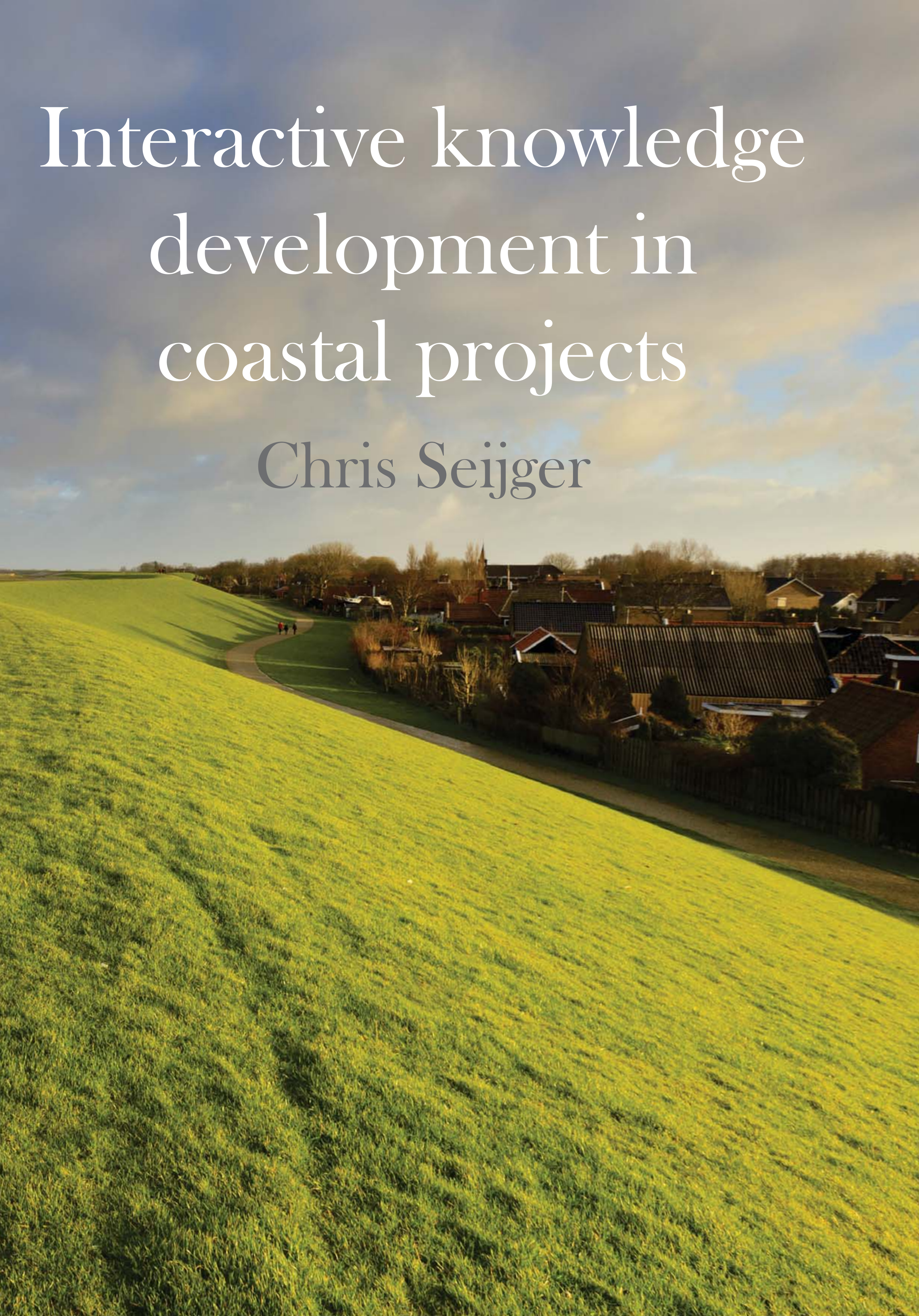
Interactive knowledge development in coastal projects

Chris Seijger



INTERACTIVE KNOWLEDGE DEVELOPMENT IN COASTAL PROJECTS

CHRIS SEIJGER

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DISSERTATION

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Christian Johannes Lambertus Seijger
born on the 11th of August 1986
in Smallingerland, The Netherlands

This dissertation has been approved by:

Prof. dr. G.P.M.R. Dewulf (promotor)

Prof. dr. ir. J.P.M. Van Tatenhove (promotor)

Dr. H.S. Otter (assistant promotor)

Summary

The prime motivation for this study has been the limited understanding of interactive knowledge development as an approach to respond to complex coastal problems. A sustainable future of the coastal environment is severely at risk since the world's coasts are deteriorating while human dependence on coastal space and resources continues to increase. Seeking solutions for coastal development is challenging. Knowledge is vital to deal with the complexity of coastal problems since they involve physical, chemical and biological processes. The complexity increases due to knowledge uncertainties in climate change and sea level rise. Moreover, the problems are linked to multiple interests of for instance flood control and nature restoration, which determine the perspectives of actors involved. Given this complex reality, the knowledge of researchers is not sufficient to respond to complex coastal problems. Various studies have argued that knowledge should be developed in interaction between researchers, policy makers and other societal actors. Such interactive knowledge development could result in research that is relevant to coastal decision-makers and more sustainable solutions that are strongly anchored in society.

This study focuses on interactive knowledge development in coastal projects. The connection between interactive knowledge development and a project's environment is novel and distinguishes this study from previous research on interactive knowledge development. Coastal projects are organised around a central purpose and knowledge is developed for multimillion dollar solutions that are constructed for a lifespan of various decades. Around the world, coastal projects construct solutions that range from flood protection to port expansion and nature restoration. However, conceptual and empirical research is limited on interactive knowledge development in the engineering project environment. This is problematic since interactive knowledge development is seen as an approach to deliver relevant knowledge for complex coastal problems whereas it remains unclear how interactive knowledge development functions and to what extent it may result in improved solutions for coastal problems.

The objective of this study has been to explore how interactive knowledge development functions in the setting of coastal projects. Various knowledge production concepts have been developed to promote processes of interactive knowledge development; for instance Mode 2 knowledge, post-normal science and engaged scholarship. Although insightful, these knowledge production concepts are too general and prescriptive to explain processes of interactive knowledge development in coastal projects. Consequently, the concept of interactive knowledge development is defined in this study as a participative form of knowledge production in which knowledge is shared and developed by using the perspectives of key actors (researchers, policy makers, stakeholders) involved in the complex problem being studied to develop relevant solutions for the problems defined in the project.

The following two research questions have guided this study:

1. How can a process of interactive knowledge development be analysed in coastal projects?
2. How does a process of interactive knowledge development function in coastal projects?

Methodology

A conceptual framework of project and knowledge arrangements is developed to analyse interactive knowledge development in coastal projects. An arrangement consists of four interrelated dimensions: actors, resources, rules and discourses. The project arrangement represents the context for which knowledge is developed. This arrangement focuses on the overall project goals and the activities undertaken to achieve them. The knowledge arrangement conceptualises the process of interactive knowledge development for a particular solution in the coastal project. In this arrangement, four main activities define a process of interactive knowledge development: problem formulation, selection of methods and techniques, interpretation of results, choice of solution. Figure I shows the main elements of the conceptual framework. The double-sided arrow emphasises the connection between the project and knowledge arrangement.

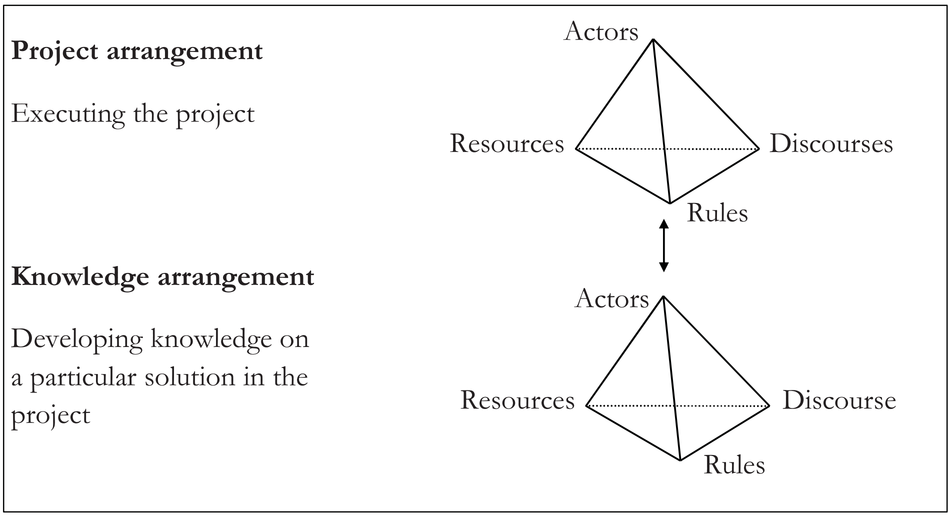

Figure I. Conceptual framework of project and knowledge arrangements

The conceptual framework is applied in three case studies: the Texel dike reinforcement project in the Wadden Sea, the South Bay Salt Pond Restoration project in San Francisco Bay and the Marconi spatial development project in Delfzijl on the banks of the Ems estuary. In each case, data were collected through semi structured interviews, observations of project meetings, project documents and field visits into the coastal area. The collected data were analysed through qualitative data analysis. More specifically, through a template coding approach and causal mechanisms. Coding refers to the labelling of text fragments. The template coding approach resulted in an analysis of the project and knowledge arrangement. From this analysis case-specific mechanisms were developed that explain the process of interactive knowledge development. Through a cross-case analysis the case-specific mechanisms were transformed into generic mechanisms.

