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Improving the Implementation of Nature-based Solutions: Principles, Challenges and Enablers

MSc Thesis

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List of Abbreviations

BwN	Building with Nature
CBD	Convention on Biological Diversity
EBA	Ecosystem-based Adaptation
EC	European Commission
ER	Ecological Restoration
ES	Ecosystem Services
EU	European Union
GI	Green Infrastructure
IUCN	International Union for the Conservation of Nature
NBS	Nature-based Solutions
OECD	Organization for Economic Cooperation and Development
PCLG	Poverty and Conservation Learning Group
SER	Society for Ecological Restoration
UNFCCC	United Nations Framework Convention on Climate Change

Abstract

Traditional engineering solutions involving the use of hard materials such as concrete are to thank for the safety and comfort of humans. However, they have been linked with increasing climate change impacts. To combat the problems caused by those traditional solutions, the concept of nature-based solutions (NBS) was introduced and established through principles and guidelines. In the Netherlands, where issues of flood safety and coastal erosion are of utmost importance, the Dutch authorities implement NBS projects for flood defense. One example of such NBS is called "sandy solutions", which include sand nourishment or sandy foreshores among others. The practical application of the principles, the challenges faced and the enablers that supported the implementation in sandy solutions in the Netherlands is still poorly covered in literature.

This thesis focuses on two projects that implement sandy solutions: the reinforcement of the Houtrib Dike and the Sand Motor. The two projects were examined by collecting empirical data from interviews with experts involved and from project reports. A three-part framework was created to analyze the collected data. The first part was related to the application of selected NBS principles in practice; the second was related to the challenges faced and how they were overcome; and the third was related to the enablers that supported the implementation of the projects. The data was analyzed and, in combination with the evidence from the scientific literature, they served to draw up recommendations to improve the implementation of NBS for flood defense in the Netherlands.

Several recommendations are provided improve the application of the principles of integration of all relevant knowledge, public participation, stakeholder engagement, and recognition and minimization of tradeoffs. Additionally, the challenges faced in the projects were found to result from the uncertainties associated with the dynamic nature of NBS. Employing decision-making under uncertainty and adaptive management was found to support informed decision-making, accommodate uncertainties in planning and facilitate mitigating their consequences. Finally, governmental support was identified as the main enabler, and it was determined that NBS implementation would be improved if that support was increased through governments prioritizing NBS projects over traditional solutions.

Keywords: Nature-based Solutions, Sandy Solutions, Flood defense, the Netherlands

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1. Introduction

1.1. Background

There is no doubt about the role played by engineering solutions on ensuring the safety and comfort of humans. Traditional engineering solutions, or grey infrastructure, rely on the use of hard materials to create structures in fields such as transportation, water distribution and flood protection (Scholz, 2016). While engineering solutions are to thank for human's modern way of living, they are also to blame for some of the threats we are facing. Scientific evidence has been found that links the increasing urbanization to a decrease in the provision and regulation of ecosystem services (Peng et al., 2017). Ecosystem Services refer to the benefits provided by the ecosystem for the wellbeing of humans such as below-ground water storage through infiltration (Bolund & Hunhammar, 1999). Thus, the continued use of grey infrastructure is rather unsustainable, since humans rely on ecosystem services to survive.

An alternative to engineering solutions is nature-based solutions (NBS) that recognize the ecosystem services. Multiple definitions exist for the term 'NBS'. The European Commission (EC) defines the NBS as "solutions that aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature, both using and enhancing existing solutions to challenges as well as exploring more novel solutions." (European Commission, 2015), while the International Union for the Conservation of Nature (IUCN) defines it as "actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN, 2016). These two definitions are broad and can apply to several ecosystem-based approaches. Therefore, NBS is considered as an umbrella term to include all approaches to improve current systems using ecosystem services (Cohen-Shacham et al., 2016). These approaches are, therefore, referred to as NBS-related approaches.

While some NBS were implemented decades ago (Kairo et al., 2001), the extent and potential of these solutions have only begun being featured in scientific research over the course of the past two decades (Cohen-Shacham et al., 2019). NBS projects for flood protection and water management in particular have gained the attention of researchers over the last decade (Janssen et al., 2020). That attention has led to advancements in understanding NBS and their potential to replace grey infrastructure. Subsequently, governments across the globe have tried to include NBS into their flood protection strategies (van Thiel de Vries et al., 2017).

The Netherlands is regarded as one of the world leaders in the field of water management. Indeed, the Netherlands Water Partnership (NWP) was established mainly for the purpose of promoting the Dutch experience in water management worldwide (OECD, 2014). This comes as no surprise given the nation's history with water. Almost one third of the country is under the sea level (Rijkswaterstaat, 2019). The threat of flooding is further amplified by the climate change and the accompanying sea level rise. It is expected that the Netherlands would be one of the leaders in the implementation of nature-based flood defenses. The country has already implemented several NBS pilots, which are relatively small-scale projects used primarily to test a project idea and understand more about the solution. Once a project idea has been tested, full scale projects may be realized (Association for Project Management, 2016). As such, some full-scale implementations of NBS projects have been carried out.

The Netherlands has used NBS more than once in their flood defense strategy as a part of the Building with Nature (BwN) Programme by the Rijkswaterstaat, the executive organization for the Ministry of Infrastructure and Water Management. BwN aims at revolutionizing hydraulic engineering projects through employing innovation, sustainability and resilience in its design guidelines. By creating a paradigm shift in all phases of project design, the project aims to work with nature instead of against it (van de Ven, 2018). One of the nature-based flood defense ideas used by Rijkswaterstaat is sandy solutions, which for instance include sand nourishment to combat coastal erosion. These solutions could be used independently or in combination with traditional engineering solutions (Zedler, 2003).

1.2. Problem Statement

Despite the increased interest in NBS, their implementation has been limited in contrast with their potential benefits. One contributing factor to this is the vagueness regarding the definition and scope of NBS. Implementers are confused as to what is considered NBS and what is not (Cohen-Shacham et al., 2019). To lessen that confusion, the IUCN has issued a set of principles or guidelines for the implementation of NBS projects (IUCN, 2016). However, the implementation of those principles in practice requires further research. Such research is essential, since practical applications often unveil areas for improvement for the theoretically developed principles.

The specific challenges associated with the implementation of sandy solutions in the Netherlands are not well-addressed in scientific literature. Similarly, neither are the enablers that support the implementation of those solutions. Identifying these challenges and enablers can support the implementers in several ways. Once the challenges and enablers are identified, the implementers would be better able to tackle the challenges and utilize the enablers to their full potential. Increased awareness about challenges and enablers would also result in better project planning, setting relevant and realistic success criteria, and a higher chance of success in achieving project objectives. Lessons learned regarding the principles, challenges and enablers can also be relevant in making informed decisions throughout the project cycle.

1.3. Research Objective

The main objective of this thesis is to propose recommendations for improving the implementation of NBS projects, with an empirical focus on sandy solutions for flood defense in the Netherlands. That objective was realized through examining two cases, namely the Houtrib Dike Sandy Reinforcement project and the Sand Motor project. Both projects were studied in depth regarding the application of specific NBS principles, the challenges they faced and the enablers that supported the implementation.

1.4. Research Questions

The objective of this thesis was achieved by answering the following **main research question**:

"How can the implementation of nature-based solutions for flood defense in the Netherlands be improved?"

To facilitate answering the main question, four **research sub-questions** were answered:

1. How were some of the NBS principles applied in the selected cases?
2. How could the application of the selected principles be improved?
3. How were the main challenges faced in the selected cases overcome in practice?
4. What were the main enablers supporting the implementation of the selected cases in practice?

Answering each research sub-question contributed to answering the main research question. Identifying how NBS principles have been applied in the selected cases was combined with the data from literature to identify how applying the selected principles could be improved in practice, resulting in several recommendations. Identifying how the main challenges faced in the selected cases were overcome in practice also served to provide recommendations to future projects. Finally, identifying the main enablers supporting the implementation of the selected cases served to identify ways to enhance these enablers to maximize their use in future projects. Combining the answers to these sub-questions highlights trends that contribute to an overall improvement of future NBS implementation.

1.5. Thesis Outline

The basis for developing the framework, which was used to analyze the two cases, is presented in chapter 2. Chapter 3 presents the research design. The empirical findings obtained from the case studies are shown in chapter 4. Those findings were used to answer the research sub-questions. Chapter 5 presents an analysis and a discussion of the findings. Thus, the two chapters together provide the answers to all research sub-questions and synthesize the answer to the main research question. Finally, chapter 6 concludes the thesis, answering the main research question and providing directions for future research.

2. Analytical Framework

This chapter establishes the framework for analyzing the selected projects and thereby answering the research questions. The framework consists of three parts, which are described in three corresponding sections. The first part is related to the principles of the NBS-related approaches. The second part is related to the challenges faced during the implementation of NBS-related approaches, and the third part is related to the enablers that supported the implementation. This chapter presents the scientific foundation upon which the collected data for the framework was analyzed.

2.1. Principles of NBS-related Approaches

The scientific attention about the potential to work with nature to improve human lives has led to the introduction of various approaches to enhance ecosystem services for human wellbeing (Pauleit et al., 2017). The approaches include the Ecosystem-based Adaptation, Blue-green Infrastructure, Ecological Restoration…etc. These approaches are referred to within this report as NBS-related approaches since the NBS approach is considered to be encompassing many of them (Cohen-Shacham et al., 2016) as mentioned in section 1.1. The implementation of the overarching NBS approach may be examined through the eight principles published by the IUCN (IUCN, 2016). Exploring the application of those principles would help understand the process of implementation of NBS for flood defense in the Netherlands and subsequently, how the implementation could be improved.

The NBS principles were expected to sufficiently cover the topics covered by the principles for each of the NBS-related approaches. However, due to the limited time dedicated to this research, an in-depth analysis of the eight principles was not possible and only a few could be analyzed. To provide legitimacy to the selection of principles, the principles of NBS were cross-checked with the principles of other NBS-related approaches for common topics. Only the topics which were mentioned in all approaches were analyzed.

While setting specific principles for each approach is essential, some terms remain poorly defined to this day. The reason for that is that some terms are more present in scientific research than others (Sarabi et al., 2019). Thus, this research was only limited to approaches that have published principles by an international organization or a scientific article. Four approaches were selected to present unique focuses related to sustainability. Furthermore, the approaches have been adopted by several multilateral frameworks, such as the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC), among others (Ruangpan et al., 2020).

The first was the NBS approach defined in section 1.1. The second was Ecosystem-based Adaptation (EBA) which is defined by the CBD as an approach that "includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change." (CBD, 2009). The third approach was Green

Infrastructure (GI) which is defined by the European Commission (EC) as being "based on the principle that protecting and enhancing nature and natural processes… are consciously integrated into spatial planning and territorial development." (European Commission, 2013). Finally, the fourth approach was Ecological Restoration (ER), defined by the Society on Ecological Restoration (SER) as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER, 2004).

The following subsections present the principles for the overarching NBS approach in addition to the three NBS-related approaches. The main reference for all data in the following subsections is mentioned in each one.

2.1.1. Principles of Nature-based Solutions

The IUCN (2016) identifies eight principles for NBS. These principles are listed below.

1-a) NBS embrace nature conservation norms (and principles).
1-b) NBS can be implemented alone or in an integrated manner with other solutions to societal challenges.
1-c) NBS are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge.
1-d) NBS produce societal benefits in a fair and equitable manner that promotes transparency and broad participation.
1-e) NBS maintain biological and cultural diversity and the ability of ecosystems to evolve over time.
1-f) NBS are applied at a landscape scale.
1-g) NBS recognize and address the tradeoffs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ES.
1-h) NBS are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

2.1.2. Principles of Ecosystem-based Adaptation

Andrade et al. (2012) have published seven principles for EBA as a document for IUCN. The principles are listed below.

