of clearly communicating these decisions to rebuild understanding and legitimacy. Incorporating such real-life examples into the framework improves its usefulness for planning and stakeholder engagement.

Taken together, the framework enables Rijkswaterstaat to respond more effectively to increased barrier closures and lays the foundation for infrastructure governance that is more anticipatory, participatory and socially robust.

5.2. Theoretical framework: social licence to operate

The concept of the Social Licence to Operate (SLO) refers to the ongoing, informal acceptance or approval of a project by its stakeholders, especially those directly or indirectly affected by its impacts. Unlike formal legal licences granted by government authorities, the SLO is dynamic, socially constructed, and rooted in perceptions of legitimacy, credibility, and trust (Thomson & Boutilier, 2011). Originating

in the extractive industries, the concept has increasingly been applied across sectors where land use, environmental trade-off, or societal risks are involved.

SLO is best conceptualised as a continuum of acceptance, ranging from withdrawal or rejection (low SLO) to psychological identification or co-ownership (strong SLO). These levels are structured as a cumulative hierarchy, often visualised as a pyramid, where crossing each level requires meeting a specific social boundary condition. The key boundary conditions are (Roche & Bice, 2013; Thomson & Boutilier, 2011):

- Knowledge boundary (contribution of this thesis): a foundational precondition for engagement is that stakeholders are aware of the project, understand its implications, and perceive it as relevant to their interests. If this awareness is absent, legitimacy judgments cannot form. This study introduces the concept of ignorance metrics, such as information access, perceived relevance, and understanding of ecological or policy impacts, as indicators of whether this boundary has been crossed.
- Legitimacy boundary: stakeholders must perceive the project as operating within acceptable societal norms, laws, and values. Projects seen as unjust or incompatible with local realities are likely to face opposition.
- Credibility boundary: credibility reflects consistency and transparency. When stakeholders believe the project proponents say what they do and do what they say, the SLO can shift from passive acceptance to active endorsement.
- Trust boundary: trust develops through dialogue, reciprocity, and shared goals. Crossing this boundary is essential to move toward co-ownership and long-term collaboration.

Each boundary builds on the previous one, reflecting the cumulative nature of stakeholder perceptions of legitimacy. This progression aligns with the layered framework proposed by Thomson and Boutilier (2011), which conceptualises the SLO as a hierarchy consisting of economic legitimacy, socio-political legitimacy, interactional trust, and institutionalised trust.

As shown in Figure 5.2, the framework consists of three linked components: stakeholder perception levels (left), social tolerance assessment metrics (centre), and boundary-specific strategies (right). The left-hand pyramid visualises stakeholder positions along a spectrum of SLO, from ignorance and resistance at the base, through conditional acceptance, to trust and co-ownership at the top. Importantly, the base of the pyramid is narrower and structurally less stable, symbolising the fragility of legitimacy when foundational engagement is lacking. As SLO theory suggests, systems that do not invest in building knowledge and addressing early signals of withdrawal are more likely to face resistance, erosion of trust, or collapse in societal support. A pyramid that rests on ignorance will eventually fall.