Interactive knowledge development in three coastal projects
The Texel dike reinforcement project (Chapter 2) was initiated by the local water board to ensure that the Wadden Sea dikes on Texel would meet the safety norms again. The water board announced that they would investigate traditional, landward alternatives to reinforcing the dikes. This was met by criticism from ten Texel-based organisations who called for research on alternative, more sustainable solutions. As a result, knowledge was developed interactively for a seaward solution entailing of a sand-based flood defence in the Wadden Sea, supplemented with salt marshes and oyster reefs. An outline of a seaward solution was jointly developed and this served as starting point for the study. An engineering firm and the water board interpreted the results and formulated the conclusions of the study. A nature recovery program and the municipality criticised the study, especially the cost estimates for a seaward solution. The case study illustrates how interactive knowledge development may produce different, alternative solutions. Eight causal mechanisms are derived that affect and explain a process of interactive knowledge development in a coastal project's environment. Some mechanisms discuss an enabling impact on interactive knowledge development such as the interdependency of the water board, province and municipality. Other mechanisms discuss a constraining impact such as how the scope for knowledge development demarcates what can and cannot be investigated.

The South Bay Salt Pond Restoration project (Chapter 3) was initiated to restore and enhance wetlands in South San Francisco Bay while providing flood management and wildlife-oriented public access and recreation. The project management team (PMT) consisted of governmental and non-governmental organisations. PMT members sought consensus among themselves prior to decision-making. The project discourse for Phase 2 planning (2010-onwards) was narrowed to tidal marsh restoration. Knowledge was developed interactively for marsh restoration alternatives that consist of breaches in salt pond levees, ecotone transition areas and public access features. Findings of the consultant team were reported in separate meetings to researchers, regulators and stakeholders. Due to these meetings the restoration alternatives changed in terms of the number of breaches and the size and shapes of proposed nesting islands. The case study highlights the difficulty of organising a process of interactive knowledge development as every actor requires careful handling. Seven causal mechanisms were derived. Some causal mechanisms connect the project arrangement to the knowledge arrangement, these mechanisms affect interactive knowledge development. For instance, how intimate knowledge of individual PMT members structures the relation with the consultant team. Other mechanisms operate within the knowledge arrangement and explain, or provide more detail on, the process of interactive knowledge development. One example is how facilitation by a consensus building organisation smoothes a process of interactive knowledge development by creating a better understanding among actors during project meetings.

The Marconi project (Chapter 4) is a spatial development project that was initiated to improve the liveability of Delfzijl, a Dutch seaport on the banks of the Ems estuary. The project partners focused on solutions that would strengthen connections between the city center, the harbour and the coastline. Knowledge was developed interactively for a solution that integrated an expansion of the city beach with tidal marsh, recreation and flood control. A research consortium conducted the study. The consortium was interested in 'building with nature' solutions in hydraulic engineering projects. The consortium and the project partners each funded 50% of the study. Their contrasting interests -generic building with nature research versus implementing a solution at Delfzijl- resulted in a struggle over the research proposal. The findings of the study were opposed by a coalition of nature organisations as the proposed solution might hamper estuary restoration. Additional research turned the criticasters into advocates.

In this case study the framework of project and knowledge arrangements is supplemented with boundary spanning and socially robust knowledge. Social robustness is a key outcome of interactive knowledge development since it refers to knowledge that is relevant and accepted by actors in the coastal project. Boundary spanning is central to social robustness, since social robustness assumes that knowledge can span, or travel across, organisational boundaries. This case study presents three theoretical conditions that specify how social robustness can be achieved in coastal projects. The conditions cover knowledge testing by boundary spanners, the involvement of diverse actors and a close connection between knowledge production and the evolving project. The theoretical conditions are compared to the Marconi case analysis. The comparison reveals the necessity of the three conditions and adds a fourth, case-specific aspect for achieving social robustness: boundary spanning among actors in the project arrangement to structure the scope of problems and solutions prior to developing knowledge for a coastal solution.

The three cases are compared in a cross-case analysis (Chapter 5). The comparison results in eleven generic mechanisms that explain the functioning of interactive knowledge development in coastal projects. They explain the functioning of interactive knowledge development as an interplay between the project and knowledge arrangement. The mechanisms cover three types of explanations (see Table I): the structural factors in the project arrangement that impact interactive knowledge development, the actor dynamics that explain how differing contributions are aligned during a process of interactive knowledge development and the consequences of interactive knowledge development for the coastal project.

Table I. Generic mechanisms that explain the functioning of interactive knowledge development in coastal projects.

Type of causal mechanism	Description
From project arrangement to knowledge arrangement: mechanisms that *affect* interactive knowledge development.	Project partners are pressed to involve other actors in knowledge production.
	Project resources structure interactive knowledge development resulting in a narrowed scope for interactive knowledge development.
	Project-level actor relationships affect the actor that is the main knowledge producer.
	Sharing responsibilities at the project level supports interaction rules for interactive knowledge development.
Within knowledge arrangement: mechanisms that *explain,* or provide more detail on, interactive knowledge development.	Actors hold different perspectives, which results in differing contributions during the process of interactive knowledge development.
	Easily understood knowledge supports contributions by non-experts.

	Professional facilitation smoothes the process of interactive knowledge development.
	Actors are excluded during one or more interactive knowledge development activities.
From knowledge arrangement to project arrangement: mechanisms that specify the *consequences* of interactive knowledge development.	Support for solutions broadens through interactive knowledge development.
	Feasibility of solutions improves through interactive knowledge development.
	Interactive knowledge development consumes more time than expected.

Conclusions and discussions

Conclusions on the research questions are drawn at the end of this study (Chapter 6). Regarding the analysis of interactive knowledge development (research question 1), it is concluded that the operationalisation of interactive knowledge development has developed from a conceptual framework to a set of eleven mechanism. The causal mechanisms open the black box of interactive knowledge development in coastal projects since they offer a detailed explanation for the functioning of interactive knowledge development. The mechanisms offer a practice-based understanding for the functioning of interactive knowledge development whereas the conditions for socially robust knowledge offer a theory-based explanation how interactive knowledge development may achieve social robustness.

Regarding the functioning of interactive knowledge development (research question 2), it is concluded that the mechanisms reveal a close connection between the project arrangement and knowledge arrangement. The mechanisms show that interactive knowledge development requires specific measures to align the contributions of participating actors (e.g. a facilitator and easily understood knowledge). The mechanisms highlight that interactive knowledge development results in a specific type of knowledge, namely a feasible, broadly supported solution to solve a structured coastal problem. The conditions for socially robust knowledge offer an additional conclusion regarding the functioning of interactive knowledge development. That is, the capacities of boundary spanning individuals and the application of boundary objects are vital in achieving socially robust knowledge.

The findings of this study are based on exploratory research in three very different coastal projects that develop solutions which combine human needs (i.e. flood protection and coastal recreation) with environmental concerns of nature restoration. Therefore, the findings of this study may be applicable to coastal zones, where a high human dependency on the coastal space puts pressure on engineering projects to combine various functions in sustainable solutions. Further research may provide more clarity on the range of institutional contexts where the findings apply.

This study presents new insights for the conceptual and empirical understanding of interactive knowledge development. The conceptual understanding is advanced by the framework of project and knowledge arrangements. The framework holds a fundamental improvement for the analysis of interactive knowledge development since the process of knowledge production is separated from the context of application. In addition, the causal mechanisms are a first attempt to uncover the underlying mechanisms that explain interactive knowledge development. The empirical understanding is advanced by presenting a generic explanation for interactive knowledge development across different projects and institutional contexts. This generic explanation clarifies the possibilities (e.g. societal support and feasibility of the developed solutions) and limitations (e.g. exclusion, substantial more time) of interactive knowledge in coastal projects. Therefore, this study contributes to an improved understanding of interactive knowledge development for coastal decision-making.

The study ends with an outlook for interactive knowledge development. Further research could study the role of consensus and conflict as well as the costs and benefits of interactive knowledge development. In addition, interactive knowledge development could be studied for other types of knowledge (e.g. modelling, monitoring, policy evaluation) and in other project domains (e.g. water management, forestry). Recommendations for practitioners are given since a key insight of this study is that *if* organisations aim to develop knowledge interactively it will require a different process than basic research. Therefore, recommendations are discussed how to organise interactive knowledge development in coastal projects. In addition, opportunities are discussed to professionalise knowledge co-creation experts, to anchor knowledge co-creation in research programs and to initiate funding systems that support interactive knowledge development for multifunctional coastal solutions.

Table of content

Chapter 1. Introduction

This chapter introduces the topic of interactive knowledge development in coastal projects and explains how this is analysed in subsequent chapters. The chapter is subdivided into five sections. Section 1.1 explains the research interest in interactive knowledge development and how this concept relates to on-going debates in creating relevant knowledge. Section 1.2 presents the objectives and research questions that direct this study. Section 1.3 introduces the conceptual framework to analyse interactive knowledge development in coastal projects. Section 1.4 discusses the research design and procedures in data collection and qualitative analysis. Section 1.5 summarises the outline of the entire study and explains how the research questions are addressed in subsequent chapters.

1.1 Background and focus

1.1.1 Responding to coastal problems through interactive knowledge development

The transition between land and sea at the coast creates a unique and wonderful environment. The combination of fresh and salt water has created ecosystems that are characterised by a rich diversity in fish, birds and other marine life. The coast is also attractive for humans, in terms of commercial ports, mega-cities, vacation destinations, commercial fisheries and exploitation of mineral resources as gas and oil. However, a sustainable future of the coastal environment is severely at risk. Unsustainable practices have impacted the coastal environment resulting in worldwide degradation of coastal ecosystems. Important coastal habitats such as wetlands, coral reefs and sea grasses are disappearing quickly under influence of human activities (UNEP, 2006). In parallel, the coastal zone is densely populated. Nowadays, nearly half of the world's population live within 150 kilometers of the coastline[1], many subject to risks of flooding. Future estimates on population growth, climate change and sea level rise will certainly increase the pressure on the coastal zone.