2-a) EBA is about promoting the resilience of both ecosystems and societies.
2-b) EBA promotes multi-sectoral approaches.
2-c) EBA operates at multiple geographical scales.
2-d) EBA integrates flexible management structures that enable adaptive management.
2-e) EBA minimizes tradeoffs and maximizes benefits with development and conservation goals to avoid unintended negative social and environmental impacts.
2-f) EBA is based on best available science and local knowledge, and fosters knowledge generation and diffusion.

2-g) EBA is participatory, transparent, accountable, and culturally appropriate and actively embraces equity and gender issues.

2.1.3. Principles of Green Infrastructure

Benedict and Mac Mahon (2002) have published seven principles for GI. The principles are listed below.

3-a) GI should act as the framework for conservation and development.
3-b) Design and planning for GI is before development.
3-c) Linkage is key.
3-d) GI functions across jurisdictions and at different scales.
3-e) GI is grounded in sound science and land use planning theories and practices.
3-f) GI is a critical public investment.
3-g) GI engages partners and involves diverse stakeholders.

2.1.4. Principles of Ecological Restoration

McDonald et al. (2016) have published six principles for ER as a document for the SER. The principles are listed below.

4-a) Ecological restoration practice is based on an appropriate local native reference ecosystem, taking environmental change into account.
4-b) Identifying the target ecosystem's key attributes is required prior to developing longer term goals and shorter-term objectives.
4-c) The most reliable way to achieve recovery is to assist natural recovery processes, supplementing them to the extent natural recovery potential is impaired.
4-d) Restoration seeks 'highest and best effort' progression towards full recovery.
4-e) Successful restoration draws on all relevant knowledge.
4-f) Early, genuine and active engagement with all stakeholders underpins long-term restoration success.

2.1.5. Merged set of principles

As shown in sections 2.1.1 to 2.1.4, the principles of each approach do not necessarily match those of other approaches. The principles are worded in a broad manner that is open to interpretation by the implementer which causes confusion about how to apply them. Furthermore, the fact that the principles were created by different authors and organizations adds to the confusion and the fragmentation. Nonetheless, the approaches share some topics, despite the different wording of the specific principles referring to these topics. For example, the importance of public participation is mentioned in each approach. Thus, the approaches build on a similar foundation. For the purpose of integration and cohesiveness between the different principles, a merged list of topics included in the principles was created.

Table 1 presents a summary of the principles mentioned in the previous sections based on their topics. Table 1 was created based on explicit mentioning of the topics in the principles or their explanations provided by the original authors of the principles. However, some of the topics are implied in the principles or their explanations. The following paragraphs further clarify the commonalities between the approaches that are explicitly mentioned and those that are implied.

Table 1 Summary of the Principles of NBS-related Approaches

Principle Topic	NBS	EBA	GI	ER
Embracing nature conservation norms	1-a			
Implementation alone or complementary to other solutions	1-b			
Solutions are site and culture-specific	1-c			
Integration of all relevant knowledge	1-c	2-f	3-e	4-e
Provision of benefits in a fair and equitable manner	1-d	2-g		
Public participation	1-d	2-g	3-g	4-f
Maintaining biodiversity and supports ecosystems evolving	1-e			4-a
Application at landscape scale	1-f			
Recognition and minimization of tradeoffs	1-g	2-e	3-f	4-d
Integration in the overall design of policies	1-h		3-a	
Integration in early planning stages			3-b	
Promoting resilience		2-a		
Stakeholder Engagement	1-h	2-b	3-g	4-f
Operation across multiple geographical scales		2-c	3-d	
Learning from other integrated approaches		2-c		
Flexible or adaptive management		2-d		
Physical linkages between projects			3-c	
Public Investment			3-f	
Based on a local reference ecosystem				4-a
Identification of key attributes as first-step of planning				4-b
Supplements natural recovery process without replacing them				4-c
Utilizing "highest and best effort" Progression towards full recovery				4-d

From Table 1, it is clear that the different NBS-related approaches share some commonalities. The highlighted cells are the topics of principles that are explicitly mentioned in the principles of all four approaches or in their explanations. The topics of "stakeholder engagement from different sectors or levels" and "public participation" are mentioned in at least one principle for each approach. However, some of the approaches differentiate between the two and, additionally, Dutch regulations differentiate between the general public and stakeholders who would be affected by the project or can affect it (Ministry of Justice, 2010). Thus, they are considered to be separate topics to be analyzed in different ways. Another common topic shared by all the approaches is utilizing all relevant knowledge from all sources. Finally, the approaches emphasize the importance of recognition of the tradeoffs of NBS and attempting to minimize them.

Moreover, the approaches share some topics which are not explicitly mentioned, but rather implied in the explanation for each principle. The approaches agree on that NBS should be integrated in policy planning and that ecological considerations should be integrated in the early design phases of the projects. Additionally, each project has characteristics specific to its location and the culture in that area which should be considered. There is no "one solution fits all". Furthermore, NBS cross geographical and juridical boundaries, which underlines the importance of cooperation among various actors and across different sectors and levels. Finally, the approaches also support that the benefits of NBS should be distributed among all the stakeholders in a fair and equitable manner.

Due to the nature of this research and the limitations in terms of time and resources, only the topics that were explicitly mentioned in all the principles were considered in the analytical framework. As elaborated below, four principles were selected to include the common topics.

1. Integration of all relevant knowledge

The importance of utilizing the knowledge of local or indigenous people for nature conservation efforts has long been acknowledged by science (Alcorn, 1993). Indeed, the validity of the knowledge possessed by these people has been confirmed again and again in scientific publications (McCarthy et al., 2018) These people usually have more knowledge about their environment than foreign experts (Cohen-Shacham et al., 2016). The explanations for this principle in all four approaches refer to utilizing traditional knowledge of the indigenous people in the project site and not only relying on scientific knowledge. The Netherlands Center for Indigenous People defines indigenous people as "the original inhabitants of distinct territories and are generally marginalized in relation to the dominant culture" (PCLG, 2019). However, there are no people with that definition in the Netherlands (Brinkel, 2002). Hence, for this thesis, the scope of the principle was redefined to include the knowledge and observations of local residents (lay people) and local experts in the project site. That definition is in accordance with Maranta et al.'s (2003) findings that lay people and their knowledge are indispensable for the scientific community.

2. Public participation

Sarzynski (2015) mentioned that public participation is considered to be part of "good urban governance for climate change adaptation". The public should be involved in the project or at least directly informed about the details of the project (Cohen-Shacham et al., 2019). As mentioned earlier, some approaches distinguish between the public and the stakeholders and that is why they are considered as separate principles. For this thesis, the term "public" refers to the general public or "residents who would not be burdened by the project more than others, but who are interested in presenting their ideas and opinions about the project". To provide an example for clarification, people using an NBS for its additional recreational benefits would be considered "public" if the NBS did not burden them more than the general public.

The definition for "public" was created given Freeman's (1984) definition of "stakeholders" where he states that "stakeholders" hold the power to affect decisions or can be affected by the decisions made. This definition was chosen as it aligns with Dutch laws. In the Netherlands, public groups or individuals that are more affected by a project compared to the general public, when not compensated, can go to court and delay the project, or even stop it completely (Ministry of Justice, 2010). Thus, for this thesis, these groups or individuals are considered to be "stakeholders" instead of "public". Further elaboration on stakeholders is provided in the next subsection about stakeholder engagement.

Public participation efforts vary in practice, where different activities correspond to different levels of participation in decision making and consequently, different outcomes (Sarzynski, 2015). Scientists developed models to categorize different types of public participation linking them to the power held by the public on decision making. Public participation can take several forms from token-participation to citizen control (Arnstein, 1969). Krywkow (2009) has developed a model to classify public participation efforts in governmental decision-making specifically. As shown in Figure 1, the model lists some of the methods for public participation and classifies them based on the level of involvement of the public in decision-making. The two models mentioned above assume that authorities responsible for increasing the level of public participation as it corresponds to improved outcomes. Indeed, Nesshöver et al. (2017) confirm that public participation increases acceptance of the NBS projects and ultimately, social and environmental sustainability.

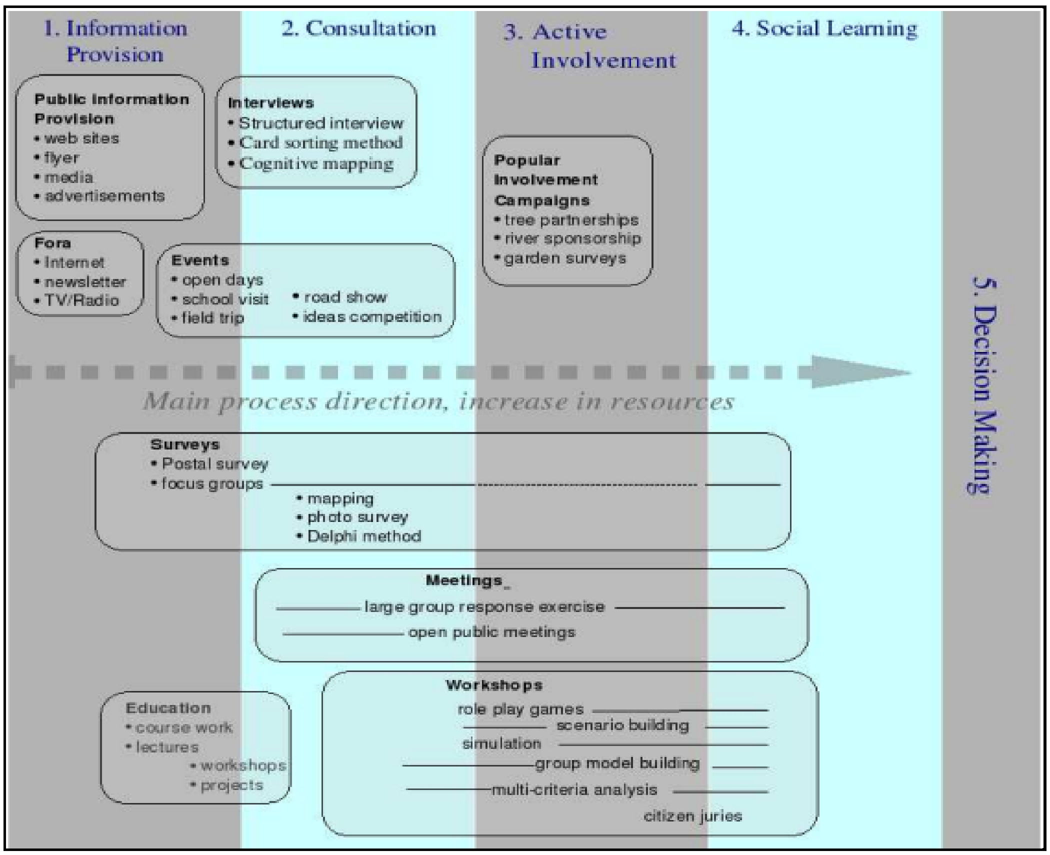

Figure 1 Levels of Public Participation
Source: Krywkow (2009)

Wamsler et al. (2020), however, state that there is no empirical evidence to show that public participation supports climate change adaptation efforts. They suggest that public participation efforts are an attempt from authorities to prevent future conflicts about the projects. Furthermore, they argue that under current conditions, public participation could hinder sustainability due to prioritization of personal interest in addition to lack of environmental awareness. Thus, the increased involvement of the public does not guarantee the success of NBS, but rather the specific characteristics of the project such as its objective and its implications on the public dictate the required level of participation.