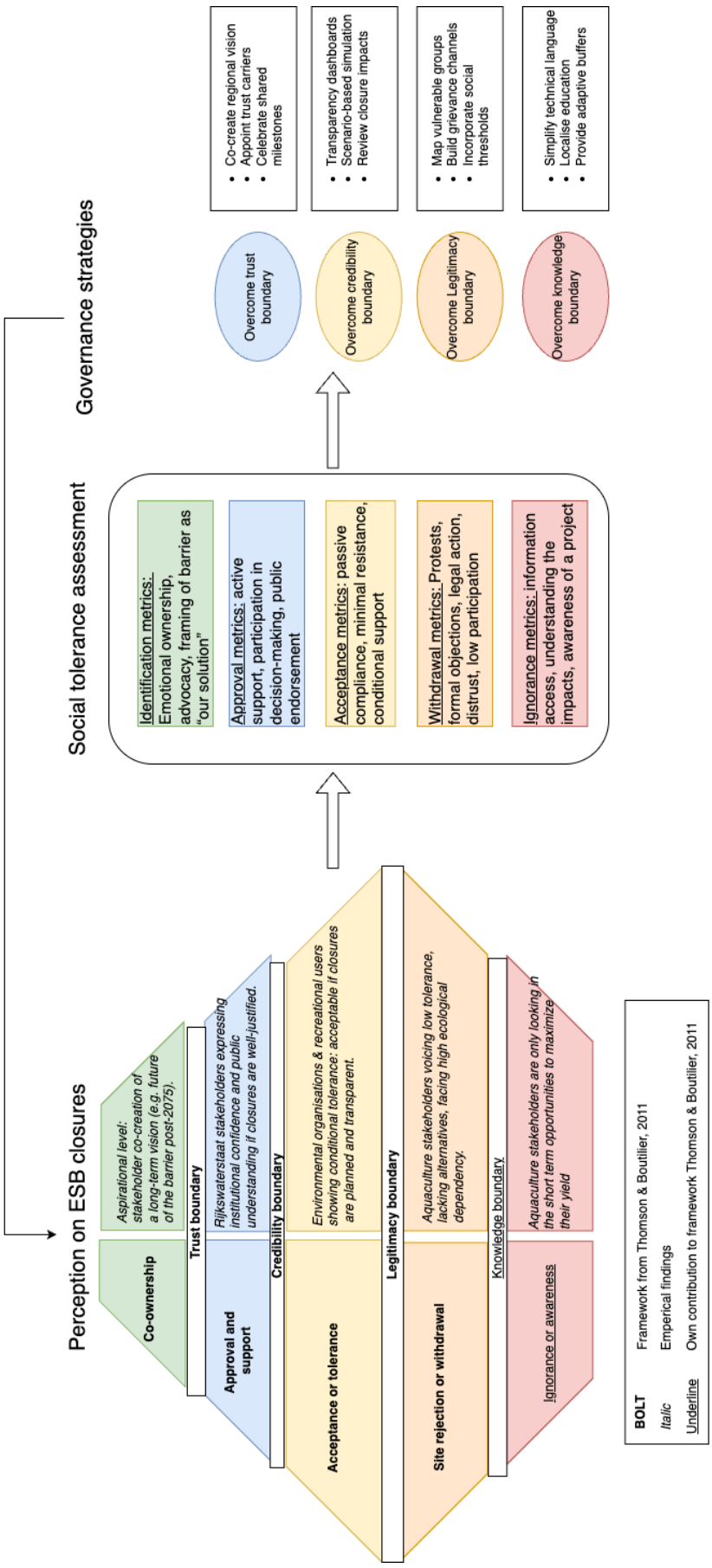

Figure 5.2: Extended SLO framework linking stakeholder tolerance levels to assessment metrics and strategies for Rijkswaterstaat.

The central column presents a corresponding set of tolerance metrics, which enable Rijkswaterstaat to assess where stakeholder groups currently stand. For example, identification metrics (e.g., emotional ownership, framing of the barrier as “our solution”) indicate strong SLO, whereas ignorance metrics (e.g., lack of awareness or impact understanding) highlight foundational engagement gaps.

The social tolerance assessment metrics were developed as an interpretative synthesis of second-order themes and aggregate dimensions identified through the GIOIA method. While the exact categories (e.g. ”identification metrics”, ”withdrawal metrics”) do not mirror the coding structure one-to-one, they reflect recurring stakeholder behaviours and perceptions, such as advocacy, distrust, or low awareness that were consistently observed across the data.

The right-hand column translates this conceptual model into practical levers. Each strategy cluster is designed to help stakeholders overcome a specific boundary:

- To overcome the knowledge boundary, Rijkswaterstaat can simplify complex closure logic using visual tools, localise public communication to make it more relatable, educate on historical closures, and offer adaptive financial support to those highly dependent on ecological flows (e.g. mussel farming).
- To overcome the legitimacy boundary, strategies include identifying vulnerable stakeholder groups early on, incorporating their constraints into the planning process and providing them with formal channels for raising concerns, thereby ensuring their meaningful inclusion.
- To address the credibility boundary, the framework suggests the use of real-time dashboards, co-evaluation of past closures, and interactive foresight methods such as scenario workshops to demonstrate transparency and commitment to learning.
- Ultimately, crossing the trust boundary necessitates closer collaboration, such as co-creating a long-term vision for the barrier, empowering esteemed community members to act as intermediaries, and celebrating shared accomplishments to foster emotional connection and confidence.

This integrated framework offers both conceptual clarity and operational relevance. It enables policymakers and infrastructure agencies such as Rijkswaterstaat to identify not only where societal resistance might emerge, but also how to respond through targeted, inclusive, and adaptive engagement strategies. In this way, it supports a more resilient and legitimate governance model in ecologically sensitive and politically complex environments.

6

Discussion, recommendations, and limitations

This chapter critically reflects on the findings of this research by linking them back to the theoretical framework introduced in Chapter 5. It does so in four parts. First, it interprets the empirical findings in light of key theoretical concepts, particularly the Social Licence to Operate and societal tolerance. Second, it evaluates the implications of these findings for infrastructure governance and stakeholder engagement. Third, it outlines practical and theoretical contributions. Finally, it concludes with recommendations for future research and a reflection on the research limitations.

6.1. Interpretation: societal tolerance in practice

Societal tolerance as a dynamic, contextual threshold

The literature (Coleman et al., 2020a; Esmalian, Dong, et al., 2021; Petersen et al., 2020) conceptualises societal tolerance as a highly context-dependent and dynamic phenomenon. It is influenced by determinants such as preparedness, perceived and actual risk, trust in authorities, the availability of alternatives, and prior exposure to disruption. These theoretical elements were clearly reflected in the findings of this study. Stakeholders from aquaculture, environmental organisations and the recreation sector revealed different tolerance thresholds that were strongly linked to the impact of closures on their work, values and capabilities.

These findings support the SLO literature by demonstrating that stakeholder acceptance is not static, but rather depends on the evolution of social and ecological conditions. In particular, aquaculture's low tolerance level aligns with the withdrawal layer of the SLO pyramid, whereas NGOs operate closer to conditional acceptance when legitimacy and long-term framing are present. This reinforces the idea that societal tolerance is uneven, shaped not only by stakeholder type, but also by sectoral resilience and institutional framing. It suggests that legitimacy in climate adaptation must be constantly re-earned in different contexts.

This raises a key question: to what extent can societal tolerance be measured and monitored in practice? Although societal tolerance is difficult to quantify directly, this study shows that it can be meaningfully assessed by breaking it down into observable, stakeholder-specific components. People may not always recognise or articulate when they are reaching a tolerance threshold, but they can describe tangible signs of stress, such as unpredictability, a lack of alternatives or perceived unfairness. This research offers a structured qualitative approach that can monitor these dimensions, paving the way for a future diagnostic tool or 'tolerance dashboard'. Rather than treating tolerance as a binary limit, this approach frames it as a dynamic, multidimensional concept that can be tracked through shifting indicators. This makes societal tolerance not only conceptually richer, but also more actionable for infrastructure governance.

Short-term urgency and the legitimacy boundary

Maslow (1943)'s hierarchy of needs suggests that basic needs must be prioritised during disruptions. This study follows a similar line of thinking, in that aquaculture stakeholders prioritised short-term ecological and economic stressors, such as disease outbreaks and starvation, over long-term planning for closure. This sense of urgency influenced their tolerance: unless immediate ecological issues are addressed, long-term strategies will lack credibility.