Seeking solutions for coastal development is challenging since decision-makers are confronted with complex coastal problems evolving around multiple, competing interests. For instance, large parts of the Wadden Sea are declared as UNESCO World Heritage for the unique geomorphology and biodiversity (Reise et al., 2010). Yet a balance has to be found between nature protection and human activities of fisheries, exploitation of mineral resources and port expansions (Floor et al., 2013; Puente-Rodriguez et al., 2014). Such different interests determine the perspective one takes in framing coastal problems and solutions (Hommes et al., 2009). In addition, coastal problems are difficult to understand as they involve physical, chemical and biological processes (Coffey and O'Toole, 2012). The problems become even more complicated

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[1] UN Atlas of the Oceans, www.oceansatlas.org visited on August 13, 2014.

due to knowledge uncertainties in global climate change and accelerated sea level rise (Hanger et al., 2013; Tribbia and Moser, 2008). Given this complex reality, knowledge of researchers is not sufficient. Instead, responding to coastal problems needs the involvement of both researchers and practitioners in knowledge production (Clarke et al., 2013; Hanger et al., 2013; Schmidt et al., 2012; Tribbia and Moser, 2008).

This study focuses on interactive knowledge development as an approach to respond to coastal problems. Interactive knowledge development represents a participative form of knowledge production that involves researchers, policy makers and other societal actors. In literature, various arguments are given why knowledge should be developed interactively for the coastal zone. Weinstein et al. (2007) discuss that more effort is needed at the interface between science and society to come to a more sustainable development of the coastal zone. Van Koningsveld (2003) argues that interaction between specialists (in coastal morphology and hydrodynamics) and coastal decision-makers is essential to ensure that research is relevant to decision-makers. Schmidt et al. (2012) discuss how engineering-based coastal protection should be anchored in society by integrating knowledge of stakeholders and decision-makers. Bremer and Glavovic (2013) conclude that knowledge and values of all stakeholders should be mobilised through dialogue to support coastal governance. In sum, interactive knowledge development for coastal solutions is needed to ensure that solutions are more sustainable, anchored in society, relevant to decision-makers and based on knowledge of coastal experts.

Interactive knowledge development has been studied in various settings. In the environmental sciences, many authors focus on interactive knowledge development in the interfaces of science-policy (e.g. Bax, 2011; Van Enst et al., 2014), science-management (e.g. Burbidge et al., 2011; Roux et al., 2006), science-society (e.g. Callon et al., 2009; Lane et al., 2011), or on a combination of these interfaces (e.g. Buizer et al., 2011; Rogers, 2006). However, the understanding of interactive knowledge development at the project level is limited. The connection between interactive knowledge development and a project's environment is novel and distinguishes this study from previous research on interactive knowledge development. In this study I analyse interactive knowledge development at the level of coastal engineering projects. The conceptual and empirical research into interactive knowledge development in the engineering project environment is very limited (e.g. Edelenbos et al., 2011; Van Buuren and Edelenbos, 2004; Hartmann and Dewulf, 2011).

The engineering project environment represents a distinct setting to analyse interactive knowledge development. Projects are organised around a central purpose (i.e. combatting coastal erosion) and activities are undertaken to achieve that purpose. Knowledge is developed for multimillion dollar solutions that are constructed for a lifespan of various decades (Seijger et al., 2014). That setting differs from science-policy interfaces that aim to produce policy-relevant knowledge (Turnhout et al., 2008), it differs from science-management interfaces that try to inform management strategies (Roux et al., 2006) and it differs from science projects that aim to develop knowledge interactively without having a strong link with decision-making processes (Lang et al., 2012; Polk, 2014). Given the limited research on interactive knowledge development in the project environment, the underlying mechanisms are unknown that may explain the functioning of interactive knowledge development in coastal engineering projects.

Coastal engineering projects respond to coastal problems worldwide. For instance, projects construct solutions to offer flood protection in the Netherlands (Janssen et al., 2014b), they facilitate port expansion in Australia (Korbee et al., 2013) or restore coastal habitats in California (Seijger et al., 2014). In addition, coastal engineering projects represent a strong connection between knowledge production and the application of developed knowledge to construct coastal solutions. Consequently, coastal engineering projects (hereafter referred to as 'coastal projects) offer an excellent opportunity to analyse practices of interactive knowledge development.

This study therefore explores how interactive knowledge development functions in coastal projects. Exploratory research is needed since the project environment represents a distinct domain that has hardly been studied in relation to interactive knowledge development. It remains unclear how interactive knowledge development functions in coastal engineering projects and to what extent it may result in improved solutions for coastal problems. This study will present a comparative analysis of very different coastal projects, to reveal the underlying mechanisms that explain the functioning of interactive knowledge development.

1.1.2 Positioning this study in relation to other knowledge-related research

Interactive knowledge development is defined as a participative form of knowledge production in which knowledge is shared and developed by using the perspectives of key actors (researchers, policy makers, stakeholders) involved in the complex problem being studied to develop relevant solutions for the problems defined in the project (Seijger et al., 2013; Seijger et al., 2014). Given the multi-actor setting of interactive knowledge development, knowledge is defined as a multi-actor process of justifying beliefs toward the truth (Nonaka, 2000). The beliefs of actors are deeply rooted in an individual's value system (idem). The remainder of this section explains how the focus on interactive knowledge development in coastal projects relates to other knowledge-related research.

Knowledge management studies conceive knowledge as a resource that a singular organisation should manage well to increase competitive advantage (Love et al., 2005; Nonaka and Takeuchi, 1995). In this study, I focus on knowledge production by multiple organisations, not to increase competitive advantage for better businesses but to develop better responses to coastal problems. Other research has focused on knowledge uptake in the fields of innovation (Klerkx and Leeuwis, 2008), (environmental) decision-making (McNie, 2007) and planning (Te Brömmelstroet and Bertolini, 2001). In this study, I approach the uptake of knowledge as a knowledge production problem. Whereas the above studies mostly focus on uptake, I focus on the process of knowledge production. The concept of interactive knowledge development is built on the insight that the uptake of knowledge is enhanced when knowledge is developed interactively. Therefore, interactive knowledge development is an approach to increase the uptake of developed knowledge. In addition, the coastal project represents a different setting to analyse the uptake of knowledge as projects construct coastal solutions with a lifespan of various decades.

Other research addresses the transfer of knowledge (Carlile, 2004; Vinke-De Kruijf, 2013) and learning between organisations (Eshuis and Stuiver, 2005; Pahl-Wostl et al., 2007). Knowledge transfer and learning are part of interactive knowledge development as the definition explains that '(…) knowledge is shared and developed by using the perspectives of key actors (…)'. In this study, I pay attention to the development of new knowledge to respond to a specific coastal problem, this involves knowledge transfer and learning between participating organisations. Furthermore, other knowledge-related research has focused on distinct types of knowledge, often dating back to Aristotle's distinct forms of knowledge: techne – applied technical knowledge, episteme- basic knowledge pursuit of theoretical questions, phronesis – practical knowledge of how to act in a given social situation (Van de Ven, 2007). More recently, distinctions are made between tacit and explicit knowledge (Tsoukas, 1996) or expert, bureaucrat and stakeholder knowledge (Edelenbos et al., 2011). In this study I build upon the insight that distinct kinds of knowledge are incomplete and that multiple organisations are involved in knowledge transfer and learning. Yet I do not specify distinct types of knowledge, instead I analyse through interactive knowledge development how a variety of actors is involved in developing new knowledge to respond to a specific coastal problem.

Lastly, within sociology much has been written under the header sociology of scientific knowledge (e.g. Callon et al., 2009; Latour, 1999) or sociology of knowledge (e.g. Berger and Luckmann, 1991). Analyses are often targeted at the societal level as authors try to explain the relation between science and society and how these relations change. Also, knowledge production concepts have been developed that advocate the opening up of processes of knowledge production to researchers and non-researchers. Mode 2 knowledge (Gibbons et al., 1994) and post-normal science (Funtowicz and Ravetz, 1993) are some of the prominent ones. In this study, I build upon this debate of opening up processes of knowledge production. However, I present a more practice-based analysis of interactive knowledge development. Instead of focusing on the societal level I focus on the level of coastal projects. Instead of examining the theoretical explanations of Mode 2 knowledge production I analyse practices of interactive knowledge development that involve researchers, policy makers and stakeholders. The next section explains why knowledge production concepts as Mode 2 knowledge are insufficient to analyse interactive knowledge development at the level of coastal projects.

1.1.3 Opening up processes of knowledge production

The interest of interactive knowledge development, and more specifically for the coastal zone, is linked to a broader societal debate on opening up processes of knowledge production to researchers, policy makers and other societal actors.

In the past decades the interest has grown in science and society to open up processes of knowledge production to researchers, policy makers and other societal actors (see Tables 1.1 and 1.2 for an overview). The prime reason for this interest is that knowledge is of limited use to practitioners when researchers develop knowledge in relative isolation from the societal context where the problem should be solved (Etzkowitz and Leydesdorff, 2000; Gibbons et al., 1994; McNie, 2007; Nowotny et al., 2001; Van de Ven, 2007). The following three reasons explain why such research knowledge is of limited use to practitioners. First, the authority of science is increasingly challenged in society (Funtowicz and Ravetz, 1993), resulting in research that is contested in a political (Floor et al., 2013) or societal context (Gibbons et al., 1994). Second, real-world problems like coastal development are too complex and cannot be solved by researchers that work within highly specialised disciplines (Gibbons et al., 1994; Merkx and Van den Besselaar, 2008; Pohl, 2005). Further, researchers may not be aware of the actual knowledge needs of the decision-makers that have to solve the problem under study (Cash et al., 2003; Tribbia and Moser, 2008). Third, options for implementation of coastal solutions will touch upon differing values and preferences of actors. When these actors are excluded from knowledge production, they may disagree with the options that are developed as their preferences are not taken into account (Gibbons et al., 1994; Seijger et al., 2013).