3. Stakeholder engagement

As mentioned in the principle of public participation, stakeholders were distinguished from the public since that distinction aligns closely with Dutch regulations (Ministry of Justice, 2010). Stakeholders were defined as people with the power to affect decisions or people who would be affected by the decisions made (Freeman, 1984). The implementation of NBS projects relies on cooperation between various stakeholders from different levels and sectors (Giordano et al., 2020). These different actors can provide different kinds of support. The more stakeholder support a project has, the more it is ensured to succeed and endure (Eggermont et al., 2015). However, Reed et al. (2009) mentioned that, in practice, stakeholder identification is usually done only when necessary which leads to marginalizing potential groups of stakeholders. The identification of stakeholders remains a topic of debate for the scientists. The debate stems from the lack of agreement about what constitutes a legitimate stake (Friedman & Miles, 2006).

Freeman's (1984) definition of stakeholders includes organizations or individuals directly involved in the implementation of the project. These groups are referred to as "implementing stakeholders", in this thesis. Additionally, from the definition, public groups or individuals who would be burdened more than the general public by the implementation of a specific project would also be considered a stakeholder as the decisions made in the project affect them. Those people also have the power to affect the project since they have the right to take legal action against the project, as mentioned earlier (Ministry of Justice, 2010). These groups are referred to as "non-implementing stakeholders", in this thesis.

4. Recognition and minimization of tradeoffs

NBS projects present tradeoffs between the environment and social aspects that arise from the limited space in cities, for example (Haase, 2017). Understanding the tradeoffs involved in implementing NBS is an essential requirement for their success as it helps planners minimize them as much as possible leading to improved planning and implementation (McShane & Wells, 2004).

Tradeoffs can also exist between financial costs and environmental benefits, since for ecosystem services, the gained benefits are hard to express in monetary values (Liekens et al., 2013). Nonetheless, research has shown that NBS can be more cost-effective than traditional solutions when those benefits are properly valued (Somarakis et al., 2019). There are some valuation techniques for ecosystem services and environmental benefits. However, these techniques fail to account for the dynamic and evolving nature of ecosystems (Dendoncker et al., 2013). Nonetheless, planners need to avoid simplifying the ecosystem by reducing its biodiversity for financial or other considerations as it results in reduced provision of ecosystem services (Cohen-Shacham et al., 2019).

2.2. Challenges of NBS Implementation

The second part of the framework involves the challenges faced in the implementation of NBS projects. There are many challenges to be faced when implementing NBS, as they are considered a relatively recent development and not as well-understood as traditional solutions (Seddon et al., 2020). Identifying these challenges can help practitioners prepare for them and subsequently, improve project planning and implementation. Sarabi et al. (2019) identified three categories of such challenges, namely socio-institutional, biophysical and hybrid.

This first group of challenges as identified by Sarabi et al. (2019) contains the highest number of challenges out of all three. Despite the long-term multi-benefits of NBS, the social and institutional setup of societies is focused on short-term gains (Frantzeskaki et al., 2017). Thus, most of the barriers faced by NBS implementers result from this mismatch. Adger et al. (2005) identified three institutional constraints that can hinder adaptation to climate change, which are related to regulatory structures, property rights and social norms. As adapting to or mitigating climate change is one of the main purposes of NBS, the institutional challenges identified by Adger et al. (2005) were considered in this thesis.

The challenges related to the regulatory structures arise from the institutional setup, which aims at minimizing risk and uncertainty (Lukasiewicz et al., 2016). NBS rely on dynamic natural and ecological processes characterized by many uncertainties unlike stable engineering structures. These uncertainties are amplified when the effects of climate change are considered (Hallegatte, 2009). Furthermore, the characteristics of NBS (e.g. not being limited to geographical or juridical boundaries) do not match how institutions are organized (e.g. departments are responsible for specific geographical areas). As for the challenges related to property rights, they concern NBS projects implemented on privately-owned lands which is not within the scope of this thesis. The last institutional challenges category identified by Adger et al. (2005), i.e., social norms, is related to how the community perceives the project. Lukasiewicz et al. (2016) argues that one of the reasons for public opposition for NBS projects is false perceptions about the negative impacts of the projects that would directly affect them. To combat that challenge, most governmental bodies resort to financial incentives or compensation schemes (Lukasiewicz et al., 2016).

Biophysical challenges are the second category identified by Sarabi et al. (2019), which relate to the characteristics of the site where the NBS is to be carried out such as land availability. The final category identified by Sarabi et al. (2019), hybrid challenges, includes challenges that relate to both the socio-institutional setup and the biophysical characteristics of the site and the solution. One of such hybrid challenges is the uncertainty about how to implement NBS and how effective they are. That, in turn, decreases the chances of NBS being taken up by governmental bodies.

2.3. Enablers of NBS Implementation

The third part of the framework involves the enablers that support the implementation of NBS projects. Highlighting these enablers can help practitioners utilize them fully in planning implementation. In a similar fashion to the challenges, Sarabi et al. (2019) grouped potential enablers into three groups: socio-institutional, biophysical and hybrid enablers.

The first group of enablers, socio-institutional, contains some of the most commonly mentioned enablers in literature (Sarabi et al., 2019). The group includes enablers such as partnerships among stakeholders, economic incentives in addition to enabling regulations. So, while inadequate regulations and legislations were considered as a barrier against NBS implementation, proper regulations provide an opportunity to support implementation (Xing et al., 2017).

The second group of enablers, biophysical, includes enablers such as appropriate planning and design of NBS projects relating to the biophysical characteristics of the project site itself in addition to combining NBS with traditional solutions (Sarabi et al., 2019). Finally, the last group of enablers, hybrid enablers, includes enablers that relate to both the socio-institutional setup and the biophysical characteristics of the site and the solution. An example of a hybrid barrier is the presence of effective monitoring and valuation systems for NBS implementation and their associated benefits (Wendling et al., 2018).

3. Research Design

This chapter presents the materials and methods used to achieve the objectives of this report. Details about the research strategy, data collection and data analysis are presented in the following subsections. Scientific ethics and research limitations are also elaborated upon.

3.1. Research Strategy

This thesis used a case study approach as its strategy. The research focused on two cases and collected data about their implementation based on the analytical framework developed through the literature study. The data was collected empirically through interviews and through desk research. A qualitative, in-depth analysis of the data was carried out to synthesize the conclusion.

3.1.1. Research Unit

The selection of the number of research units was done taking into consideration the limited time dedicated to finalizing this research. Additionally, the number of projects relied on the availability of the interviewees. Two sandy solutions for nature-based flood defense in the Netherlands were considered for in depth analysis.

3.1.2. Selection of Research Unit

Selection of the cases, i.e., projects, was based on the following criteria:

- The projects are water related.
- The projects involve sandy solutions.
- The projects are considered as innovative nature-based alternatives for traditional flood defense measures.
- Each project has published reports and documentation.
- The published reports are in English.
- The projects are completed or are in the monitoring phase.
- The projects are part of the BwN project and implemented by Rijkswaterstaat as the entity responsible for flood defense in the Netherlands.
- The availability of experts involved in the projects who were willing to be interviewed.

3.1.3. Research Boundary

The research boundary is selected to ensure the research is done within the specified time period with the best possible quality and value. The boundary for this research was as follows:

- The number of cases was limited to two as mentioned in 3.1.1.
- The case studies are selected based on the criteria mentioned in 3.1.2.
- The implementation of nature-based flood defense sandy solutions in the Netherlands was considered based on the data collected from the case studies only.
- The projects were analyzed based on the created framework only.

3.2. Data Collection

3.2.1. Acquired Data

The acquired data for this research in order to answer the research sub-questions is presented in Table 2.

Table 2 Acquired Data for the Research Sub-questions

Research Sub-question	Acquired Data
How were some of the NBS principles applied in the case studies?	Details about the application of the selected principles in the case studies: -integration of all relevant knowledge. -public participation. -stakeholder engagement. -recognition and minimization of tradeoffs.
How could the application of the selected principles be improved?	Information about how the principles should be applied according to research.
	Experts opinions about how the principles should be applied to ensure they do not pose a challenge for implementation.
How were the main challenges faced in the case studies overcome in practice?	Details about the challenges faced in the implementation of the case studies.
	Categories of challenges for NBS implementation.
	Details about how the project team overcame the challenges faced in the implementation of the case studies.
What were the main enablers supporting the implementation of the case studies in practice?	Details about the enablers that supported the implementation of the case studies.
	Categories of enablers for NBS implementation.

3.2.2. Operationalization of Principles, Challenges and Enablers

This section explains how the four principles were operationalized and how the challenges and enablers were identified. Table 3 presents the acquired data that served to operationalize the principles and identify challenges and enablers.

Table 3 Operationalization of the Principles, Challenges and Enablers

Principle/ Topic	Data Acquired about:
Integration of all relevant knowledge	The availability of local knowledge (both from residents and experts) in the project site.
	Whether the available local knowledge was utilized.
Public participation	The kind of organized activities for public involvement.
	What the level of public participation was.
	The time of public consultation with regards to the project life cycle.
	Who was invited.
	How they were invited.
	The power held by the public to influence decisions.
Stakeholder engagement	Whether the two categories of stakeholders were involved.
	How the non-implementing stakeholders were identified.
	How often stakeholders were updated about project progress
	The power held by stakeholders to influence decisions.
Recognition and minimization of tradeoffs	Whether the project team was aware about all potential negative impacts in the early stages of the projects.
	How the unexpected impacts were mitigated.
	When the unexpected impacts were mitigated.
	Whether decisions were taken that would simplify the ecosystem for immediate financial or social benefits.
Challenges and enablers	To identify challenges and enablers, the interviewed experts were explicitly asked about the main challenges and enablers in the project. They were asked more probing questions to further explore the nature and causes of the challenges, how the project team overcame them and the enablers that supported the project.

3.2.3. Sources of Data and Methods of Data Collection

The general sources and methods of collection for the acquired data are presented in Table 4. The following subsections provide further details about the data collected for each case. The guideline upon which the interviews were conducted is in Appendix A.

Table 4 Sources and Methods of Collection for the Required Data

Acquired Data	Source	Method of Collection
Details about the application of the selected principles in the case studies: -integration of all relevant knowledge. -public participation. -stakeholder engagement. -recognition and minimization of tradeoffs.	**Secondary data:** Project reports	Content Analysis
	Primary data: Interviews with experts	Online Interviews
Information about how the principles should be applied according to research.	**Secondary data:** Scientific Literature	Content Analysis
Experts opinions about how the principles should be applied to ensure they do not pose a challenge for	**Primary data:** Interviews with experts	Online Interviews
Details about the challenges faced in the implementation of the case studies.	**Secondary data:** Scientific Literature	Content Analysis
	Primary data: Interviews with experts	Online Interviews
Categories of challenges for NBS implementation.	**Secondary data:** Scientific Literature	Content Analysis
Details about how the project team overcame the challenges faced in the implementation of the case studies.	**Secondary data:** Project reports	Content Analysis
	Primary data: Interviews with experts	Online Interviews
Details about the enablers that supported the implementation of the case studies.	**Secondary data:** Scientific Literature	Content Analysis
	Primary data: Interviews with experts	Online Interviews
Categories of enablers for NBS implementation.	**Secondary data:** Scientific Literature	Content Analysis

3.2.3.1. Houtrib Dike Data

The sources of the data about the Houtrib Dike were available documents on the Houtrib Dike page on the Rijkswaterstaat website (Rijkswaterstaat.nl, 2019) and the Houtrib Dike Page on the Ecoshape website (Ecoshape.nl, 2020a). Several interviews with experts working on the project were conducted in addition to representatives from Rijkswaterstaat to collect more practical data. Furthermore, the interviewees Table 5 presents the names and affiliations of the interviewees.