This reinforces the idea that the legitimacy boundary in the SLO model is not only about fairness, but also about relevance and responsiveness. When authorities fail to address urgent lived realities, legitimacy is withdrawn.

A key finding of this research is that societal tolerance becomes irrelevant if the ecological system collapses. If biodiversity and ecosystem functioning are lost, discussions about closure regimes become irrelevant. This emphasises the importance of safeguarding ecological integrity as a prerequisite for any meaningful long-term management.

Preparedness and substitutability as drivers of perceived risk

Murphy and Gardoni (2007) and Petersen et al. (2020) underscore the importance of preparedness and service substitutability. This is reflected in the structural vulnerability of the aquaculture sector: a lack of insurance, a lack of a technical substitute for tidal flow and limited economic resilience. As one respondent noted, when the barrier closes, 'there's nothing we can do but wait it out'.

This confirms the link between low substitutability and low societal tolerance. At the same time, however, the sector demonstrated a certain degree of financial resilience due to its experience of variability dependent on nature. However, whether this resilience would be sufficient under compounding stress remains an open question. This finding not only reinforces previous research on critical infrastructure vulnerability, but also calls into question whether traditional risk preparedness strategies are sufficient in socio-ecological systems that lack redundancy.

Social capital: latent but underdeveloped

The literature (Aldrich, 2011; Coleman et al., 2020a) suggests that strong community ties act as a buffer against disruption. Although aquaculture stakeholders described their communities as 'close-knit', they also acknowledged limited formal collaboration. Although there is latent social capital, it has not yet been structured into collective resilience mechanisms such as cooperatives or joint advocacy.

Interestingly, business exits often result in consolidation within the sector, suggesting a potential platform for strategic alliances and trust-building. This lends support to the future application of the trust-carrier concept (trusted intermediaries who maintain dialogue) from the SLO strategy framework. The findings suggest that future governance should engage not only with stakeholders as individuals, but also facilitate the emergence of collective structures that can absorb and redistribute risk.

Perception over memory: the credibility gap

Stakeholders showed limited awareness of past closures, such as those in 1990. This supports Coleman et al. (2020a) argument that perception outweighs institutional memory. Current reactions are shaped more by how risks are framed and communicated than by past experience.

This also indicates a credibility boundary gap: even if performance is historically consistent, present-day legitimacy depends on real-time framing and the visibility of precautionary logic. Therefore, historical exposure alone does not equate to institutional resilience, unless it is accompanied by consistent, proactive communication. Legitimacy must be repeatedly maintained, not assumed.

6.2. Implications for governance and policy

Embedding tolerance monitoring in operational planning

The proposed framework enables Rijkswaterstaat to track societal positioning on the SLO continuum and integrate this into barrier closure planning. For example, low tolerance groups (e.g., aquaculture) may trigger co-monitoring, early warning systems, or compensatory strategies. Incorporating perception metrics as operational indicators would allow for more adaptive closure protocols and increase

institutional responsiveness.

Shifting from broadcast to co-creation

Findings show that even well-informed stakeholders can feel excluded if they are not involved in early decision-making. This supports a transition from reactive communication to co-creative planning. By involving stakeholders in scenario development and policy simulation, Rijkswaterstaat can improve both ownership and strategic foresight.

Re-framing resilience to include societal tolerance

This study suggests that resilience should not only reflect system robustness but also relational legitimacy. Tolerance is a critical indicator of governance adaptability. Tolerance should be monitored alongside ecological and technical performance, creating a three-pillar model of sustainable infrastructure management.

Tailoring engagement strategies to tolerance thresholds

The extended SLO framework offers Rijkswaterstaat a toolkit to differentiate between stakeholder groups based on their current tolerance position. Targeted engagement such as visualising closure consequences or offering compensation can increase efficiency and reduce legitimacy risks.

6.3. Recommendations for policy and practice

Building on the SLO-based framework developed in this thesis, the following policy recommendations are proposed to help Rijkswaterstaat institutionalise societal tolerance as a governance parameter within storm surge barrier management. These recommendations aim to move from reactive legitimacy management to proactive, participatory governance.

1. Institutionalise societal tolerance monitoring: Develop a dedicated monitoring system to track stakeholder positioning across the SLO continuum from ignorance to identification. Use both qualitative and quantitative indicators such as complaint frequencies, ecological impact signals, engagement behaviour, and media sentiment. Assign internal responsibility for regularly reviewing these signals.
2. Integrate tolerance thresholds into operational protocols: Supplement hydrological triggers (e.g., water level thresholds) with stakeholder-sensitive moments such as mussel spawning periods, tourism peaks, or ecological restoration windows. These should be embedded in closure scheduling to prevent legitimacy erosion among vulnerable groups.
3. Appoint trust-carriers and improve continuity of contact: Designate consistent points of contact for each stakeholder sector. Trust-carriers should act as boundary spanners who can facilitate dialogue, translate technical terms into sector-relevant language, and build durable institutional memory.
4. Develop a tiered early-warning system: Extend the existing “call-list” with a formalised warning ladder (e.g., 7-day, 48-hour, and 6-hour alerts) that communicates closure likelihood. Include visual communication tools that clarify trade-off and institutional logic in accessible formats.
5. Translate technical decisions into sector-specific narratives: Use tailored communication strategies that reflect the concerns, capacities, and values of different groups. For example, for aquaculture: tidal fluctuation implications; for nature organisations: biodiversity timelines; for recreation: access and predictability.
6. Embed tolerance into the Strategic Asset Management Plan (SAMP): Define societal tolerance as a measurable performance condition, alongside flood safety and reliability. Develop tolerance indicators that can inform investment decisions and operational reviews across the storm surge barrier network.
7. Strengthen structural resilience in the aquaculture sector: Explore co-designed compensation models, adaptive farming pilots, and ecological co-monitoring. Facilitate the formation of cooperatives or joint insurance mechanisms to increase buffering capacity and reduce sectoral withdrawal risk.