A range of knowledge production concepts have been developed to understand and improve the production and uptake of knowledge. Although the concepts differ in their characteristics, they share the logic that it is necessary to open up processes of knowledge production to researchers, policy makers and other societal actors to develop knowledge of practical relevance. The concepts are summarised in Table 1.1

Table 1.1. Knowledge production concepts emphasise an opening up of processes of knowledge production for complex real-world problems.

Knowledge production concept	Description	Reference
Mode 2 knowledge	Mode 2 knowledge explains how the production of knowledge is undergoing fundamental changes and results in a new mode of knowledge production that is reflexive, transdisciplinary and involves a heterogeneous group of organisations.	Gibbons et al., 1994
Engaged scholarship	Engaged scholarship is a participative form of research that can produce more penetrating and insightful knowledge than when researchers or practitioners work on problems alone.	Van de Ven, 2007
Post-normal science	To respond to complex environmental problems, post-normal science relies on extended peer communities, consisting of those with a stake in the policy issue for which research is conducted.	Funtowicz and Ravetz, 1993
Transdisciplinary research	Transdisciplinary research takes into account the complexity of an issue, addresses science's and society's diverse perceptions of an issue and works outside the idealised context of science to produce practically relevant knowledge.	Pohl, 2005
Sustainability science	Sustainability science asserts that knowledge should be developed in interaction between researchers and practitioners, in order to turn knowledge into action for sustainable development.	Kates et al., 2001
Integration and implementation sciences	Integration and implementation science (I2S) mostly builds upon the above knowledge production concepts by making advancements in a research style and underpinning discipline. In addition, I2S focuses on team research and complex real-world	Bammer, 2013

	problems.	
Collaborative knowledge generation	Collaborative knowledge generation is key to achieve a civic science research process in which scientific actors collaborate with actors in civil society.	Van Wyk et al., 2007
Joint knowledge production	Joint knowledge production covers collaboration between scientists, policy makers and other societal actors in specific projects. It is a manifestation of both Mode 2 research and post-normal science.	Hegger et al., 2012
Knowledge co-production	Knowledge co-production is the interaction process between experts, bureaucrats and stakeholders. It involves discussion and negotiation, but leads to a common knowledge ground which is authorative for participating actors.	Edelenbos et al 2011

These knowledge production concepts have been influential. They have not only sparked debate within the scientific community on changing processes of knowledge production (e.g. Hessels et al., 2008; Shinn, 2002; Weingart, 2008). They also have impacted the societal debate since many institutions promote an opening up of knowledge production to researchers and non-researchers. Table 1.2 provides an overview of such organisations and research programs.

Table 1.2. Organisations actively promote an opening up of processes of knowledge production to researchers and non-researchers.

Organisation	Focus	Reference
OECD (Organisation for Economic Co-operation and Development).	Engagement and dialogue between societal actors and the research community.	OECD Global Science Forum, 2008
Several Dutch institutions: Rijkswaterstaat, national Environment Assessment Agency, the Rathenau Institute, the Wadden Academy*.	Adopt terms of knowledge co-creation and co-creation.	Kabat et al., 2009; Merkx, 2012
European Commission.	Societal relevance and practical application are relevant in funding research.	European Commission, 2010; European Research Advisory Board, 2007; Mejlgaard et al., 2012; Steinhaus et al., 2013
US National Science Foundation.	Societal relevance and practical application are relevant in funding research.	Lok, 2010; Roberts, 2009
Research programs on climate adaptation in Germany (Klimzug) and	Try to apply principles of knowledge co-	Hegger and Dieperink, 2014

the Netherlands (Climate Changes Spatial Planning, Living with Water, Knowledge for Climate).	creation.	
Research programs on public private innovation in the Netherlands, the United Kingdom, Finland and Australia.	Try to apply principles of knowledge co-creation.	Dewulf and Noorderhaven, 2011

* Rijkswaterstaat is responsible for highways and waterways; the national Environment Assessment Agency conducts policy analyses in the fields of environment, nature and spatial planning; the Rathenau Institute promotes political and societal debates on science and technology, the Wadden Academy identifies knowledge gaps and coordinates research in the Wadden Sea.

Despite these initiatives in science and society, researchers and practitioners struggle to develop knowledge interactively (e.g. Pohl et al., 2010; Wiek et al., 2012b). One key reason is that researchers, policy makers and stakeholders hold different norms and values towards knowledge production and knowledge use (Edelenbos et al., 2011). They work for different organisations and have different core businesses, thereby making it increasingly difficult to develop knowledge that is relevant and valid to all. Cash et al. (2003) discuss that knowledge should meet three criteria to be relevant. Knowledge needs to be salient – relevant to the current needs of decision makers, credible – accurate and correct, and developed in a legitimate way– such that parties trust the process through which knowledge was developed. However, these criteria are normative (Hegger et al., 2012; Vogel et al., 2007) and actors therefore interpret them differently. Moreover, the criteria involve trade-offs and are therefore difficult to achieve simultaneously (Cook et al., 2013; White et al., 2010). In addition, institutional barriers are often mentioned as a major constraint to open up processes of knowledge production since much of the academia still acts as a closed knowledge system (Cornell et al., 2013; Van der Leeuw et al., 2012).

Given the difficulty of developing knowledge interactively, this study focuses on practices of interactive knowledge development in coastal projects. However, these practices are poorly understood since very few studies exclusively focus on interactive knowledge development in multiple cases (e.g. Wiek et al., 2012b). Some coastal projects are characterised by interactive knowledge development. In these projects solutions are developed that address knowledge uncertainties and touch upon differing values of how the coast should be developed. Therefore, an analysis of interactive knowledge development in coastal projects can contribute to a more practical understanding on how to improve connections between research and practice in knowledge production. Yet the existing knowledge production concepts of Table 1.1 are insufficient to analyse processes of interactive knowledge development in coastal projects for the following four reasons.

First, the key knowledge production concepts of Table 1.1 are too general to explain processes of interactive knowledge development. The seminal works of Mode 2 knowledge (Gibbons et al., 1994), engaged scholarship (Van de Ven, 2007) and post-normal science (Funtowicz and Ravetz, 1993) are theoretical since they lack a firm empirical underpinning. They remain too abstract to analyse practices in interactive knowledge development whereas these practices are characterised as dynamic and complicated (Edelenbos et al., 2011; Hegger et al., 2012; Roux et al., 2006).

Second, the key knowledge production concepts are prescriptive as they advocate one type of knowledge production, ranging from Mode 2 knowledge production to transdisciplinary research or a particular form of science (e.g. post-normal, sustainability, civic). As a result alternative modes of interactive knowledge development are excluded and can therefore not be analysed. This is problematic since Table 1.1 already contains various approaches to develop knowledge interactively. For instance post-normal science advocates the use of extended peer communities whereas engaged scholarship promotes engagement with practitioners when formulating and solving research problems.

Third, the knowledge production concepts were not developed to analyse practices of interactive knowledge development in coastal projects. Concepts as integration and implementation science, post-normal science and engaged scholarship are primarily targeted at researchers and scientists. This does not correspond with the variety of key knowledge producers in coastal projects, ranging from experts in governmental organisations to researchers in applied research institutes and engineers in consultancy firms. In addition, there is a strong connection between knowledge production and use of knowledge as coastal projects plan to construct the solutions for which knowledge is developed. Therefore, the coastal project represents a different setting to develop knowledge interactively than the knowledge production concepts that mostly focus on how researchers should conduct research (e.g. transdisciplinary research, engaged scholarship).

Fourth, knowledge production concepts as joint knowledge production, collaborative knowledge generation and knowledge co-creation have a prescriptive character that emphasise the collaborative setting of knowledge production. They have limited attention for the possibility that actors might be excluded or only partially involved during processes of knowledge production. Therefore, this study applies the term 'interactive' since that emphasises the interactive character of knowledge production and enables a focus on the process of knowledge production without prescribing a joint or collaborative process between researchers and practitioners. The concept of interactive knowledge development therefore focuses on interactions during knowledge production and not so much on the joint or co-produced outcomes. It thereby fits the research interest of this study, which is to explore how different actors interact with each other during processes of knowledge production in coastal projects.

Consequently, these four reasons provide justification to introduce and elaborate the concept of interactive knowledge development. The definition was given in Section 1.1.2, its main elements will be discussed in Section 1.1.4.

1.1.4 Elements of interactive knowledge development in coastal projects

Elements of the key knowledge production concepts (as discussed in Table 1.1) are used to specify the key elements of interactive knowledge development. Interactive knowledge development is a participative form of knowledge production that involves a *heterogeneous group of people*. This element is similar to the other knowledge production concepts as each advocates the involvement of various actors. Yet the definition of interactive knowledge development does not specify who should be involved in what way nor promotes researchers over other main knowledge producers.

Interactive knowledge development focuses on *solutions for complex coastal problems*, and has to deal with multiple interests and major knowledge uncertainties. Although other knowledge production concepts also focus on complex real-world problems (e.g. transdisciplinary research, integration and implementation sciences), the connection with solutions is not as explicit as in interactive knowledge development.

Interactive knowledge development has a clear context of application since knowledge is developed for solutions in a *coastal project*. Although existing knowledge production concepts emphasise the production of relevant knowledge, it remains unclear to whom the knowledge should be relevant. For instance, Mode 2 knowledge is developed in the 'context of application', yet what this context precisely is remains vague. Similarly, sustainability science remains general by stating that researchers should engage with practitioners involved in real-world problems of sustainable development (Clark and Dickson, 2003; Kates, 2012).

A key outcome of interactive knowledge development is *socially robust knowledge*, which is achieved when all actors involved in the coastal project accept the developed knowledge. Such an outcome is also central to the other knowledge production concepts. For instance, engaged scholarship should result in more penetrating and insightful knowledge than when researchers or practitioners do not interact (Van de Ven, 2007). The term socially robust knowledge was coined in relation to Mode 2 knowledge production referring to knowledge that is relevant and accepted in the context of application (Gibbons et al., 1994; Nowotny, 2003).