Table 5 Names and Affiliations for Interviewees for the Houtrib Dike Project

Name	Affiliation	Role
Ellis Penning	Deltares	Ecologist for the Pilot
Hans Vos	Rijkswaterstaat	Operation and Maintenance for the Dike
Henk Steetzel	Deltares	Project Manager for the Pilot
Jasper Fiselier	Retired	Environmental Consultant
Petra van Konijnenburg	Rijkswaterstaat	Area manager for the Reinforcement of the Houtrib dike
Rinse Wilmink	Rijkswaterstaat	Project Leader of the Monitoring of the Houtrib Dike

The interviewees provided some additional documents that were not accessible on the websites. Table 6 presents these additional documents.

Table 6 Additional Documents and Sources of Data about the Houtrib Dike

Document Title	Type	In-text Citation
Natural Foreshores as an Alternative to Traditional Dike Reinforcements: a Field Pilot in the Large Shallow Lake Markermeer, the Netherlands	Conference Paper	(W. E. Penning et al., 2015)
Establishing Vegetated Foreshores to Increase Dike Safety along Lake Shores	Journal Article	(E. Penning et al., 2016)
Building with Nature Pilot Sandy Foreshore Houtrib Dike: Design and Behavior of a Sandy Dike Defense System	Conference Paper	(Steetzel et al., 2017)
Houtrib Dike Sandy Foreshore Pilot Project	Report	(Ecoshape, 2018a)
Foreshore Pilot Project for the Houtrib Dike - General Final Report	Unpublished Report	(Ecoshape, 2018b)
How to Bridge the Disciplinary Divide in Implementing Nature-based Solutions: Showcase Pilot Houtribdijk in the Netherland	Conference Paper	(W. E. Penning et al., 2019)

3.2.3.2. Sand Motor Data

The data about this project was collected from the Sand Motor page on the Ecoshape website (Ecoshape.nl, 2020b) and the Sand Motor Website (Dezandmotor.nl, 2020). Furthermore, interviews with experts involved in the project were conducted as well as representatives from Rijkswaterstaat. Table 7 presents the names and affiliations of the interviewees.

Table 7 Names and Affiliations for Interviewees of the Sand Motor Project

Name	Affiliation	Role
Arjen Luijendijk	Deltares	Project Manager for the Monitoring Program
Erik van Eekelen	Deltares	Environmental Engineer
Jasper Fiselier	Retired	Environmental Consultant
Petra Demsma	Rijkswaterstaat	Technical Manager for the Monitoring Program

3.3. Data Analysis

3.3.1. Method of Data Analysis

This research relied solely on qualitative analysis of data using the framework provided in Chapter 2. Methods for data analysis for the required data are presented in Table 8.

Table 8 Data Analysis Methods

Required Data	Method of Analysis
Details about the application of the selected principles in the case studies: -integration of all relevant knowledge. -public participation. -stakeholder engagement. -recognition and minimization of tradeoffs.	**Qualitative:** Confronting with the information identified through the literature study.
Information about how the principles should be applied according to research.	**Qualitative:** Confronting with the collected empirical data about the application of the selected principles.
Experts opinions about how the principles should be applied to ensure they do not pose a challenge for	-
Details about the challenges faced in the implementation of the case studies.	**Qualitative:** Confronting with the challenge categories identified through the literature study.
Categories of challenges for NBS implementation.	**Qualitative:** Confronting with the collected empirical data about the challenges.
Details about how the project team overcame the challenges faced in the implementation of the case studies.	**Qualitative:** Drawing up lessons learned from the challenges faced implementation of sandy solutions in the Netherlands.
Details about the enablers that supported the implementation of the case studies.	**Qualitative:** Confronting with the enabler categories identified through the literature study.
Categories of enablers for NBS implementation.	**Qualitative:** Confronting with the collected empirical data about enablers.

Table 9 shows a visual representation of the analytical framework. The framework was applied to each case to answer the research sub-questions. Furthermore, the data acquired after the application of the framework was used to synthesize the answer to the main research question. The filled-in framework is presented in Appendix B.

Table 9 Visual Representation of the Analytical Framework

Principles	
1. Integration of all relevant knowledge	**How it was applied**
	Notes on application
	Expert opinion
	How it could be improved
2. Public participation	**How it was applied**
	Notes on application
	Expert opinion
	How it could be improved
3. Stakeholder Engagement	**How it was applied**
	Notes on application
	Expert opinion
	How it could be improved
4. Recognition and minimization of tradeoffs	**How it was applied**
	Notes on application
	Expert opinion
	How it could be improved
Challenges	
Challenge 1	**Description**
	How it was overcome
	Category
Challenge 2	**Description**
	How it was overcome
	Category
…	**Description**
	How it was overcome
	Category
Enablers	
Enabler 1	**Description**
	Category
Enabler 2	**Description**
	Category
…	**Description**
	Category

The acquired empirical data about the application of the principles from the case studies was confronted with the data collected from the literature in section 2.1.5. Moreover, the interviewed experts were asked for their opinions about whether they considered the principles to be challenges or enablers and how to apply them to ensure they would support the implementation of the projects. That served to analyze the current application of the principles and draw recommendations to improve the application and thus answer the first two research sub-questions.

The identified challenges faced in the implementation of the case studies were categorized based on the data collected from the literature in section 2.2. That served in identifying the most prevalent category of challenges in the implementation of sandy solutions in the Netherlands where significant improvement is needed. Additionally, the acquired details about how the project teams overcame the challenges served in drawing up lessons learned from the challenges and in answering the third research sub-question.

Furthermore, the identified enablers that supported the implementation of the case studies were categorized based on the data collected from the literature in section 0. That served in highlighting the biggest drivers for the implementation of sandy solutions in the Netherlands so that practitioners could fully utilize them and thus answering the fourth and last research sub-question. Finally, the main research question was answered based on the conclusions drawn from answering the research sub-questions.

3.3.2. Validation of Data Analysis

The data analysis was validated by data triangulation where the same data was collected from more than one source, namely project reports and several interviewees involved in the same project. That method served to validate the data in addition to avoiding any research bias from the author.

3.4. Scientific Ethics

This research project was done in full compliance with scientific ethics norms, specifically those established by the University of Twente and the MEEM Program. Additionally, the research had been submitted for reviewing by the BMS ethical committee and approved. The research involved human participants to provide input through interviews conducted online. The author explained the research topic to the participants and recorded their consent for recording the interviews and the use of the data provided. The recordings were uploaded to the Google Drive of the University's student email University's Google Drive which has a GDPR Privacy Certification and were destroyed as soon as they were transcribed. The transcriptions were destroyed after the completion of the thesis.

3.5. Research Limitations

The effects of the global pandemic of COVID-19 and the accompanying psychological distress to the author were one of the main limitations in this research. As for the limitations in the research design, the thesis relied on cross-checking the published principles of some NBS-related approaches to provide more validation for the topics. Nevertheless, not all NBS-related approaches were considered due to time restrictions. Furthermore, the selected cases were implemented on public lands and had the same objective of flood defense. Including a solution implemented on private lands or having a different objective could have provided an insight on how those projects apply the principles. The reason behind the limitation, however, was that the sandy solutions for flood defense implemented by the Rijkswaterstaat were all large-scale and did not involve privately-owned land. Finally, the unwillingness of some of the contacted interviewees to participate in the research due to busy schedules was another limiting factor. In fact, it was one of the primary determinants for the selected case studies. Originally, the research was designed to study a higher number of cases, however, due to the lack of available interviewees, only two were considered. Nonetheless, considering only two cases made it possible to provide a more in-depth analysis.

4. Results

This chapter presents the results of running the two case studies through the analytical framework. The information included in this chapter is presented as elicited from the interviewed experts and the documents that were available about the two cases. The following subsections provide the answers to the research sub-questions. Chapter 5 presents an analysis of the findings and a synthesis for the answer to the main research questions.

4.1. The Houtrib Dike Case

The Houtrib Dike (in Dutch: Houtribdijk) connects the city of Lelystad to the city of Enkhuizen. Despite being designed to serve as a dike and being called one, the Houtrib Dike is a dam as it separates two water bodies: the Ijsselmeer and the Makkermeer. It serves as a breakwater between the two lakes during storms and thus protects the Ijsselmeer region from floods. After years of wear and tear, the dike was set to undergo reinforcements for failing to meet the safety requirements laid down by the Water Act (Ministry of Infrastructure and Water Management, 2010).

In 2016, the Rijkswaterstaat created a plan for the dike reinforcement with a main objective of flood safety. The plan included traditional hard solutions as well as some NBS. As shown in Figure 2, the plan consisted of three parts. The first part was the creation of Trintelzand, a natural reserve along the dike consisting of sand and mud flats to support life forms that enhance the water quality and improve the biodiversity and aesthetics of the area. The second part of the plan relied on sandy solutions by creating sandy banks along half the length of the dike starting from Enkhuizen. That solution served to dissipate waves and to support animal and plant growth. The third and last part of the plan was the traditional engineering solution involving the use of quarry stones and poured asphalt protecting the other half of the dike from Lelystad to midway along the dike's length. This thesis only considers the sandy foreshore, the second part of Rijkswaterstaat's plan.

Using sandy foreshores in saltwater bodies has been gaining wide popularity in research. However, sandy foreshores in a lake environment had never been studied before. That was why before the full-scale implementation of the solution, a pilot project was started, with Rijkswaterstaat as the main stakeholder funding most of the project. The pilot project covered a small part of the length of the dike (400 m) and had a width of 150 m. The pilot project mainly aimed at testing the effectiveness of the solution and understanding its behavior.

Figure 2 The Plan Presented by Rijkswaterstaat to Reinforce the Houtrib Dike
Source: Rijkswaterstaat (2019)

The information in this section is about the pilot project in addition to the full-scale sandy reinforcement of the dike. The pilot directly affected the planning for the full-scale implementation. Additionally, the findings from the pilot served to shed light on the transition that NBS go through from ideation to realization. However, due to the nature of the pilot project and its main purpose being for scientific validation, some of the principles were not applied. The conclusions that would be derived from the findings about the pilot project would not serve to answer the main research question. Thus, the findings from the pilot projects were not further discussed in chapters 5 and 6.

4.1.1. Principles

1. Integration of all relevant knowledge

The Houtrib Dike is a man-made structure in the middle of the water. Hence, there are no residents in the area. However, there were local experts in the area, namely the operators of the dike. At the time of the implementation of the pilot, Mr. Hans Vos from Rijkswaterstaat carried that role. In the interview with him, he mentioned that the only role he played in the pilot was to help in determining a suitable location for it. He was not consulted further for the pilot. Thus, the pilot did not apply that principle. However, the pilot project team experts argued that the principle was of little relevance to the implementation of the pilot as it was a temporary development set to test the behavior of using a sandy solution in a lake environment and develop scientific knowledge.

For the full-scale implementation, Mr. Rinse Wilmink, the manager of the monitoring program for the full-scale implementation, mentioned that in terms of consulting local residents, the principle was irrelevant due to the remote location of the dike. However, he confirmed that the project team relied on the inputs of the local asset manager of the dike, a successor of Mr. Vos. Therefore, the project did utilize local expert knowledge.

The rest of the experts agreed that in the case of the sandy reinforcement of the Houtrib Dike, that principle was not fully applied due to the remote location of the dike and the innovation of the solution itself. Consulting local managers was deemed sufficient for the aims of the pilot and the full-scale implementation. However, in the case of other projects where local knowledge is available, they agreed that it should be included in the project. At the same time, they argued that the local knowledge should be confirmed with science to be considered. Mr. Wilmink added to that that while local observations are always valid, the explanations for the observations require scientific verification.