8. Promote social cohesion as a resilience strategy: Monitor and support community-based initiatives, collective action platforms, and information-sharing networks. Prioritise sectors with high ecological dependency and low formal organisation.
9. Leverage historical memory to build adaptive identity: Incorporate narratives of past closures (e.g., 1990) into storytelling, education campaigns, and exhibitions. This can help normalise future disruptions and build a shared understanding of adaptive governance.
10. Develop a long-term regional vision for the Eastern Scheldt: Launch a co-creation process for a 100-year adaptation strategy that balances flood protection, ecological vitality, and social acceptance. Use participatory scenario building to align stakeholder expectations with future system transitions.

6.4. Theoretical contributions

Advancing societal tolerance as a governance concept

This thesis contributes to the expanding literature on climate-resilient infrastructure governance by offering four key theoretical insights, particularly in the context of storm surge barrier management.

Firstly, it reconceptualises societal tolerance as a proactive planning instrument rather than a reactive outcome to disruption. While previous studies have examined tolerance in response to service failure or environmental stress, this research takes a forward-looking approach. It shows how tolerance can be anticipated and assessed in advance through stakeholder engagement, enabling more adaptive, inclusive and preventive decision-making.

Secondly, the study integrates societal tolerance into both operational and strategic layers of infrastructure governance. Rather than treating tolerance as an abstract concept, it is operationalised through stakeholder-specific indicators such as ecological dependency, risk awareness, and behavioural responses. This creates a tangible interface between technical management and socio-political legitimacy, bridging engineering routines with democratic accountability. It positions societal tolerance as a performance dimension in its own right, on par with safety, reliability, and cost.

Thirdly, this is among the first studies to qualitatively investigate societal tolerance in the context of storm surge barrier management using semi-structured interviews. While prior research has relied largely on large-scale surveys, this approach yields context-rich insight into how tolerance is shaped by vulnerability, institutional trust, and lived experience. This methodological contribution deepens understanding of how social thresholds are experienced and articulated by affected groups.

Finally, the conceptual framework developed in this thesis holds theoretical value beyond the case of the Eastern Scheldt. Its modular design centred around the causal sequence of disruption, impact, awareness, tolerance, and response makes it transferable to other socio-technical systems under environmental pressure. The framework provides a structured, comparative lens for studying tolerance-sensitive governance in varied infrastructure and regional settings.

Extending SLO: theoretical advancements of this study

This thesis also contributes to the development of Social Licence to Operate (SLO) theory, extending it from its original corporate and extractive sector focus to the realm of public infrastructure governance. Four main contributions stand out:

- Contextualising SLO for state infrastructure: whereas SLO literature has primarily examined private-sector projects, this study demonstrates that SLO principles are equally applicable to government-led infrastructure. In the case of the Eastern Scheldt Barrier, stakeholders evaluate not only technical performance but also symbolic, ecological, and procedural dimensions of Rijkswaterstaat's role as a public authority.
- Introducing the knowledge boundary: this study adds a foundational layer to existing SLO models by identifying a "knowledge boundary" that must be crossed before legitimacy or trust can be established. Societal awareness of ecological consequences, long-term risk, and personal relevance is a precondition for engagement. This layer is made operational through proposed ignorance metrics, expanding the entry points for empirical assessment.

- Embedding ecological dependency and social adaptability: the framework links stakeholder tolerance to ecological vulnerability and adaptive capacity. Groups with high dependency on estuarine flows (e.g., aquaculture) exhibit lower tolerance and require differentiated engagement strategies. By embedding ecological and adaptive variation into SLO assessment, this study introduces a more nuanced, resilience-aware version of legitimacy.
- Bridging theory and application through planning tools: the societal tolerance planning matrix developed here translates layered SLO theory into a practical tool. By mapping stakeholder positions based on dependency and adaptability, it supports anticipatory governance and decision-making. Together with participatory monitoring and simulation techniques, the tool operationalises the concept of “earning” and “maintaining” a licence to operate over time.

6.5. Recommendations for future research

To better understand societal tolerance for increased barrier closures, future research could focus on the following four key areas:

Firstly, a quantitative study involving a large-scale survey could capture a broader range of stakeholder perspectives, including those of both direct and indirect actors. This would validate and quantify the tolerance determinants identified in this qualitative study, helping Rijkswaterstaat define precise, differentiated tolerance thresholds.

Secondly, temporal studies, such as longitudinal research, could track how tolerance develops over time. By examining stakeholder reactions before, during and after closures, such studies could reveal whether tolerance increases through adaptation or declines due to cumulative pressures. Currently, the evidence base remains limited to a single point in time.

Thirdly, ecological research is needed to assess the impact of prolonged closures on the Eastern Scheldt ecosystem. Future studies could investigate changes in nutrient flows, oxygen levels and water circulation to offer clearer insight into ecological tipping points and support more adaptive, ecosystem-sensitive barrier management.

Fourthly, the conceptual framework proposed in this study would benefit from further validation. While it is theoretically grounded and informed by stakeholder input, its practical utility as a guidance tool remains untested. Future research could pilot the framework in a real-world or simulated decision-making context to evaluate its effectiveness in identifying tolerance thresholds, informing closure strategies, and facilitating stakeholder dialogue.

Finally, simulation gaming could be a valuable participatory research methodology for testing stakeholder responses to closure scenarios in a controlled environment. This approach enables researchers to explore decision-making under uncertainty, measure tolerance thresholds in practice, and develop a shared understanding of the trade-off between safety, ecology, and societal needs.