1.2. Objective and research questions

Previous studies on interactive knowledge development did not focus on coastal projects. In addition, the conceptual and empirical research into interactive knowledge development in the engineering project environment is limited. Consequently, interactive knowledge development in the coastal project's environment remains a black box. This is problematic, since interactive knowledge development is seen as an approach to deliver relevant knowledge for solving complex coastal problems, yet it remains unclear whether this logic holds for coastal projects. Empirical research is therefore needed beyond single case studies, to understand how these processes of knowledge production function in practice and to grasp the possibilities and limitations of interactive knowledge development for responding to complex coastal problems.

So, the objective of this study is to explore how interactive knowledge development functions in the setting of coastal projects. Two research questions are developed to open the black box of interactive knowledge development in coastal projects.

RQ 1. How can a process of interactive knowledge development be analysed in coastal projects?

RQ 2. How does a process of interactive knowledge development function in coastal projects?

Figure 1.1 visualises the topic and research questions of this study.

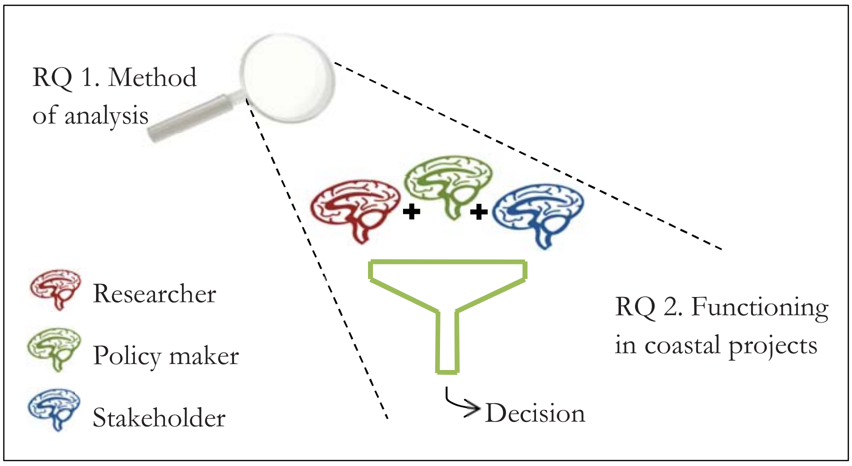

Figure 1.1. Research questions on interactive knowledge development in this study.

The first research question is mainly answered in this chapter. A first step has been made by introducing the concept of interactive knowledge development in Section 1.1. Section 1.3 discusses the conceptual framework that structured the analysis into interactive knowledge development in various coastal projects. Section 1.4 discusses the applied methodology (research design, data collection and data analysis) that created the analyses of interactive knowledge development. Subsequent chapters have shortened method's sections.

The second research question is answered in the chapter's 2 to 5. Chapters 2 and 3 present exploratory research into the functioning of interactive knowledge development in two different coastal projects. Chapter 4 develops conditions to achieve social robustness that are compared to another coastal project. Chapter 5 integrates the findings of chapters 2 to 4 through a cross-case analysis.

The thesis is based on four papers that were submitted to scientific journals. These papers represent a combination of exploratory and explanatory research. This combination reflects the evolving insight on the functioning of interactive knowledge development. The earlier articles (Chapter 2 and 3) have an exploratory character and present case-specific insights. The later articles (Chapter 4 and 5) build upon these insights and provide more generic explanations for the functioning of interactive knowledge development in coastal projects. Section 1.5 provides a detailed reading outline of the entire study.

1.3. Developing a conceptual framework to analyse interactive knowledge development

A new conceptual framework is needed to analyse interactive knowledge development as existing knowledge production concepts are insufficient (as discussed in Section 1.1.3 and 1.1.4). In addition, frameworks that were developed to analyse interactive knowledge development in projects (Edelenbos et al., 2011; Hegger et al., 2012), do not analytically separate processes of knowledge production from the context of application for which knowledge is developed. This is problematic, since actors in the project are crucial in determining whether knowledge is socially robust or not. These frameworks are of limited use as they cannot explore the interrelations between the coastal project and the process of interactive knowledge development. Consequently, a new conceptual framework is needed that accounts for actor dynamics of interactive knowledge development and the coastal project as particular context of application.

1.3.1 The policy arrangement approach as foundation for the conceptual framework

The policy arrangement approach (Van Tatenhove et al., 2000) serves as foundation for a conceptual framework for the following reasons. First, the social dynamics of interactive knowledge development are rather similar to the setting of policy domains for which the policy arrangement approach has been developed. A range of actors is involved in interactive knowledge development, having differing norms and values (Edelenbos et al., 2011). Further, power plays are inevitable as power can define what gets to count as knowledge and knowledge results in power (Flyvbjerg, 1998). In addition, coalitions may be formed between researchers and policy makers to pursue specific interests (Van Buuren and Edelenbos, 2004). Second, the policy arrangement approach offers a solid theoretical foundation for analysing actors in their context as it is strongly rooted in Giddens' structuration theory (Giddens, 1984). Lastly, the policy arrangement approach is compatible to the project environment as policy arrangements are dynamic and temporary – two characteristics that apply to projects (Turner and Müller, 2003).

The overall objective of the policy arrangement approach is to analyse the institutionalisation of policy arrangements. Institutionalisation refers to the phenomenon whereby patterns arise in people's actions, behaviour gradually solidifies into structures, and those structures in their turn structure behaviour (Arts et al., 2006). The institutionalisation of arrangements is informed by the duality of agency and structure as discussed by Giddens' (1984). His structuration theory states that social practices are neither fully explained by actions of actors (agency), nor by rules and resources structuring social practices (structure). Instead, action is tied to structure and structure is tied to action, resulting in the duality of agency and structure in social practice (Jones et al., 2011).

This duality of structure is captured by the policy arrangements. A policy arrangement has been defined as "the temporary stabilisation of the content and organisation of a policy domain" (Van Tatenhove et al., 2000) and is analysed along the following four dimensions:

- actors and their coalitions;
- the division of resources between actors that lead to variations in power and influence;
- the rules of the game in operation, both in formal procedures and routines of interaction;
- discourses that entail views and narratives of actors involved.

These four dimensions are interconnected and illustrated by a tetrahedron shape (see Figure 1.2).

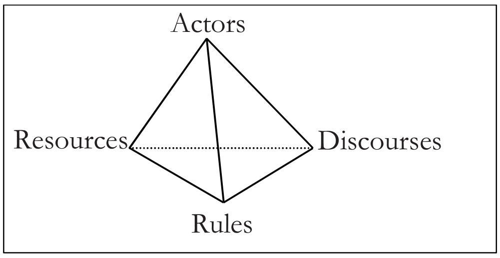

Figure 1.2. The policy arrangement consists of four interconnected dimensions.

The dimensions have great analytical value since they can analyse the arrangement wherein knowledge is developed interactively without prescribing it. Furthermore, policy arrangements are defined as temporary and changes in one dimension may invoke changes in another dimension (Liefferink, 2006). This dynamic and temporary description fits that of projects where resources (human and non-human) are pulled together in a temporary organisation to achieve a specified purpose (Cleland and Kerzner, 1985; cited in Turner and Müller, 2003). Consequently, the policy arrangement approach offers a solid starting point for analysing actor practices in coastal projects. Thus, the functioning of interactive knowledge development is analysed in terms of actors, rules, resources and discourses. The interplay and dynamics between the dimensions offer explanations for the arrangements of interactive knowledge development.

The policy arrangement approach is used as analytical framework to structure the analysis into practices of interactive knowledge development[2]. However, the policy arrangement approach has to be adapted to analyse interactive knowledge development in coastal projects. Activities of interactive knowledge development are not covered by the policy arrangement approach. In addition, the unit of analysis is the policy arrangement, whereas a framework is needed that analyses the interplay between different arrangements. More specifically, the interplay between arrangements of interactive knowledge development and a coastal project.

1.3.2 The conceptual framework of project and knowledge arrangements

The conceptual framework for the analysis of interactive knowledge development in coastal projects distinguishes two types of arrangements: the project arrangement and the knowledge arrangement[3]. The project arrangement focuses on the overall project goals whereas the knowledge arrangement conceptualises the processes of interactive knowledge development for a particular solution in the project. The four dimensions of the policy arrangement approach

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[2] To understand the functioning of interactive knowledge development, causal mechanisms will be inductively derived in different coastal projects. Section 1.4.3 explains how these mechanisms are inductively derived within case-specific project and knowledge arrangements.

[3] In recent years, other researchers have provided different interpretations of project and knowledge arrangements in relation to the policy arrangement approach. Korbee and Van Tatenhove (2013) develop the concept of project arrangements to analyse how ecological considerations are included in the design of marine infrastructure development projects. Janssen et al. (2014) develop the concept of knowledge arrangements to capture the interaction between a knowledge base and a specific policy field within the setting of greening flood protection.

apply to both arrangements (see Figure 1.3). These dimensions are operationalised with indicators that emphasise the actor-based perspective of this study:

- Actors are defined as individuals or groups of individuals who are involved or affected by the arrangement. Actors are studied through the indicators of actor involvement, actors relations, actors affected and actor coalitions.
- Resources are defined as means available to an actor that can be used to influence or determine outcomes of an arrangement. Resources are studied through time, money and information.
- Rules define the possibilities and constraints for actors to act within an arrangement (Van Tatenhove et al., 2000; Van der Zouwen, 2006). Both formal and informal rules may affect the actor constellation in a project. Rules are studied through the indicators of access rules, allocation of responsibilities, interaction rules, legislation and policy rules.
- A discourse is defined as an interpretive framework or dominant interpretive scheme that give understanding and meaning to a particular arrangement (after: Van Tatenhove et al., 2000). The discourse is studied by analysing how actors describe the rationale (reason of the arrangement), the central purpose and the solutions of the arrangement.