2. Public participation

The pilot project covered a small portion of the length of the Dike. The location was midway through the dike and far away from any buildings or residents. In fact, according to Mrs. Penning, that location was specifically selected to be remote from the public. Furthermore, as the pilot was considered a test for the technical aspects of the NBS, it was to be removed after its lifetime of four years was over. So, arguably, even if it did pose some inconveniences for people using the Dike, they would be minor and temporary. Thus, according to the experts, there was no need to consult the public before implementing the pilot.

On the other hand, for the implementation of the full-scale NBS, public participation was essential. A Rijkswaterstaat employee, Mrs. Van Konijnenburg, was responsible for informing the public about the dike and collecting any ideas for improving the project or demands they might have. Earlier on in the planning phase, an advertisement was placed in the local newspapers for the two cities, Lelystad and Einkhuizen with an invite to an open discussion about the project. The number of attendees was very low, according to Mrs. Van Konijnenburg. Additionally, the plans for the dike improvement have been on the Rijkswaterstaat website along with the dates when the dike would be closed for the construction works. From Krywkow's model (2009), the levels of public participation applied for the project were the first two: information provision and consultation.

The Dutch public organize themselves into groups sharing an interest about a specific topic, such as nature conservation or cycling. For the Houtrib Dike full-scale implementation, one of the interested parties that attended the open invitation meetings, the fishermen, were later considered a non-implementing stakeholder, as the project would directly affect their livelihoods. Another interested party was the kite surfers who requested that a small beach would be created for them along the dike. That suggestion was taken into consideration and implemented in the full-scale project.

All the interviewed experts emphasized the importance of the principle and of applying it from the early onset of the project as it has the potential to present many problems when ignored, such as unclear identification of stakeholders. Mr. Jasper Fiselier, a retired consultant who was involved in the implementation of both the pilot and the full-scale Houtrib Dike, mentioned that the importance of public participation and its impact on a project depend on the main objective for the project. For the Houtrib Dike, the reinforcements had to be carried out for flood safety. The only impact the public would have would be minor as the safety and design standards already determine much about the project.

3. Stakeholder engagement

The pilot project involved many implementing stakeholders from the national government (Rijkswaterstaat), and the Ecoshape Consortium which includes Deltares, Arcadis and Van Oord among others. The Rijkswaterstaat was the main funding partner for both the pilot and the full-scale implementation. The Rijkswaterstaat is a hierarchical governmental multi-level organization and several of those management levels were involved in the project. Implementing stakeholders were updated in progress meetings that took place once every three months. Non-implementing stakeholder identification was the responsibility of the Rijkswaterstaat as the main implementer. As mentioned earlier, for the pilot project, public participation activities were deemed irrelevant and thus, non-implementing stakeholders were not identified. Nonetheless, despite not being involved in the implementation, the municipalities were considered among the stakeholders for the project in that they were updated frequently and invited to progress meetings.

As for the full-scale implementation, the experts confirmed that principle was applied well in terms of engaging implementing stakeholders. That included Rijkswaterstaat and the municipalities of Lelystad and Einkhuizen in addition to external implementing companies. The power held by them was less than that of the Rijkswaterstaat who held the decision-making power, according to the experts. For example, Mr. Wilmink mentioned that the sandy solution was demanded by the municipality of Lelystad to enhance recreation in the municipality. However, the Rijkswaterstaat did not consider the solution until they believed that it was at least as cost-effective as traditional solutions.

When considering the non-implementing stakeholders for the full-scale implementation, the identification was carried out by Rijkswaterstaat. As mentioned in the previous section about public participation, through the open meetings, the non-implementing stakeholders were identified and were invited to more frequent meetings for communication. For the Houtrib Dike full-scale implementation, the main non-implementing stakeholders were the fishermen as they would not be allowed to fish during implementation. Mrs. Van Konijnenburg mentioned that the fishermen influence was minor since their permits mandated them to relocate in the event of infrastructure works in the Markermeer. Thus, the implementation did not rely on their approval of the project. Nonetheless, Mrs. Van Konijneneburg confirmed that they were informed about the details of the project and how it would affect them.

The experts agreed that the principle represents an enabler since it provides support for the project from more than one source, especially from implementing stakeholders. Mr. Steetzel added that even in the case of having stakeholders who are critical of the project, the principle presents an enabler in that it forces the project team to address the concerns of those stakeholders. That, in turn, makes the planning phase even more comprehensive. Furthermore, in the Netherlands, failure to involve non-implementing stakeholders, according to Mrs. Konijnenburg could result in lawsuits that have the potential to stop the project completely. That is in accordance with the Dutch General Administrative Law Act cited in section 2.1.5.

4. Recognition and minimization of tradeoffs

This principle was not specifically relevant for the pilot, since its purpose was to learn more about the system and potential negative impacts. The pilot did not apply the principle due to the nature of the project and its scale which was believed to be too small to pose any serious negative impacts. Additionally, any unexpected impacts arising in the pilot were considered to be lessons for the full-scale implementation. For example, Mr. Steetzel mentioned that one of the negative impacts of the solution was that the sand was blowing on the road, so it had to be stabilized by adding a coating of clay on.

The fact that a pilot had been done in advance to test the solution implies that for the full-scale implementation, the planners were well-aware of the potential negative impacts of the project, how to mitigate them, and the short-term costs. However, Mr. Fiselier mentioned that the lifetime for the pilot was too short to learn everything about the system, and therefore monitoring was still needed for the full-scale implementation. He added that the full-scale implementation is considered a continuation for knowledge development about the solution. At the time of the data collection, the full-scale implementation was just concluded. Thus, the extent of the minimization of tradeoffs by the project team could not be assessed as the operation time was not sufficient for any potential negative impacts to be observed.

Mr. Fiselier mentioned that the full-scale implementation of the sandy solution along the shallower half of the dike was cheaper than the traditional engineering solution. The long-term benefits were numerous as with most NBS projects, and the project team was aware that they could turn out to be higher than those in the objectives. Thus, the implementation of the project was not constricted by financial matters. That, according to him, supported the implementation of the full-scale project.

With regards to simplifying ecosystems for financial or other considerations, Mrs. Penning believed that decision-makers need to be aware that the initial cost-benefit analysis is not certain since most ecological benefits cannot be valued in monetary terms. Additionally, ecological systems are dynamic, and therefore unexpected benefits could arise that were unaccounted for in the planning phase.

4.1.2. Challenges

The main challenges in the pilot project were in the planning and startup phase. Getting decision-makers to agree to implement the project was one of those challenges, according to Mr. Steetzel. The team managed to overcome that challenge by identifying the common concerns and addressing them in the plan. Additionally, according to Mrs. Penning, there was a challenge due to the interdisciplinary nature of the project, which involved ecologists, civil engineers and hydrologists among other experts. Each of those fields have their own technical language. Therefore, it was very important to familiarize experts from other fields with common terminology that would be used frequently within the project reports. Mrs. Penning mentioned that that challenge was overcome as, over time, the experts became familiar with the terminologies used by different experts.

As mentioned in the section about recognition and minimization of tradeoffs, one of the challenges for the pilot was that the sand was blowing off onto the road. In the case of the pilot, the solution to that problem was to put a windscreen on the road. However, for the full-scale implementation, installing a windscreen along the dike length was not feasible. The dike had been closed on several occasions due to stormy conditions. That, in turn, has led the operators of the dike to request that the sand be covered by a layer of earth which would serve in holding on to the sand until the vegetation is established and can do that function.

As for challenges facing the implementation of the full-scale project, Mr. Steetzel mentioned that the main barrier was the amount of sand required and the method of placing the sand. Mr. Fiselier elaborated on this issue, saying that the project team did not manage to receive a permit to collect sand from the Ijsselmeer, and therefore they had to move it across the dike. Moreover, they were not allowed to use large dredging machines so as not to disturb the birds using the lake, so it took even longer to collect the sand for the reinforcement. Thus, the challenge was caused by the permitting procedures in the country.

Another challenge was that the scale of the pilot was much smaller than the full-scale implementation and the duration of the pilot was too short to obtain all the results needed for the implementation of the full-scale project. Both of those challenges resulted in limited understanding about the system and uncertainties about its effectiveness. The solution for that challenge was the continued extensive monitoring for the NBS.

Mr. Wilmink mentioned that uncertainties about the system's behavior were one of the biggest challenges that they still had not overcome. However, the way to overcome that challenge, in his opinion, was to be aware of the aspects that have uncertainties and plan to mitigate them as they pose problems. A longer duration for the pilot would have helped eliminate some of the technical uncertainties. However, the pilot team could not receive the approval for longer time or more money. The government was adamant on implementing the full-scale solution which would, consequently, destroy the pilot.

4.1.3. Enablers

According to the pilot project team, the main enabler for the implementation of the pilot was that some of the decision-makers were enthusiastic about the project. Their support helped receive the approval of the rest of the decision-makers. Furthermore, according to Mrs. Penning, one of the main enablers for the pilot was the relationships between the pilot project team members outside of work. She believes that building the team spirit played an important role in the success of the project.

Governmental support was identified by all interviewees to be the most significant enabler for the full-scale implementation project. Mr. Fiselier and Mr. Wilmink added that that support was due to the cost-effectiveness of the solution that was coupled with more long-term benefits than traditional solutions.

4.1.4. Summary of the results from the Houtrib Dike case

As shown above, the pilot project was different from the full-scale implementation project. Some principles were not applied in the pilot such as the integration of all relevant knowledge, public participation and recognition and minimization of tradeoffs. The experts deemed these principles irrelevant to the nature of the project and its scale. The arguments to support their belief were that the pilot aimed to develop the scientific knowledge for the solution; it was located in a place where it would not affect the public; and its objective was to test the solution to understand more about the tradeoffs. As for stakeholder engagement, the pilot involved mainly the implementing stakeholders that were involved in the research without identifying potential non-implementing stakeholders.

On the other hand, the full-scale sandy reinforcement of the Houtrib Dike applied all principles up to an extent. Local experts were consulted in developing the solution however, the area was remote from any residents. Public participation activities were carried out where the public was informed and consulted in the early planning phases of the projects. Nonetheless, the number of attendees was low. The public participation activities resulted in identifying the non-implementing stakeholders who were updated about the solution frequently. The project involved all implementing stakeholders and the identified non-implementing stakeholders. However, their power to influence decisions was less than Rijkswaterstaat, the main funding entity. Finally, the pilot helped uncover some of the negative impacts of the project and helped prepare for them in the full-scale implementation. Nonetheless, it was too early in the project life to assess whether the solution would run into unexpected hurdles.

For the pilot, the main challenges were present in the startup phase where the decision-makers had to be convinced to implement the project. Additionally, there were several technical challenges that also arose during the pilot. Those challenges, when overcome, improve the planning for the full-scale implementation.

The main challenges for the full-scale implementation were related to the uncertainties about the system. Adaptive management was introduced by one of the experts as the way to overcome the problems posed by those uncertainties as they emerged. Additional challenges were related to obtaining permits which resulted in technical challenges of acquiring the large amounts of sand. The main enabler for both the pilot and the full-scale implementation was governmental support.

4.2. The Sand Motor Case

The Sand Motor, also referred to as "the Sand Engine", is located in the Province of South Holland in the west of the Netherlands. Considered as an innovative approach to combat coastal erosion, the Sand Motor involved the placement of a large amount of sand before the beach in the shape of a hook. The concept was that the natural driving forces of the waves would help spread the sand and nourish the beach for a duration of two decades. Prior to the Sand Motor, beach nourishment activities were carried out every five years.