6.6. Research limitations

Firstly, trust in authorities is not static. While the stakeholders in this study generally expressed confidence in Rijkswaterstaat, the literature suggests that trust can erode over time if institutions repeatedly fail to address concerns or adapt effectively to changing conditions. Since this research provides a snapshot of a particular moment in time, it cannot account for how trust and tolerance might change in the event of prolonged or repeated disruption.

Secondly, the sample size was limited to a select group of stakeholder representatives with direct economic or ecological ties to the Eastern Scheldt. While these individuals offered valuable insights, the study did not encompass the broader public or other relevant groups, such as tourists, yacht club owners, and local residents without direct economic interests. Furthermore, no mussel or oyster breeders were interviewed in person, only their representatives were interviewed, which may result in differing or more nuanced individual opinions being overlooked. This is particularly pertinent given the widespread ignorance observed regarding the consequences of climate change.

Thirdly, the findings are geographically and contextually specific. The Eastern Scheldt is a unique socio-ecological system, and tolerance levels here are shaped by specific regional dynamics, economic

dependencies and ecological characteristics. Consequently, the conclusions drawn may not be directly transferable to other storm surge barriers in the Netherlands or internationally.

Furthermore, the research is scenario-dependent. The interviews were exploratory, focusing on future expectations rather than experience of frequent closures. As societal tolerance is likely to evolve before, during and after disruptive events, this study primarily captures pre-event perceptions. Further longitudinal research would be valuable in order to understand how tolerance fluctuates over time and in response to actual closure events.

While this study qualitatively explored stakeholder tolerance, it did not define precise tipping points. Future research could focus on identifying these thresholds quantitatively, for example using surveys, scenario testing or modelling, to determine when societal tolerance shifts into resistance. This would complement qualitative insights and support more targeted, data-driven decision-making.

Lastly, while the GIOIA method provides a robust framework for qualitative analysis, the process remains inherently interpretative. Coding decisions and thematic classifications may have been influenced by the researcher's assumptions or analytical focus, introducing subjectivity into the findings.

Closing reflections

This chapter has shown how societal tolerance operates as a strategic lens through which to design more legitimate and adaptive infrastructure governance. Through a combination of empirical insight and theoretical innovation, this study provides a practical and conceptual pathway for incorporating public legitimacy into storm surge barrier planning and decision-making. By reconceptualising societal tolerance as both measurable and governable, it contributes to a broader shift from protective to participatory infrastructure regimes.

7

Conclusion

This chapter synthesises the main findings of the research, as outlined in Section 1.4, by integrating insights from the literature review, stakeholder interviews, and expert input. It reflects on how increased closures of the Eastern Scheldt Barrier affect ecological systems, economic sectors, and societal tolerance, and provides direction for integrating these insights into storm surge barrier management.

What is the current knowledge on increased closures of the Eastern Scheldt Barrier and societal tolerance?

While the technical and ecological implications of increased barrier closures are relatively well documented, such as changes in tidal exchange, biodiversity impacts, and sediment transport, the societal dimension remains under explored. The existing literature primarily focuses on flood safety and ecosystem function, with limited attention to how affected communities perceive and tolerate operational changes. Societal tolerance, as defined in recent studies, is a dynamic and context-sensitive threshold shaped by institutional trust, perceived fairness, risk awareness, and dependency on ecosystem services. However, prior research has not translated these insights into actionable frameworks for public infrastructure governance.

This thesis addresses that gap by applying a SLO lens to barrier management, re-framing tolerance as a layered governance condition rather than a passive public reaction. Through this perspective, increased closures are not only a technical adjustment, but a social process requiring legitimacy, shared understanding, and active engagement to maintain long-term acceptance.

How is the perception of increased closures experienced by stakeholders?

Stakeholder perceptions of increased closures vary significantly depending on ecological dependency, adaptive capacity, and trust in institutional processes. This thesis shows that these perceptions can be meaningfully positioned along the SLO continuum, ranging from ignorance to identification and shared ownership. Aquaculture actors, whose operations are directly affected by reduced tidal exchange, expressed withdrawal and urgency, often perceiving closures as externally imposed and inadequately mitigated. Their responses reflect not only ecological vulnerability but also limited institutional inclusion, situating them near the legitimacy and knowledge boundaries of the SLO-model.

By contrast, environmental organisations expressed conditional acceptance, recognising the long-term necessity of climate adaptation while emphasising the need for ecological stewardship and transparent decision-making. Recreational users displayed higher levels of flexibility and trust, showing more tolerance provided that closures are predictable and communicated in advance. Across all groups, perception was shaped less by technical arguments and more by how closure decisions were framed, explained, and experienced in practice. This reinforces the need to understand societal tolerance not only as an outcome of risk exposure, but also as a function of communication, representation, and procedural legitimacy.

How can societal tolerance for increased closures be assessed?
This thesis proposes assessing societal tolerance through a structured set of qualitative indicators derived from stakeholder positioning on the SLO continuum. Rather than measuring tolerance directly, the framework identifies five tolerance states: ignorance, withdrawal, acceptance, approval, and identification which can be inferred through behavioural cues, discourse, and engagement levels. These states are supported by diagnostic metrics developed through GIOIA analysis, such as the presence of emotional ownership, the framing of the barrier as "our solution," or indicators of distrust and disengagement.

These metrics offer a practical way for Rijkswaterstaat to monitor stakeholder sentiment over time, using methods such as satisfaction surveys, stakeholder dialogues, complaint tracking, or media analysis. For instance, a rise in withdrawal signals (e.g., protest, sector exit, refusal to engage) may indicate that a stakeholder group is nearing or has crossed its tolerance threshold. Conversely, high levels of perceived fairness, participation, and co-development suggest that tolerance is stable or increasing. Importantly, these indicators must be interpreted contextually linked to sectoral dependency, seasonal vulnerability, and historical engagement to ensure that they reflect capacity and not momentary sentiment.