The dimensions are interconnected within one arrangement. Although the indicators for the four dimensions are the same for each arrangement, they may have different values as the arrangements differ in scope. The project arrangement represents the context of application for which knowledge is developed. The project arrangement focuses on the overall project goals and the activities undertaken to achieve them. For instance, the project arrangement explains how actors define the coastal problems (discourse), how they obtain funding (resources) and how project partners (actor coalition) allocate responsibilities among them (rules). The knowledge arrangement conceptualises the process of interactive knowledge development for a particular solution in the project. This different scope results in a knowledge arrangement that differs from the project arrangement. For example, other actors, like researchers or advocates of the particular solution, may participate in the knowledge arrangement, new resources in terms of funding and information may play a role in the knowledge arrangement, and, different legislation may be relevant to the particular solution when compared to legislation for the coastal project. The knowledge arrangement is analysed both in terms of the four dimensions and the following four activities that define a process of interactive knowledge development (Van Buuren et al., 2004; Van de Ven, 2007):

- problem formulation – the scope of a problem is determined and research questions are formulated;
- selection of methods and techniques – discussions focus on the use of methods, techniques, models and theories for knowledge development;
- interpretation of results – results are interpreted, after which conclusions are drawn;
- choice of solution – a solution is chosen to solve the problem under study.

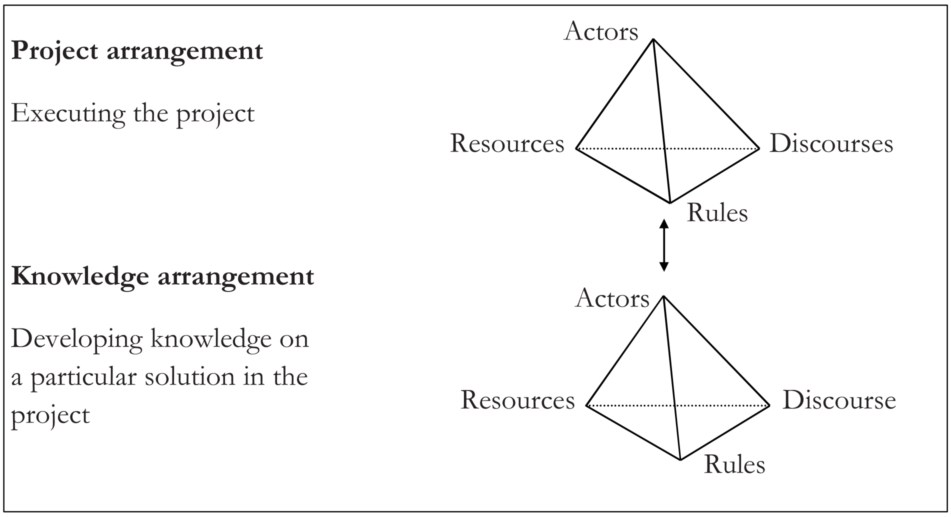

Figure 1.3. Conceptual framework of project and knowledge arrangements

The project and knowledge arrangement are closely related. This is emphasised by the double-sided arrow in Figure 1.3. On the one hand, developments in the project arrangement may impact the knowledge arrangement. For instance, limited time in the project arrangement may impact the involvement of actors in the knowledge arrangement. On the other hand, developments in the knowledge arrangement may impact the project arrangement. For example, the involvement of a range of actors in the knowledge arrangement may result in broad support for the developed solution, thereby broadening support for the project arrangement. The connection between the arrangements represents a similar logic as in Giddens' duality of structure. The practices of interactive knowledge development are neither fully explained by actions of actors in the knowledge arrangement, nor by decisions in the project arrangement structuring these practices. Instead, the two are tied to each other and both are needed to analyse practices of interactive knowledge development.

In this study, the framework of project and knowledge arrangements is used to structure analyses of interactive knowledge development in three coastal projects.

1.4. Methodology

1.4.1 Research design: the case study method

The case study is selected as research method in this study. The case study is defined as an intensive study of a single unit for the purpose of understanding a larger class of (similar) units (Gerring, 2004). In a case study, complex social phenomena are analysed in their context, in which boundaries between phenomena and context are not always clear (Yin, 2003). I apply the case study method as interactive knowledge development is a complex social phenomena. The case study method can ground this study in the reality of those that attempt to develop knowledge interactively. In this study, a case is defined as a coastal project where actors attempt to develop knowledge for a coastal solution in interaction between researchers, policymakers and stakeholders.

The case study method has been prone to concerns regarding methodological rigor (Gerring, 2007; Gibbert et al., 2008). Case-study researchers can improve the rigor of case studies by explaining how their study meets rigor criteria (Gibbert et al., 2008). Commonly used criteria are construct validity, internal validity, external validity and reliability. Table 1.3 summarises these criteria. The remainder of this sub-section explains how these criteria (in italics) are related to this study.

Table 1.3. Tests for validity and reliability of case study research.

Criteria	Description	Test for case studies	Reference
Construct validity	Operationalisation of variables to capture the theoretical constructs.	The collected empirical data captures the concepts of the conceptual framework accurately.	Mitchell and Bernauer, 2004
Internal validity	The causal relationships between variables and research findings.	Logical reasoning is provided that is powerful and compelling enough to defend the research conclusions.	Gibbert et al., 2008
External validity	Generalisation of findings to a broader class of cases than the one(s) studied.	The boundary is accurately identified between the class of cases to which the findings can be validly generalised and beyond which valid generalisations are unlikely.	Mitchell and Bernauer, 2004
Reliability	Study is reliable as errors and biases in the study are minimalised.	Another researcher that follows the same procedures and conducts the same case study all over again arrives at the same conclusions.	Yin, 2003

The case study method has a high *construct validity* since it gives a researcher the ability to identify and measure the indicators that best represent the theoretical concepts a researcher intends to measure (George and Bennet, 2005). Therefore it allows for an in-depth analysis of complex, uncertain and multidimensional phenomena in their context (Flyvbjerg, 2006), a description that fits the subject of interactive knowledge development. Consequently, the case study method gives the opportunity to develop the conceptual framework of project and knowledge arrangements, and, it gives the opportunity to apply it in the setting of coastal projects where actors attempt to develop knowledge interactively. The construct validity of this study is increased by providing case analyses in the terms of the conceptual framework.

Given the intensive study of a single unit, case studies have a high *internal validity* (Flyvbjerg, 2006; Gerring, 2007) as analyses can capture the context-specific details of the studied cases. The internal validity can be improved by inferring causal mechanisms that explain how one variable influences another within the case studied (George and Bennet, 2005). In this study causal mechanisms are derived and developed that explain interactive knowledge development in the project and knowledge arrangement. In addition, data sources were triangulated during the data analysis to make the findings more powerful such that they defend the conclusions of the case studies.

The case study method is weaker in *external validity* as only a few cases can be studied. The generalisation to a broader class of cases may improve by comparison of a few cases (Flyvbjerg, 2006; George and Bennet, 2005; Gerring, 2007). Three cases are analysed in this study as the next paragraph will explain. Furthermore, the comparison among a few cases may result in a deeper understanding of the phenomenon under study as patterns may emerge that remain unnoticed within one case (Miles and Huberman, 1994). In addition, the external validity of this study is improved by explaining the range of cases to which findings of this study apply (in Chapter 5, Section 5.6 and Chapter 6, Section 6.1.2).

Explaining the rationale in case selection is another strategy to improve the *external validity* (George and Bennet, 2005; Gerring, 2007). In this study, the criteria for case selection were derived from the research interest: coastal projects that address complex coastal problems and attempt to develop knowledge for solutions in interaction. Three cases were selected: two coastal projects in the Netherlands (Wadden Sea and the Ems estuary) and one in the USA (San Francisco Bay). These choices reflect a 'most different' research design (George and Bennet, 2005; Gerring, 2007; Landman, 2008) in that they share a number of key characteristics and a similar outcome, yet differ in terms of other possible explanatory factors. The shared characteristics are the case selection criteria: coastal projects addressing complex coastal problems through interactive knowledge development. The coastal projects differ in three aspects of project management, namely how they manage time, manage costs and project scope (Atkinson, 1999; Morris and Geraldi, 2011). A fourth defining aspect is the institutional context in which a project is embedded. The prevailing institutional structure both enables and constrains the practices of actors in projects (Grabher, 2002; Morris and Geraldi, 2011). Table 1.4 shows how the three cases differ in terms of these four aspects.

Table 1.4. Similarities and Differences identified in the most different research design

	Wadden Sea: dike-reinforcement project	**San Francisco Bay: nature restoration project**	**Ems estuary: spatial development project**
Similarities			
Coastal zone	Dikes protecting Texel from the Wadden Sea.	Salt ponds between Silicon Valley and South San Francisco Bay.	Delfzijl's maritime zone adjacent to the Ems estuary.
Complex coastal problem	17 km of dikes no longer meet safety norms.	The project owns 60.7 km^2 of salt ponds that could be restored.	The liveability of Delfzijl is seen as problematic, the project focuses on options in the maritime zone (35 km^2).
Interactive knowledge development actors	Government (regional and local), experts (mainly consultants), nature organisations.	Government (federal, state and local), experts (scientists and consultants), stakeholder forum.	Government (regional and local), experts (scientists and consultants), port authority, nature organisations.

Differences			
Scope	Provide flood control.	Restore tidal marsh.	Improve liveability.
Financial	Funding for project solutions is largely covered by a national program.	Funding for project solutions is organised for each phase of implementation.	The project lacks funding to implement solutions.
Time	Considerable time pressures as original delivery deadlines were not met.	Little time pressure as final implementation phase should be completed by 2058.	No time pressure due to absence of funding for implementation.
Institutional context	The Netherlands.	California, USA.	The Netherlands.