Like the Houtrib Dike, the Sand Motor was also a pilot project, albeit on a much larger scale. The project aimed to test the concept of using natural driving forces to spread sand across the coast resulting in a slowed beach nourishment replacing frequent beach nourishment. An additional consequence of placing a large amount of sand would be the creation of a peninsula above the water. That peninsula would serve to attract migrating birds, grow vegetation and provide space for recreational activities for the public. Thus, the main objectives of the project were in the areas of safety, nature and recreation.

The construction of the Sand Motor was completed in 2011. The development of the project was monitored for the changes in the morphology of the peninsula to confirm the validity of the models used in planning. Additionally, the ecological development in the area and the behavior of the visitor to the leisure areas were monitored. Figure 3 depicts the evolution of the Sand Motor since its construction in 2011 up until 2016.

Figure 3 The Evolution of the Sand Motor since its Construction in 2011
Source: Dutchwatersector.com (2016)

4.2.1. Principles

1. Integration of all relevant knowledge

As a pilot, the Sand Motor aimed to prove the feasibility of the solution. Before the Sand Motor was implemented, the beach was mainly used for recreational activities. Although, it was one of the less crowded beaches due to its rapidly changing currents, according to Mrs. Damsma, the technical manager of the Sand Motor monitoring program from Rijkswaterstaat. The experts argued that there was no relevant local knowledge from the residents because the concept of the solution was new, and the project was implemented to develop knowledge about the system.

Mr. van Eekelen raised the point that in the Netherlands, most knowledge is well-documented in databases. Those databases contain information and observations about the Dutch Coast and is updated yearly, according to Mrs. Damsma. So, while the knowledge about the tides or wave intensity is collected by local managers, it is documented and those specific people do not have to be consulted, as Mr. Eekelen argued. However, according to the interviewed experts, the local experts indeed were consulted in the early planning phases of the Sand Motor. The local experts included water managers responsible for monitoring and maintaining that region of the Dutch Coast from the government.

The experts agreed that the principle is important to include when it is relevant and applicable. The Sand Motor was considered a pilot to develop the knowledge about the system, and thus the principal was of little relevance, according to the experts. Additionally, they believed that for the Sand Motor, and most large-scale flood defense projects in the Netherlands, the locals merely reside in the area and do not necessarily have knowledge about the ecosystem. That knowledge resides with governmental departments responsible for monitoring various aspects of the ecosystems. Thus, including those local experts in the planning phases and referring to information databases is how the principle is usually applied in projects in the country.

2. Public participation

The Sand Motor received a lot of media coverage for being the first of its kind and consequently, public interest in the project was high. According to the experts, the information sharing about the project took place on a large scale. From early in the project planning, there were open markets for gathering ideas or demands and other formal procedures that enabled individuals and groups to share their thoughts on the project, such as workshops. An example of such demands that were met included a bike path requested by the cyclist group. The people were invited to the open nights through advertisements in the local newspapers. Mr. Fiselier confirmed that many people attended those events.

One reason for the Sand Motor's popularity was that it had recreation as one of its objectives, and therefore, the public had interest in the project. Mrs. Damsma added another reason for the public interest in the project which is the innovation of the solution and the extensive media coverage. She mentioned that the media coverage lasted through the planning, implementation and early monitoring phases. The media coverage has significantly decreased after the first few years of monitoring, however, the public is still kept informed about the Sand Motor through the official website and the occasional newspaper articles about important updates. From Krywkow's model (2009), the levels of public participation that took place in this project were information provision and consultation.

Despite the public interest, Mr. Fiselier mentioned that the public influence in the project was considered secondary to technical and regulatory considerations. The public demands would only be considered in auxiliary aspects of the project, such as the details of the recreational activities that could be achieved by the project. Furthermore, he mentioned that in most cases, public demands are related to personal interest instead of common wellbeing or even environmental considerations.

The experts agreed that public participation is an essential part of planning. Furthermore, they refer to the fact that public participation helps avoid future prosecution through stakeholder identification as mentioned in section 2.1.5. Inviting the public for an open discussion about the project helps the project team understand the expectations of the public and consequently, improve the design to serve those expectations, if possible.

3. Stakeholder engagement

Figure 4 shows the main partners of the Sand Motor which include many implementing stakeholders and some non-implementing stakeholders such as Dunea, the drinking water company. The project was mainly funded by the Rijkswaterstaat and the Province of South Holland.

Figure 4 The Partners of the Sand Motor
Source: Baltissen et al. (2016)

The implementing stakeholders were involved since the early stages of the planning, and therefore, they had the opportunity to influence the design. They were all working towards the same goal, but with different specific objectives. For example, Rijkswaterstaat was more interested in the safety and the innovation of the solution while the Province was more interested in the additional recreation space created by the project. However, those objectives were not conflicting, and they could all be achieved through the NBS. Additionally, the national and regional government were both funding the project so their influence on decision-making was close-matched. The collaboration between all these stakeholders went smoothly, according to the experts.

As for the non-implementing stakeholders, Mrs. Damsma mentioned Dunea, the drinking water company in the project area. While not being directly involved in the implementation of the solution, the company was invited to the planning table and was able to raise some concerns relating to the quality of the groundwater within the area. These concerns were addressed by the project team in that the groundwater levels and quality were monitored to detect any changes and mitigate them in due time. On the other hand, the interviewed experts did not believe that the public participation activities resulted in identification of specific public groups that would be affected by the solution and would require more frequent consultation.

The experts all agreed that the principle is an enabler, as it plays a role in getting the solution accepted and the involved stakeholders share a sense of ownership over the project.

4. Recognition and minimization of tradeoffs

As mentioned, the Sand Motor was a large-scale pilot project that served, primarily, to test the solution. Mr. van Eekelen said that the project team carried out an extensive environmental impact assessment that took into consideration the short-term impacts. For example, one of the negative effects of the solution was that the placement of such large amounts of sand would disturb benthic creatures. However, the Sand Motor was meant to replace frequent nourishment activities. So, the benthic creatures would be disturbed during the implementation, but they would be allowed to develop for many years as the Sand Motor operates. That was a significant improvement compared to frequent nourishment, which would disturb the creatures every five years.

However, according to Mr. Eekelen, one of the main concerns that were overlooked during the planning of the project was swimmers' safety. In the early phases of the operation of the project, the flow velocities in some areas in the peninsula would be high which would pose risks to swimmers in the area. In fact, people had already drowned because of that. The project team quickly rectified their mistake by modelling the flow over large periods of time. The modelling study allowed them to identify when it might be dangerous for swimmers. Those times were communicated to lifeguards in the area via mobile apps created solely for that purpose.

The interviewees confirmed that the team had very few financial restrictions. The project was funded from the flood protection fund in addition to the innovation fund by Rijkswaterstaat. Furthermore, the province of South Holland provided funding for the project. Given the extensive funding, the Sand Motor was not designed in the most cost-efficient way. Mr. Fiselier mentioned that a smaller amount of sand could have served to achieve the main objective for the project which was the safety; but the team chose to use a larger amount was more likely to achieve more benefits both environmentally and relating to recreation. Thus, the high costs did not restrict the implementation of the project.

The experts considered the principle to be a requirement for sound planning. Regarding financial considerations, Mr. Fiselier mentioned that cost-benefit analyses is an important decision-making tool and should be carried out more than once during the project life cycle with varying focus and level of details. However, better valuation for environmental benefits is needed to improve cost-benefit analyses.

4.2.2. Challenges

The Sand Motor, like many NBS, had various uncertainties relating to its efficiency due to the dynamic nature of the ecological aspects of the solution and the innovation of the solution. The uncertainties were related to how exactly the system would behave and how long the provided flood protection would last. These uncertainties posed a challenge to the project team who had to leave room for them in the planning. The project team understood that they could not possibly identify the exact behavior of the system and thus, were taking on an observatory role as with most pilots. On the other hand, the North Sea Region had been extensively studied for decades, creating ample scientific knowledge about the behavior of the coastal system and its various components. That knowledge and proper planning helped overcome some of the challenges posed by uncertainties both for the project team and decision-makers.

Another one of the challenges that faced the Sand Motor was swimmers' safety, elaborated on in the section about recognition and minimization of tradeoffs. Another challenge mentioned by Mr. van Eekelen was the difficulty in defining the finance streams. That was a challenge mainly because the benefits obtained from the project had no monetary value. It was difficult for the team to identify a revenue stream because the project had intangible benefits, rather than monetary ones. However, for the Sand Motor, that challenge was minor, since the project had a large budget from multiple funding sources.

4.2.3. Enablers

According to Mr. Fiselier, the main enabler for the Sand Motor was governmental support. The national and provincial governments were very enthusiastic about the project. For example, the Province's objective of creating a recreational area led them to contribute more funding to the project to achieve its demands. That helped the implementation of the project in its current scale. Additionally, Mr. van Eekelen mentioned that the working environment in the Sand Motor project was very supportive of the innovation. The stakeholders and the project team were all aware of the importance of actualizing that idea and had, thus, worked hard to make it happen.

4.2.4. Summary of the results from the Sand Motor case

The Sand Motor Project applied all the principles to an extent. The project team consulted local experts from the area and utilized the databases containing measurements and observations about the area. Residents in the area were not consulted, however, as their input was deemed unnecessary by the experts. Public participation efforts in the early planning phase included open markets with open invitations for consultation in addition to information dissemination through various sources. The project had many partners that were involved in the design and implementation. Additionally, non-implementing stakeholders, such as the water company, were also involved in the planning phase. The interviewed experts did not provide information about the identification of public groups as non-implementing stakeholders through participation activities. Finally, the project team had no financial restrictions and were well-prepared to mitigate the negative impacts of the projects. Yet, they overlooked one important aspect which was swimmer's safety and had to rectify their mistake after implementation.

The main challenge for the project was due to the uncertainties in the system relating to how it behaves. Those uncertainties posed a challenge to both implementers and decision-makers. However, the project was seen as an opportunity to learn more about the behavior of the system and eliminate some of the uncertainties. The government and the actors were all aware of the impact that innovation would make and thus the project had received funding and support. That was the main enabler for the project.

4.3. Improvement of the Application of the Principles

Sections 4.1 and 4.2 discussed the findings from the case studies thus answering the first, third and fourth research sub-questions. This section presents potential areas of improvement for the principles based on the opinions of the interviewed experts and thus answering the second research sub-question. Suggestions for the improvement of those areas are presented in chapter 5.

The first principle was about the integration of the all relevant knowledge. The experts agreed that the principle was of little relevance in the country due to the lack of relevant knowledge held by the local residents or lay people. The principle was applied through inclusion of local experts except in the case of the pilot. Thus, potential improvement for the principle would be through utilizing the knowledge of the lay people.

The second principle was about public participation. The experts agreed that the application of the principle is important in the identification of stakeholders, avoiding future conflicts and adjusting the design to the expectations of the public. The main limiting factor in the application of the principle was due to the lack of interest of the people in attending the public participation activities organized by the government. Thus, increasing public interest would improve the application of the principle.

The third principle was about stakeholder engagement. Non-implementing stakeholder identification takes place through the public participation activities. Through improving the application of those activities, stakeholder engagement would be improved. Additionally, improved stakeholder mapping through contemporary techniques would serve to improve the application of the principle.

The fourth and last principle was about recognition and minimization of tradeoffs. The tradeoffs arose when an impact was overlooked in the impact assessments. Thus, refining the requirements for those assessments for NBS projects, specifically, would improve recognition of tradeoffs. Additionally, better valuation of ecosystem services would significantly minimize tradeoffs due to financial considerations.

5. Discussion

Chapter 4 presented the results from the analysis of the collected data regarding the two cases. The data from the previous chapter served to answer the research sub-questions. This chapter further discusses the data in the previous chapter, refining the answers to the research questions and synthesizing the answer to the main research question. Appendix B presents the table showing the overview of the answers to all research sub-questions. Based on the information presented in this chapter, the recommendations and the answer to the main research question are presented in chapter 6.