How can societal tolerance be integrated into the Eastern Storm Surge Barrier management?
Societal tolerance can be integrated into barrier management by treating it as a governance objective that evolves alongside physical risk. The framework developed in this thesis positions tolerance within a layered SLO structure, identifying critical boundaries: knowledge, legitimacy, credibility, and trust, that must be addressed to maintain public support. Each boundary corresponds to specific strategies, such as improving risk communication, appointing trusted intermediaries, or adapting closure timing to seasonal sensitivities.

Operationally, this means embedding societal tolerance into planning routines through co-developed closure scenarios, tolerance indicators, and stakeholder feedback loops. For example, tolerance metrics can be used as early warning signals that trigger pre-defined responses, such as ecological buffering or targeted stakeholder engagement. Strategically, tolerance should inform the revision of the SAMP, ensuring that social thresholds, such as spawning periods, recreational demand, or vulnerability exposure, are treated alongside hydrological risk parameters.

This integration requires shifting from a purely technical model of storm surge barrier management to one that anticipates societal expectations, interprets legitimacy signals, and institutionalises adaptive communication practices. Doing so enables Rijkswaterstaat to not only protect physical infrastructure, but also to sustain its SLO in an era of climate-driven uncertainty.

Main research question

The main research question was defined in Section 1.4 as: *How can societal tolerance for the increased closures of the Eastern Scheldt Barrier be assessed and integrated into storm surge barrier management?*

This thesis demonstrates that societal tolerance can be assessed and integrated by embedding it within a broader governance framework grounded in the SLO-model. Rather than conceptualising tolerance as a fixed public opinion or binary approval state, this study reframes it as a dynamic and layered condition shaped by ecological dependency, procedural fairness, institutional trust, and stakeholder inclusion.

Assessment of societal tolerance is made possible by identifying five stakeholder positions: ignorance, withdrawal, acceptance, approval, and identification along the SLO continuum. These positions were derived from GIOIA-informed analysis of stakeholder interviews and are expressed through qualitative indicators such as emotional ownership, withdrawal behaviours, perceived fairness, or co-development efforts. For example, aquaculture stakeholders positioned near the withdrawal boundary showed disengagement and low tolerance, while nature organisations demonstrating long-term strategic alignment reflected conditional acceptance or approval. These positioning cues allow Rijkswaterstaat to move from generalised engagement to a differentiated understanding of how specific groups perceive and respond to closures. This can be supported through tools such as tolerance dashboards, stakeholder

mapping, and targeted perception monitoring.

Integration of societal tolerance into barrier management requires translating this diagnostic understanding into concrete governance strategies. The SLO-framework identifies four key legitimacy boundaries: knowledge, credibility, legitimacy, and trust in which must be actively addressed for societal acceptance to emerge and be maintained. These boundaries can be navigated through measures such as enhancing public understanding of closure logic, improving procedural fairness, strengthening communication through trusted intermediaries, and co-developing regional visions with vulnerable stakeholders. Tolerance should be treated as a formal performance criterion alongside hydrological risk and ecological integrity, and integrated into the SAMP, operational protocols, and participatory decision-making processes.

This approach calls for a shift from reactive legitimacy repair to anticipatory legitimacy stewardship. By institutionalising stakeholder engagement and tolerance monitoring into routine planning, Rijkswaterstaat can proactively govern its SLO. This not only supports public acceptance and adaptive capacity, but also positions the organisation as a frontrunner in socially responsive infrastructure governance.

In summary, societal tolerance can be both assessed and integrated through the SLO framework, which provides a structured, stakeholder sensitive lens for understanding legitimacy. By linking empirical insight with adaptive strategy, Rijkswaterstaat can ensure that storm surge barrier management remains robust, inclusive, and future-proof in an era of climate uncertainty.

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A

Questions stakeholders

The following questions were asked during the stakeholder interviews and have been translated from Dutch. They served as a semi-structured guide to explore perceptions, experiences, and tolerance related to the increased closures of the Eastern Scheldt Barrier.

1. Socio-demographic factors

Could you please explain to me your (understand the context/setting):

a) Age/average age in your organisation:
b) Profession:
c) Responsible of organisation:
d) Duration in this position/active in the organisation:
e) Educational level (in your organisation average?):
f) Average income (for people in your organisation?):
g) How did you come into this business: did you start it, family tradition, passion, etc?
h) Are there programs or safety nets (insurance coverage) if you have a production issue? (Check on fallback)

2. Hierarchy of Needs

a) What role does the Eastern Scheldt Barrier play in your life, work, or environment?
b) In what ways does the closure of the Eastern Scheldt Barrier affect your daily life, work, or local environment?
c) If closures were to become significantly more frequent, which aspects of your life, work, or community would be most affected?
d) Follow-up: What would you consider the most important consequences?
e) Follow-up: Are there any opportunities or benefits that you foresee emerging from more frequent closures?

3. Level of Preparedness

a) Have you taken any steps to prepare for more frequent barrier closures? If so, what kind of actions have you taken?
b) How would you describe your ability to adapt to increased closures of the Eastern Scheldt Barrier?
c) Follow-up: What specific steps have you already taken, or would consider taking, to adapt to these changes?
d) Follow-up: Are there any limitations or challenges that prevent you from adapting more effectively?

4. Service Substitutability

a) Are there alternatives or solutions your organisations can rely on during closures (e.g., tools, strategies, locations)?

b) What barriers (e.g., cost, access, knowledge) limit your organisation's ability to use these alternatives?