The last criterion for scientific rigor is *reliability*. The reliability of a case study may improve by being transparent about the research process. Such transparency enables virtual replication (Boeije, 2010). Four measures were taken to increase the transparency of this research process. First, case study protocols were created prior to each case study (Yin, 2003). Each protocol addressed the following topics: how the coastal project fitted into the entire study, how access was granted to the project, how data would be collected, a risk analysis of the case study, a time schedule, questions that the case study should answer and the output it should deliver. In addition, the protocol helped to ensure that the case studies were conducted similarly. Second, I kept a research diary wherein I wrote about the main outcomes of meetings, phone calls and interviews. Key decisions in data collection were also written down. For instance, on which individuals to interview or how the case unfolded to me while collecting data. I continued to write in the diary during the data analysis, for instance about the steps taken and emerging insights from the analysis. Lastly, virtual replication of this study is enhanced by sharing the procedures in data collection and analysis (Section 1.4.2 and 1.4.3). Consequently, this study is reliable since the four measures provide sufficient transparency for virtual replication.

1.4.2 Data collection

In each case, case analyses were created from four sources of data: semi-structured interviews, observations, project documents and field trips. Data were collected one case at a time. Table 1.5 summarises the time periods and data sources in each case.

Table 1.5. Overview of collected data in each case.

	Wadden Sea: dike-reinforcement project	**San Francisco Bay: nature restoration project**	**Ems estuary: spatial development project**
Time period of data collection	September 2011 – February 2012	May 2012 – December 2012	May 2013 - October 2013
Time period analysed	2005-2011	2003-2013	2009-2013
Interviews project arrangement	5	9	9
Interviews knowledge arrangement	5	10	6
Project meetings	2	6	4
Field trips	2	5	2
Project documents (number of files)	373	842	107

Semi structured interviews were held to obtain views of key actors on interactive knowledge development in the coastal projects. Interview guides were developed that consisted of an introduction, the interview questions and a closure (after: Emans, 2002). The interview guides, one for the project arrangement and one for the knowledge arrangement, covered research questions for each indicator of the arrangement. Appendix I presents the interview questions that were used in the Wadden Sea case study. I tested the interview guides in interviews with two Dutch experts, who were involved in water management projects that attempted to develop knowledge interactively. In each case study, I conducted two types of interviews. One focused on the project arrangement and the other on the knowledge arrangement. Interviewees were purposefully sampled. Individuals were interviewed that were familiar with the project and had a sense for relations with other actors in the coastal project. Key informants in the project helped to create the list of interviewees. The interviews offered insights into the actor's views of on-going dynamics in the project and knowledge arrangement. During the interview, follow-up questions were asked using clean language questions (Tompkins and Lawley, 1997). Each interview was conducted face to face, recorded and transcribed for data analysis. An interview typically lasted between 60 and 90 minutes. During the course of the case study, follow-up questions were asked when things appeared to be unclear or in contrast with what others said before.

Observations of project meetings were another source of data collection. Since most meetings were 'closed' meetings of the project management team, I had to discuss my presence in these meetings with project managers. In the meetings, I participated as observer by taking the role of a researcher conducting observational research. Participants in these meetings were aware of this role since I introduced myself and my role at the start of these meetings. The observations were less-structured (Foster, 1996) as I focused on everything the actors said both verbally and nonverbally. I directly wrote this down using key words and initials of the specific actor. After a meeting ended, I converted these field notes into meeting notes by writing down as detailed as possible what was said by whom. Then, I formulated my interpretations on the basis of these observations. The observations enabled me to directly observe interaction processes between actors, thus providing a different data source than the interpretations of interviewees.

Other data sources included project documents and field visits. I received project documents from key actors. I categorised in each case the project documents to facilitate easy retrieval. Among the project documents were reports, meeting notes, presentations, letters and records of decisions. Based on the documents, two lists of critical events were created for the project and knowledge arrangement. Both lists were validated with several respondents prior to, or as part of the interviews. The project documents were important sources to cross-check statements of the interviewees. Lastly, field visits were made to the coastal areas that the projects were targeting. I made pictures of these areas and wrote down my observations in the research diary or on the computer. The visits improved my understanding about the physical, ecological and social dynamics that are relevant to the project. This enabled me to ask more specific questions to interviewees when their answers were fairly general. Each case-study chapter (Chapter 2, 3, 4) shows on the title page a picture that was taken during a field visit.

1.4.3 Qualitative data analysis

I rely on qualitative data analysis techniques since I consider a phenomenon of interactive knowledge development too complex to be analysed in a quantitative manner (e.g. surveys). In addition, perspectives of respondents differ on processes of interactive knowledge development, therefore requiring the interpretation of a researcher to come to an understanding of the main concepts in the framework of project and knowledge arrangements. The qualitative data analysis involves deductive and inductive reasoning. Deductive reasoning is involved since the analyses are structured by the framework of project and knowledge arrangements. Inductive reasoning is applied given the limited understanding of interactive knowledge development in the project environment. I have analysed the collected data in a structured manner. Figure 1.4 shows the undertaken steps of qualitative analysis, the remainder of this section discusses these steps.

Coding refers to the labelling of text fragments. I transcribed in each case the interviews and coded them using the software package of QSR Nvivo. The interviews were coded in clusters that consisted of interviews related to the project-arrangement and interviews related to the knowledge arrangement. A cluster typically consisted of three project arrangement interviews and two knowledge arrangement interviews. When coding for one cluster was completed I started coding the next cluster, thereby moving multiple times through the coding procedure. In addition, by coding project and knowledge arrangements within a cluster, the analysis directly focused on dynamics within and between the project and knowledge arrangement. I developed a coding procedure that is based upon a template coding approach (Crabtree and Miller, 1999; Miles and Huberman, 1994) and logic of axial and selective coding (Boeije, 2010). This template coding approach is applied in each case study. It consists of three rounds of coding: template coding, axial coding and selective coding.

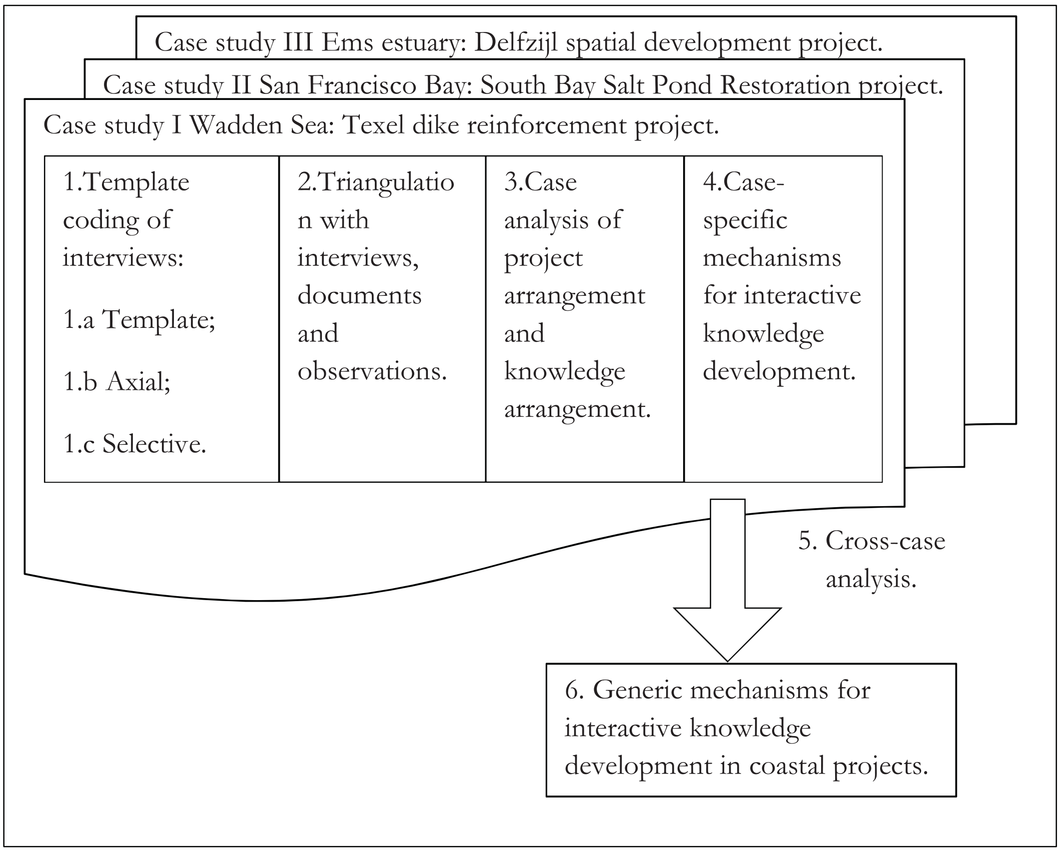

Figure 1.4. Qualitative data analysis for practices of interactive knowledge development in coastal projects. The numbers in the Figure correspond with numbers in the text.

(1.a) The *template* coding round is deductive, since the reasoning moves from the coding template to the text. Thus, the transcribed interviews are sorted along the codes of the template. The applied coding template is presented in Appendix II. It was derived from the dimensions and indicators of the project and knowledge arrangement. With template coding I broke down the transcribed interviews into separate text fragments labelled by the codes of the template. For instance in the Texel case, under the code 'actor relations' in the project arrangement were all text fragments placed that referred to relations between actors in the dike reinforcement project.

(1.b) In the *axial* coding round, coded fragments are further categorised. This is done rather inductively, since the reasoning moves from text fragments –the ones coded with template codes- to new codes[4]. These new codes formed sub-categories of existing template codes. The axial coding created a better understanding on the case-specific meaning of the template codes by zooming in on each template code. For example, fragments of the template code 'actor relations' were axially recoded into character, motive, role and level of a relation in the Texel case.