The Houtrib Dike Pilot and the Sand Motor differ in their application of the principles despite both being considered as pilots. The Houtrib Dike pilot conforms more to the definition of a pilot in being on a relatively smaller implementation scale in addition to being followed by a "full-scale" implementation unlike the Sand Motor. The experts interviewed for the Houtrib Dike case all agreed that the pilot did not help the team learn everything they needed to know for the full-scale implementation. Furthermore, they consider the full-scale implementation as an ongoing experiment on whether the solution works. On the other hand, the full-scale implementation for the Houtrib Dike has several commonalities with the Sand Motor case in terms of the application of the principles. Section 5.1 discusses the commonalities and differences between the application of the principles for the two cases. Based on that discussion, several recommendations were developed for addressing the improvement areas mentioned in section 4.3.

5.1. Principles

5.1.1. Integration of all relevant knowledge

As mentioned in section 2.1.5, there are no "indigenous" people in the Netherlands in the literal definition. For this thesis, the principle's definition was revised to refer to consulting local experts and residents in the project area. The fact that such revision was needed suggests that the IUCN's principles need modifications to better represent all NBS. Nonetheless, the mismatch between the literal definition of the principle and its application in the Netherlands does not imply that the principle is irrelevant or unnecessary. All interviewed experts agreed that the principle is essential in countries where it is applicable. Experts involved in the implementation of NBS in the Global South, specifically, emphasized the importance of utilizing the knowledge held by the locals after validating it with science.

The application of the principle in all case studies involved only consulting local managers in addition to referring to databases that contain measurements and observations and are updated yearly. One of the interviewed experts argued that the existence of such databases makes consulting even local managers obsolete since all their observations and activities are recorded. However, that overlooks the role played by practical experience. Indeed, Pusca et al. (2017) support the idea that hands-on experience is essential in engineering projects as it decreases the gap between theory and implementation.

Another contributor to the limited application of the principle was that the projects were pilots aimed at developing and validating scientific knowledge. That meant that the solutions were never implemented anywhere, and the residents and local managers would offer no more knowledge about the solution than the project team. That contributor is evident in the case of the Houtrib Dike Pilot project where the local managers were only involved in determining the pilot location. Nonetheless, while the local managers' knowledge about the solution was limited, their knowledge about the project and the area was more than that of the project team given their practical experience.

None of the cases applied the principle in terms of consulting local residents or lay people in the area. The experts argued that lay people had no knowledge to offer large-scale governmental flood defense projects. However, as mentioned in section 2.1.5, lay people and their knowledge are essential. It was also argued that any knowledge held by lay people could be presented in the public participation activities organized. While that is true, the lack of interest in attending those activities could limit utilization of lay people's knowledge. Thus, to improve the application of this principle, public participation needs to be improved to offer lay people an opportunity to share their knowledge. Additionally, improving the involvement of local experts and the power they have to influence decisions would also serve to improve the application of the principle.

5.1.2. Public participation

The Sand Motor and the full-scale Houtrib Dike implementation applied public participation through open invitations for open meetings in the newspapers during the planning phase. However, that those were carried out on a larger scale for the Sand Motor than the Houtrib Dike due to increased public interest in the project. That interest was mainly due to extensive media coverage which was not the case for the Houtrib Dike. The first was advertised as an innovative solution to replace traditional sand nourishment and at the same time provide social and environmental benefits, while the latter was advertised mainly as a flood safety project without much emphasis on the social and environmental benefits. That was further evident in the specialized website for the Sand Motor as opposed to the page dedicated to the Houtrib Dike Reinforcement on the Rijkswaterstaat website.

The levels of public participation for both projects were limited to information provision and consultation according to Krywkow's (2009) model. According to that model, public participation would be improved by increased involvement of the public and their opinions through organization of more interactive activities. However, in the two case studies, the main objective was flood safety, so they aimed at overall public wellbeing and protection. The projects were on public lands which were owned by the government who was also the implementing entity of the projects. Additionally, the decisions about the projects were limited by design and safety considerations. Therefore, the level of public participation and the public influence on decision-making could not have been increased for the case studies due to those limitations.

The interviewed experts agreed that public participation is essential for project implementation as it helps avoid future conflicts and increases public acceptance. Their comments reflected they believed the proper application for public consultation was through information provision and consultation. Their arguments supported Wamsler et al.'s (2020) statements that public demands mainly stem from personal interests instead of environmental concerns which could impede sustainability.

As mentioned in section 4.3, the application of the principle could be improved through stimulating public attendance to the open meetings through educating the public about the environment, increasing their interest in sandy solutions or NBS generally. Furthermore, improving information dissemination about the project and its implications for the public could increase public interest in attending the meetings. The information dissemination could be improved through media coverage in addition to making the information more accessible to the public through the internet. An example for that is advertisement about the project on social media platforms and creating a specific website for the project where people can learn about it. Finally, public participation would be potentially improved through utilizing modern technology such as Smartphone Applications to promote digital participation in lieu of physical.

5.1.3. Stakeholder engagement

Both projects provided good examples of the inclusion of implementing stakeholders. As entities and individuals directly involved in the implementation, their support for the projects was essential. As for the non-implementing stakeholders, their identification mainly took place through the public participation activities. The groups who would be more affected than others by the solution were contacted more frequently and informed about updates about the projects more than "the public". The role to identify and communicate with these groups was taken by a stakeholder manager from Rijkswaterstaat for both the Houtrib Dike full-scale implementation and the Sand Motor.

However, as mentioned by one of the experts, for the Houtrib Dike full-scale implementation, the fishermen as non-implementing stakeholders did not hold the power to challenge the decisions. Even if they wished to take legal action against the implementation, they could not as their permits specifically required them to stop fishing in case of maintenance or constructions in the lakes or the dike. On the other hand, the drinking company as a non-implementing stakeholder for the Sand Motor had concerns about water quality and level. Those concerns were addressed by the project team who placed monitoring wells to be able to detect and quickly mitigate any unfavorable changes. The difference in decision-influencing power between the two groups suggests that the opinions of non-implementing stakeholders are only considered when they have the power to halt the project not when they are burdened by it.

The recommendations for public participation would serve to improve stakeholder engagement. This is because currently, public participation activities help in identifying non-implementing stakeholders. As mentioned earlier, the public interest in attending the public participation activities is not high. Thus, potential non-implementing stakeholder groups could be unaware about the details of the project and its potential impacts on them. This may result in these groups being marginalized or overlooked. An additional recommendation to improve the application of the principle would be through employing different non-implementing stakeholder identification techniques, as mentioned in section 4.3. For example, the framework for stakeholder mapping created by Meglio (2019). Furthermore, non-implementing stakeholder groups need to be fully compensated for their burdens even if they do not have the power to take legal actions against the project. That would promote equity and fairness which would, consequently, improve the acceptance for the project.

5.1.4. Recognition and minimization of tradeoffs

Both the Sand Motor and the full-scale implementation of the Houtrib Dike applied the principle through conducting environmental and social impacts assessments as mandated by Dutch law (Ministry of Infrastructure and Water Management, 2012). The construction for the Houtrib Dike was only recently completed in 2020. Therefore, the assessment of the conducted impacts assessment was not possible. Meanwhile, the Sand Motor team overlooked one essential consideration, swimmer’s safety. This shortcoming could be because the authorities set general requirements for those assessments that are not specifically for NBS projects. Upon discovery of the problem, however, the project team immediately took the necessary actions to mitigate it as they employed adaptive management according to one of the experts.

Neither of the two case studies faced financial restrictions that led to decisions that would compromise the created ecosystem or its ability to evolve. In fact, the Sand Motor was not designed in a cost-effective way as the increased budget would lead to more environmental and social benefits. The sufficient funds were secured mainly due to the innovation of the solutions. However, in the future, when sandy solutions are considered less innovative, that could pose restrictions to the implementation.

As mentioned in section 4.3, the application of this principle could be improved through utilizing adaptive management to accommodate the uncertainties associated with NBS that cannot be fully planned for in the planning phase of the project. Adaptive management would also facilitate overcoming unexpected impacts as soon as they arise so they would not create tradeoffs. Additionally, the creation of ecosystem services valuation systems would result in a better balance between the complete costs and benefits of the project which would lead to informed decisions. Furthermore, the requirements for the social and environmental impact assessments need to be modified for NBS projects, specifically. Finally, both projects received funding for their innovation and their role in flood defense. However, there should be a special funding scheme for NBS projects for their environmental benefits. That would ease some of the pressure off project managers trying to cut down expenses and consequently, potentially compromising the ecosystem.

5.2. Challenges

The challenges mentioned by the experts stemmed from the uncertainties about the solutions and how they would behave. Unlike stable engineering structures, which are designed to minimize risk, NBS are dynamic and not fully predictable (Somarakis et al., 2019). Meanwhile, decision-makers in charge of public money aspire to make decisions with as little uncertainty as possible

(OECD, 2017). The report published by the OECD (2017) helps decision makers improve risk governance and introduces guidelines for decision-making under uncertainties. However, the gap between theory and practice still needs to be bridged. The interviewed experts confirmed that the uncertainties made it harder to get decision-makers' support for the projects in the initial phases. So, while uncertainty about the system is considered a hybrid barrier by Sarabi et al. (2019), it gave rise to some socio-institutional challenges relating to regulatory structures and institutional setup.

Other challenges mentioned by the interviewed experts were technical challenges. Those challenges were more prevalent than average due to the nature of the projects being never-implemented-before pilots aimed at studying the solutions and exploring potential negative effects. Thus, the hybrid challenge of uncertainty about the behavior of the system was also to blame for the technical challenges in the case studies. Sarabi et al. (2019) did not include a separate category for technical challenges as it was out of scope of the paper. Nonetheless, the interviewed experts primarily mentioned technical challenges when asked about the main challenge faced in the project. That could be attributed to the fact that most of the interviewed experts were involved with the technical aspects of the projects.

As mentioned in the section about recognition and minimization of tradeoffs, the project teams overcame the challenges relating to uncertainties in two main approaches. The first was through proper planning for the projects, studying the location and the system, recognition of all potential negative impacts and planning for their mitigation. The second was through employing adaptive management which was evident with the swimmer's safety incident with the Sand Motor. Those two approaches also managed to reassure decision-makers that the team would be prepared for potential risks which helped overcome some of the regulatory challenges.

The Houtrib Dike full-scale implementation encountered a challenge related to permitting when trying to dredge sand from the Ijsselmeer. The permitting authority believed that the dredging activities would disturb the benthic creatures and the birds in the lake. While that was a challenge for the project team who had to look for an alternative way to acquire the required sand, from an ecological perspective, that was a sound decision.

Another challenge was due to the short lifetime of the Houtrib Dike pilot which limited the findings from the pilot since biological processes usually take a long time to establish and start developing. The reason for the was that the plans for the full-scale implementation were already set by the government and the pilot had to be destroyed during construction. Thus, a socio-institutional challenge improper planning by the Rijkswaterstaat caused the pilot to fall short of achieving its objective of fully understanding the system. The way the project team tried to mitigate the potential negative effects of that decision was to set a monitoring program for the full-scale implementation of the sandy solution to keep studying its development.

The least common challenge category in the two cases was the biophysical category in its definition given by Sarabi et al. (2019). That category included challenges related to time and space restrictions which are more common to NBS implemented in urban areas which is not applicable for the selected cases for this thesis.

5.3. Enablers

The main enabler mentioned by all interviewed experts was governmental support which is a socio-institutional one. Getting that governmental support was considered as the biggest challenge by all the interviewed experts. However, when that support was secured, it became the main enabler. Furthermore, in order to earn that support, the project team have to prove to the authorities that the project will achieve many benefits, which would be worth the risks in addition to proving that the team is prepared to mitigate the negative impacts. That results in better planning for the project.