5. Social Capital

a) To what extent do you rely on support from neighbours, local networks, or associations during times of disruption?

b) Can you describe any examples of community cooperation or support that have helped during previous closures?

6. Previous Experience and Risk Awareness

a) Have you experienced any difficulties caused by barrier closures? If so, how did you respond at the time?

b) How aware do you feel about the potential impacts of more frequent closures due to climate change? Context: In 1990, the barrier closed 7 times.

7. Service Expectations

a) What do you consider a "normal" number of barrier closures per year?

b) Follow-up: At what point would you consider it problematic, and why?

c) Follow-up: Are you familiar with what a closure of the barrier means and its possible effects on the environment, economy or your own activities?

d) Follow-up: If not, would it help if I briefly explain how closures work and what their potential impacts are?

e) How do you expect the authorities or Rijkswaterstaat to act when closures become more frequent?

8. Risk Communication

a) How would you describe your interaction with the authorities regarding the Eastern Scheldt Barrier closures?

b) Follow-up: Have you received communication about upcoming closures and their potential consequences?

c) Follow-up: Have you participated in any meetings, consultations or other forms of engagement with RWS or local authorities?

d) Follow-up: Do you feel your concerns or input are acknowledged in these interactions?

e) What information (and how: communication method) would help you better understand and accept future increased closures?

9. Extra Questions

a) How have you personally experienced or been affected by the increased closures of the Eastern Scheldt Barrier?

b) How have your opinions or attitudes toward the Eastern Scheldt Barrier changed over time? If so, what influenced those changes?

B

Topology of the Eastern Scheldt region

This map illustrates the recreational zoning and activities around the Eastern Scheldt. It highlights assigned recreational activities such as marinas, beaches, camping and diving zones, etc. which are essential for the regional tourism economy.

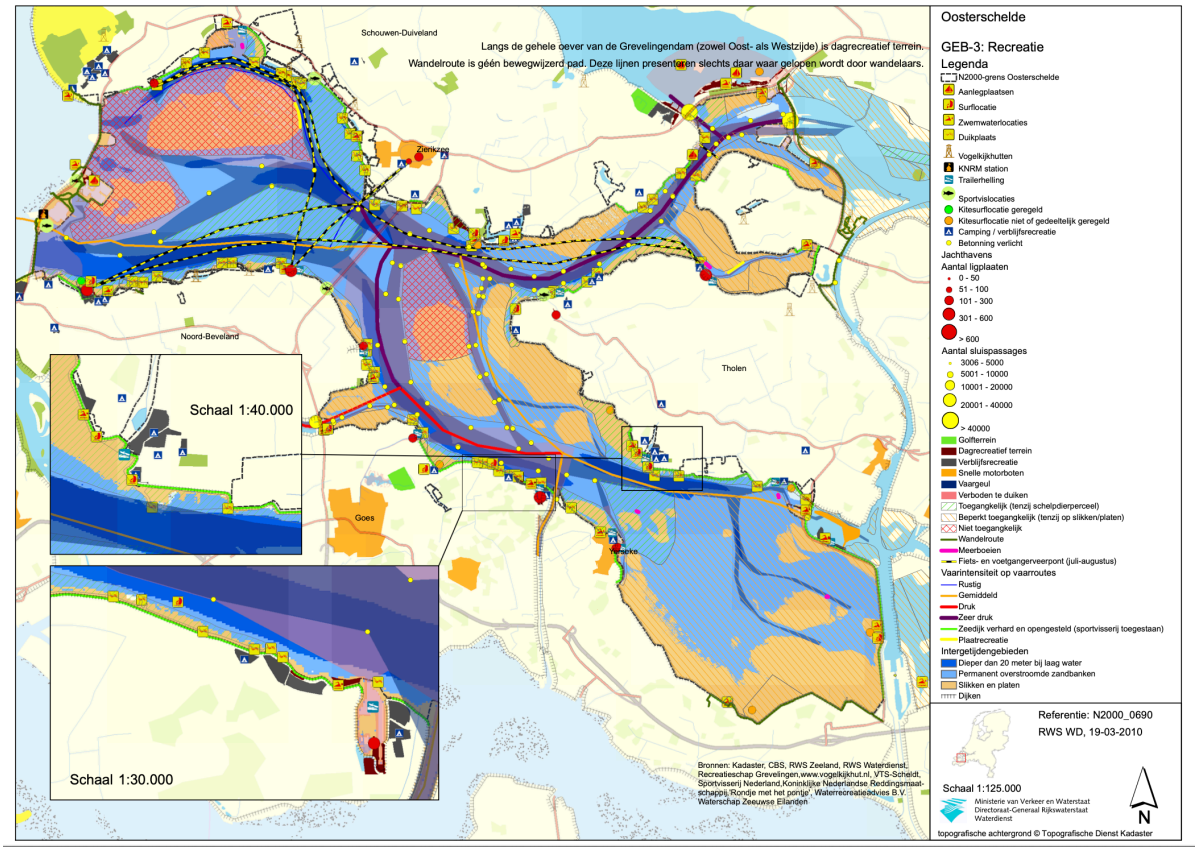

Figure B.1: Eastern Scheldt Region: Recreation (Natura 2000, n.d.)

This map illustrates the designated aquaculture zones within the Eastern Scheldt, including mussel and oyster farming plots, and fisheries. These areas represent an important economic activity for the region, highly sensitive to changes in water quality, tidal flow, and barrier operations.