Another enabler mentioned by the experts for the Houtrib Dike full-scale implementation was that the NBS was cheaper than traditional engineering methods. At the same time, the solution promised to provide more benefits than traditional methods. That hybrid enabler was also a contributor in securing governmental support for the projects. Finally, the interviewed experts for the Sand Motor mentioned that the innovation of the solution was another hybrid enabler. That enabler helped the project in getting sufficient funding from many sources, who were enthusiastic about becoming partners in the implementation.

6. Conclusions and Recommendations

This chapter presents the answers to the research sub-questions and presents recommendations for the improvement of the implementation of sandy solutions in the Netherlands thus answering the main research questions. Moreover, suggestions for future research are proposed.

6.1. Answers to Research Sub-questions

This section presents the answers to the research sub-questions. First, the application of the principles is discussed then the challenges and the enablers are identified in addition to how the challenges were faced.

The first principle was the integration of all relevant knowledge. After refining the definition to be applicable to the country, it was found that the principle was applied in terms of consulting local managers and referring to databases including observations and measurements from the area. Knowledge from lay people was deemed irrelevant by experts. However, the organized public participation activities provided a channel for lay people to share their knowledge, if they wish. The application of the principle would be improved through utilizing the knowledge of the lay people.

The second principle was about public participation. The application of the principle involved open invitations in the newspapers to meetings where the public could be informed about the project and share their ideas. These meetings were organized in the early planning stages of the project. While the public could share their ideas and demands, their influence on decision-making was limited by safety and design considerations since the main objective for both projects was flood safety. These considerations limited the levels of public participation in the case studies to information provision and consultation, based on Krywkow's model (2009). Nonetheless, when the public demands could be incorporated in the solution without compromising other considerations, they were. Increasing public interest in attending public participation activities would serve to improve the application of the principle.

The third principle was stakeholder engagement, which included two categories of stakeholders: implementing stakeholders and non-implementing stakeholders. Public participation activities lead to identification of some non-implementing stakeholders who were later consulted frequently and updated about the projects. The power they held to influence decisions, however, seemed to rely on their ability to affect the project rather than the burdens placed on them by the project. As for implementing stakeholders, they were involved in planning and throughout the project lifecycle as without their support the project would cease to exist. Employing contemporary stakeholder identification techniques would result in an improved application of the principle.

The fourth and last principle was the recognition and minimization of tradeoffs. In the Netherlands, the law mandates that social and environmental impact assessments be carried out in the planning phase for projects. That requirement implied that the project teams would be aware about most potential negative impacts and have plans to mitigate them. However, the assessments did not prevent one case study from failing to notice one major consideration related to safety. On the other hand, financial considerations did not cause any tradeoffs as both projects were further funded for their innovation in addition to their contribution to flood defense. The application of the project would be improved through revised requirements for the impact assessments specifically for NBS. Additionally, better valuation techniques for ecosystem services would limit tradeoffs due to financial considerations that could compromise the ecosystem.

The challenge category that was most prevalent in the case studies was related to regulatory structures caused by the risk minimization aspirations of governmental officials. This, combined with uncertainties accompanying NBS implementation and the innovation of the case studies, posed many challenges in getting governmental support for the projects. The project teams had to plan for all potential negative impacts and how to mitigate them, which helped secure governmental support and strengthen the planning for the project. Additionally, to overcome other challenges caused by these uncertainties, the project teams had to employ adaptive management to be able to face the challenges as they arise.

The efforts to overcome the challenges and secure governmental support were crucial for the projects' success since governmental support was the biggest enabler for implementation. Other enablers included the perceived cost-effectiveness of the solution compared to traditional approaches as well as the innovation of the two case studies which were implemented as pilots to test and study the solutions.

6.2. Recommendations

This section presents the recommendations derived from the results summarized in section 6.1. These recommendations are meant to improve the implementation of sandy solutions in the Netherlands from the perspective of principles, challenges and enablers.

Regarding the principles, detailed recommendations for their improvement were provided in chapter 5. However, these recommendations are briefly summarized here. Increasing the interest of the public in attending the public participation activities would serve to improve the application of the first three principles since these activities provide platforms for lay people to share their knowledge and non-implementing stakeholders to be identified. Media coverage, advertisements on social media, and digital participation would increase the public's interest and motivation to contribute to those events. Moreover, compensation schemes for non-implementing stakeholders who are negatively affected by a project even if they do not have the right to take legal action to affect the project would serve to improve the application of stakeholder engagement. Refined criteria for impacts assessment for NBS projects and improved valuation systems for ecosystem services would serve to enhance the recognition of potential tradeoffs and minimize them. Finally, allocation of a specific budget for NBS would minimize tradeoffs arising from financial restrictions.

Regarding the challenges, to tackle the socio-institutional challenges related to regulatory structures, the whole structure needs to be revolutionized to accommodate NBS and their uncertainties in consideration of their benefits. However, that is easier said than done. Instead, decision-makers need to utilize decision-making under uncertainty for NBS projects. The second category of challenges was hybrid relating to the uncertainties associated with NBS which results in other technical challenges. To minimize those challenges, project planners need to be aware of their existence and employ adaptive management to overcome them as they arise.

As for the enablers, there was a consensus that the main enabler for the projects was governmental support. Thus, to further support NBS implementation, governments should prioritize NBS projects to traditional engineering solutions. Additionally, through considering the recommendations mentioned above, the implementation of NBS would improve which, in turn, would encourage governments to implement NBS projects.

6.3. Future Research

Despite the growing body of literature about NBS, there remains a gap between scientific publications and practical applications. This section provides three research directions that can aid in bridging that gap. Firstly, the analytical framework developed in this thesis can be applied to sandy solutions implemented in other countries to compare the evidence from the Netherlands with other countries and potentially improve both. Secondly, different types of NBS projects implemented in the Netherlands can be studied to identify and compare the empirical insights from the application of the principles, challenges and enablers. Thirdly, the analytical framework can be expanded to include the application of the remaining topics in the NBS principles to understand how the principles are applied as well as assess and modify them, if necessary.

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Appendix A

Interview Guide

Introduction

- Introducing myself.
- Introducing the topic.
- Ethics declaration.
- Do you have any questions before we begin?

General Question

- How has your experience with NBS projects been?

Project-specific Questions

- Which NBS projects were you involved in other than the *NAME OF THE PROJECT*?
- Could you explain your role in the project? (What specific tasks did you carry out?)
- What were the main objectives for the project? (Climate change mitigation, social justice…etc.)

Principles

According to the literature, NBS have a published set of principles. Now I will ask about how you applied some of them in this project.

- One of the principles is about **public participation**. Could you elaborate if and how you did that in the project?
  - Who was involved?
  - How did you reach out to them?
  - When did you start reaching out to them?
  - Was that principle a challenge or an enabler? Could you elaborate?
- One of the principles is about the **integration of all relevant knowledge**. Could you elaborate if and how you did that in the project?
  - What kind of knowledge did you use?
  - Were the residents consulted for the project?
  - Were the local experts consulted for the project?
  - Was that principle a challenge or an enabler? Could you elaborate?
- One of the principles is about **stakeholder engagement.** Could you elaborate if and how you did that in the project?
  - Which sectors were involved in the project? (Public actors, private actors…)

    - What were their roles?
    - Were there any conflicts?
    - How did you overcome them?
    - Was that principle a challenge or an enabler? Could you elaborate?

- One of the principles is about **recognition and minimization of tradeoffs**. Could you elaborate if and how you did that in the project?
    - What were some of the negative impacts of the projects?
    - Were they accounted for in planning and mitigated?
    - Were there any unexpected impacts for the projects?
    - How and when did you mitigate them?
    - Was that principle a challenge or an enabler? Could you elaborate?

<u>Challenges/Barriers (please list more than one, if possible)</u>

- What were some of the main challenges that were faced during the project implementation?
- How did you overcome them?

<u>Opportunities/Enablers (please list more than one, if possible)</u>

- What were some of the main opportunities that facilitated the implementation of the projects?
  How did that help?

<u>Final Questions</u>

- Do you think the project was successful? Why or how do you define that?
- How could you improve the project if you could?
- Is there anything you would like to add?
- Contact recommendations
- Thanking for participation

Appendix B

Principles		Houtrib Dike Pilot	Houtrib Dike full-scale	Sand Motor
1. Integration of all relevant knowledge	How it was applied	not applied	local experts were consulted	databases and local experts consulted
	Notes on application	not relevant due to remote location	no residents in the area	all observations are saved in databases that are publicly accessable
	Expert opinion	requires scientific verification		only local experts consultation is needed in NL
	How it could be improved	-		
2. Public participation	How it was applied	not applied	open in the newspaper for open meetings in the planning phase	open in the newspaper for open meetings in the planning phase
	Notes on application	not relevant due to nature and scale of project	information provision and consultation	information provision and consultation
	Expert opinion	for flood safety projects, public impact on decisions is minor		public impact is minor but important to understand the public's expectations
	How it could be improved	increase public interest in attending the organized public participation activities		
3. Stakeholder engagement	How it was applied	only implementing stakeholders	both categories of stakeholders involved	mainly implementing stakeholders and non-implementing entities but not public groups
	Notes on application	public groups affected by the solution were overlooked due to nature and scale of project	Rijkswaterstaat held the most decision-making power	public groups affected by the solution were not consulted more than general public
	Expert opinion	provides support for the project, improves planning and prevents lawsuits		helps get the solution accepted and develop a sense of ownership over the project
	How it could be improved	better techniques for non-implementing stakeholder identification and consideration even when they don't have the power to affect the project		
4. Recognition and minimization of tradeoffs	How it was applied	not applied	the pilot uncovered some negative impacts that were mitigated; financial considerations were not restricting	extensive impact assessment in planning phase; financial considerations were not restricting
	Notes on application	the pilot aimed at understanding the system and potential tradeoffs	the duration for the pilot experiment was too short to learn everything; the NBS was cheaper than traditional solutions	overlooked swimmer safety; the NBS was heavily funded from many sources
	Expert opinion	cost-benefit analyses should not be restricting the implementation since the gained benefits are hard to measure in monetary values		better valuation for environmental benefits is needed
	How it could be improved	better valuation of ecosystem services; allocating specific budgets for NBS for their environmental benefits		

Challenges				
Challenge 1	**Description**	**getting decision-makers' support**	**sand blowing on the main road**	**uncertainties about feasibility**
	Category	regulatory structures	technical	hybrid
	How it was overcome	meetings and talks with decision makers; addressing their concerns	covering sand with a layer of earth	knowledge about the project site; monitoring of the solution to be able to interfere in time if needed; adaptive management
Challenge 2	**Description**	**different technical languages in the project team**	**not permitted to dredge in the Ijsselmeer**	**defining the finance streams with non-monetary environmental benefits**
	Category	socio-institutional	regulatory structures	regulatory structures
	How it was overcome	memos and emails explaining different terms	moving the sand across the dike	Sand Motor's budget was large
Challenge 3	**Description**	**sand blowing on the main road**	**uncertainties about feasibility**	**high currents and swimmer's safety**
	Category	technical	hybrid	biophysical
	How it was overcome	wind-screens	monitoring of the solution to be able to interfere in time if needed	an app that determines when it is safe to swim
Enablers				
Enabler 1	**Description**	**governmental support**	**governmental support**	**governmental support**
	Category	socio-institutional	socio-institutional	socio-institutional
Enabler 2	**Description**	**the relationship between the project team members**	**cheaper than traditional solutions**	**innovation of the solution**
	Category	socio-institutional	hybrid	hybrid