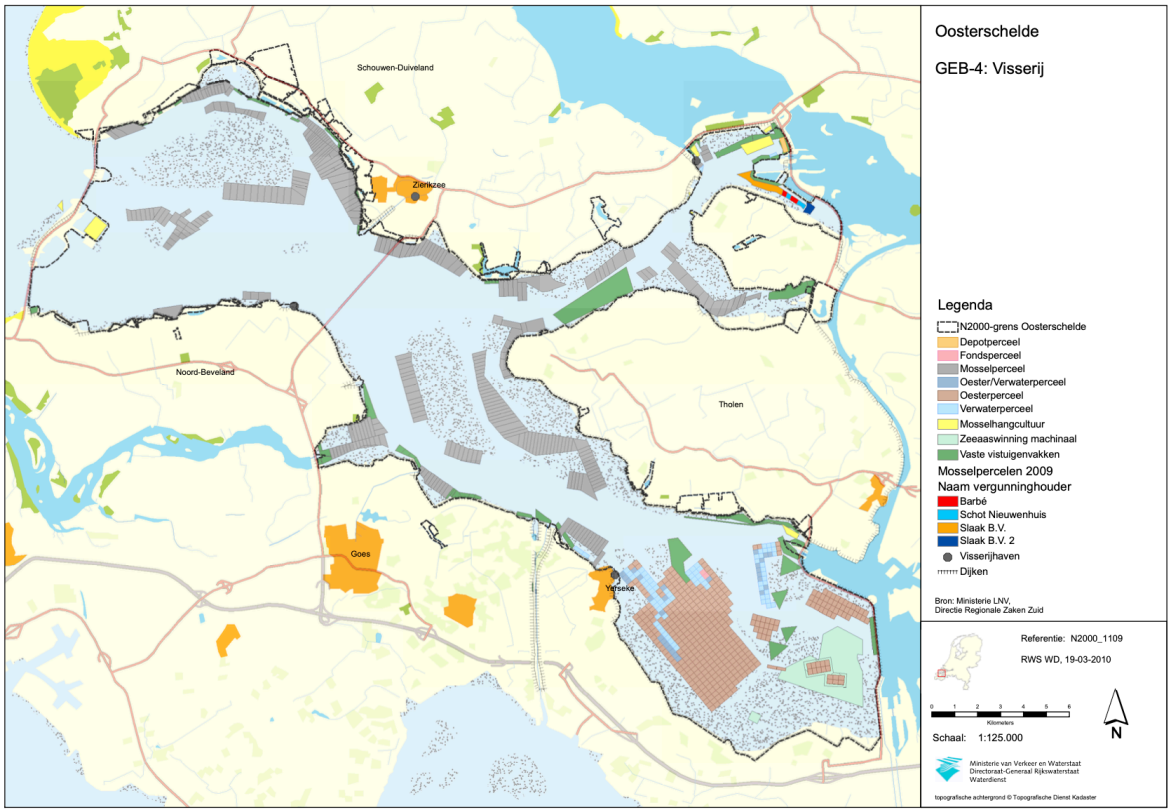

Figure B.2: Eastern Scheldt Region: Aquaculture (Natura 2000, n.d.)

C

Informed consent forms

All participants were informed about the purpose, scope, and voluntary nature of the study prior to their interview. Each respondent provided signed consent for the recording, transcription, and use of their anonymised data. The informed consent forms shown below were approved as part of the official ethics procedure at TU Delft and correspond to Data Management Plan ID: 5354. For privacy reasons, my personal contact details (e.g., phone number and email address) have been redacted in this public version.

Informed Consent Form

Dear Participant,

You are being invited to participate in a research study titled assessing societal tolerance for non-functionality of the Oosterscheldekering (Eastern Scheldt Barrier). This study is being done by James Buysschaert from the TU Delft in cooperation with Rijkswaterstaat (RWS) under supervision of Menno Nagelhout (RWS), Johan Ninan (TU Delft).

The purpose of this research study is to assess what the societal tolerance is for increased closures of the Barrier and will take you approximately *60* minutes to complete. The data will be used for making a framework to better understand the stakeholders' expectations and tolerance levels which will lead to better management of the barrier in the future when more closures likely occur. We will be asking you to give insights on what your needs are, to maintain daily practices.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by storing them behind 2-step authenticators cloud environments and storing it anonymously. After the study, all (personal) information will be deleted.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. After two weeks after the interview, you with like to delete information from the interview, this will be done when notified.

Thank you for participating, it is very much appreciated.

Feel free to ask any questions

James Buysschaert

Figure C.1: Informed Consent Form 1

Explicit Consent points

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated __/__/____ *(dd/mm/yyyy)*, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions, and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: • Answering (personal) questions on individual tolerance levels • Being recorded and that the video will be transcript for research purposes. The recording will not be shared with RWS, TU Delft or other people. After the transcription is done, it will be shared with the participant. Modification can be done until two weeks after the interview. • de-identified transcripts (remove all socio-demographic factors such as name, age, income, gender, community ties, etc.) will be shared with only the project team of the TU Delft and Menno Nagelhout from RWS.	☐	☐
4. I understand that the study will end around the beginning of July 2025.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) such as name, age, income and other socio-demographic factors and associated personally identifiable research data (PIRD) with the potential risk of my identity being revealed.	☐	☐
6. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: • Anonymous data collection • Secure data storage in password cloud (2-step authentication) • Transcription of participants answers • Audio-recordings are destroyed after the transcription (after 2 weeks)	☐	☐
7. I understand that personal information collected about me that can identify me, such as income, gender, age and other socio-demographic factors, will not be shared beyond the study team.	☐	☐
8. I understand that the (identifiable) personal data I provide will be destroyed at the end of the thesis (beginning of July 2025).	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
9. I understand that after the research study the de-identified information, I provide will be used for this master thesis of James Buysschaert and will be published in the TU Delft library (Repository).	☐	☐
10. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐

Figure C.2: Informed Consent Form 2

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

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

James Buysschaert	_____	_____
Researcher name	Signature	Date

Study contact details for further information: James Buysschaert - [redacted]

Figure C.3: Informed Consent Form 3