[4] Strictly speaking, this is reversed axial coding since in axial coding reasoning moves from codes to text fragments (Boeije, 2010). The coding in my template coding approach is still axial, since it consists of coding around axes (that is, the codes of the template) yet moves from text fragments to new codes.

(1.c) The *selective* coding round is rather deductive since connections are explored between dimensions and indicators of the project and knowledge arrangements. In this selective coding round, text fragments are no longer coded in Nvivo. Instead, tables were created that explore connections within and between the dimensions and indicators. Further, schemes were drawn to capture the essence of the project arrangement and knowledge arrangement. For instance the connection between actor relations and resources was explored. The key findings of the project and knowledge arrangement were derived through the selective coding round.

(2) The findings from the template coding procedure are based on the transcribed interviews. These findings were triangulated in two ways. Initially, the findings were compared during the coding procedure across the interviews. Later, the findings were validated with project documents and observations of project meetings. These triangulation efforts increased the internal validity of this study since findings are stronger tied into different sources of data.

(3) The template coding approach and triangulation efforts resulted in analyses of the project arrangement and knowledge arrangement. These analyses discuss the actor dynamics in the arrangements in terms of actors, rules, resources and discourses.

(4) Case-specific mechanisms were developed from these analyses. Causal mechanisms link causes with outcomes and thereby describe how causes contribute to observed outcomes (Beach and Pedersen, 2013; George and Bennet, 2005). This results in an understanding that goes beyond cause-effect relationships since the mechanisms describe how the effects are produced. I derived a set of causal mechanisms within each case. The mechanisms derived in this study specify the functioning of interactive knowledge development. The mechanisms were developed by iterating between the case analysis – that explained what happened in the case, the conceptual framework –that offered potential explanations for interrelations, and the drafted causal mechanisms –that gave a first explanation for the functioning of interactive knowledge development. The iteration process ended when the case-specific explanation of interactive knowledge development no longer improved. Thus, the case-specific mechanisms are inductively derived from case analyses that were structured by the conceptual framework of project and knowledge arrangements. The case-specific mechanisms are therefore the result of deductive and inductive reasoning.

(5-6) The case-specific mechanisms are transformed through a cross-case analysis into generic mechanisms that explain interactive knowledge development in coastal projects. The cross-case analysis is informed by a variable oriented strategy where variables are compared across cases (Miles and Huberman, 1994). The case-specific mechanisms served as variables that were compared with each other to arrive at the generic mechanisms. The generic mechanisms were developed iteratively by filling cross-case tables and re-examining the single case analyses.

1.5. Reading outline

This introduction has provided the background to study processes of interactive knowledge development in coastal projects. Interactive knowledge development is analysed through the conceptual framework of project and knowledge arrangements using the case study method.

Chapter 2 discusses the research gap of interactive knowledge development in the project environment. The functioning of interactive knowledge development is analysed in the dike reinforcement project on the island of Texel, located in the Wadden Sea. In this project, knowledge is developed interactively for a seaward solution entailing of a sand-based flood defence in the Wadden Sea, supplemented with salt marshes and oyster reefs. The case-analysis results in causal mechanisms that explain interactive knowledge development.

Chapter 3 outlines the relevance and difficulty of interactive knowledge development for coastal decision-making by presenting a case analysis of the salt pond restoration project in South San Francisco Bay. Knowledge is developed interactively for restoration alternatives that consist of breaches in salt pond levees, ecotone transition areas and public access features. Causal mechanisms are developed that explain interactive knowledge development in this restoration project.

Chapter 4 focuses on social robustness as key outcome of interactive knowledge development. Social robustness refers to knowledge that is relevant and acceptable to actors in the coastal project. Theoretical conditions how knowledge can be made socially robust in coastal projects are compared to a spatial development project at Delfzijl, a Dutch seaport located on the banks of the Ems estuary. Knowledge is developed interactively for a solution that integrates an expansion of the city beach with tidal marsh, recreation and flood control.

Chapter 5 analyses interactive knowledge development against the backdrop of sustainable coastal development. A cross-case analysis is presented of the cases that are analysed in chapters 2, 3 and 4. The case-specific arrangements and causal mechanisms are compared to arrive at generic mechanisms that explain the functioning of interactive knowledge development in coastal projects.

Chapter 6 integrates the findings of the previous chapters to provide the key conclusions for the two research questions. Further, the chapter contains the implications of this study by discussing contributions to science and methodology. The limitations of the study are discussed to clarify the limits of the study. The chapter ends with recommendations for further research and recommendations for practitioners to facilitate interactive knowledge development.

The thesis outline and connections between the chapters and research questions are summarised in Figure 1.5.

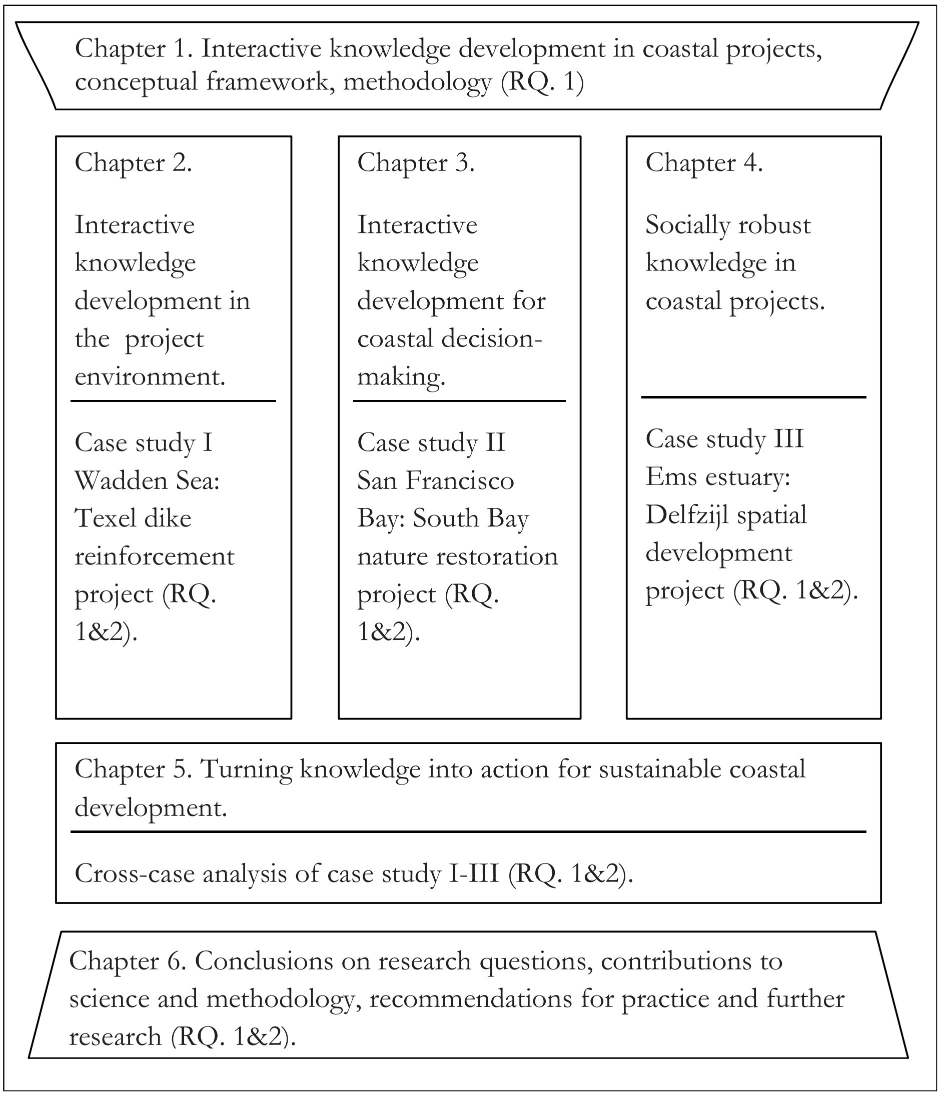

Figure 1.5. Thesis outline. The outline summarises the topics and research questions in each chapter.

Chapter 2. Understanding interactive knowledge development in coastal projects[5]

Photo I. The Wadden Sea dike bordering the Prins Hendrik polder on the island of Texel. Seventeen kilometers of the Wadden Sea dike are reinforced since dike sections do not meet the safety norms. The perspectives vary on how to reinforce this specific dike section. The local water board announced to investigate traditional, landward solutions whereas Texel-based organisations demanded research into an innovative seaward solution. The Texel dike reinforcement project is the first case study in this study. This chapter explores how knowledge was interactively developed for a sand-based seaward solution in front of the Prins Hendrik Polder. (Source: photo taken by Chris Seijger on October 12, 2011)

[5] This chapter has been published as: Seijger, C., G. Dewulf, H.S. Otter and J. Van Tatenhove (2013). Understanding interactive knowledge development in coastal projects. Environmental Science & Policy 29: 103-114.

Abstract

Various concepts have been developed that refer to interactive modes of knowledge production. Examples such as Mode 2 knowledge and post-modern science highlight the involvement of researchers, decision makers and other societal actors, in order to develop relevant knowledge for decision making. Existing research into such modes of knowledge development focuses on the interfaces between science, policy and society. This paper introduces a conceptual framework for the connection between interactive knowledge development and a project environment. The aim of this paper is to improve the understanding of interactive knowledge development in a project's environment, by presenting a case study of interactive knowledge development in a coastal project. Coastal projects intend to develop solutions in the coastal zone: a dynamic and fast changing environment. This paper adapts the policy arrangement approach to study interactive knowledge development longitudinally in the Texel dike reinforcement project. Eight mechanisms are derived that affect and explain the process of interactive knowledge development in this case. The mechanisms indicate how interactive knowledge development may result in more relevant knowledge and broadly accepted solutions.

2.1. Introduction

A gap exists between knowledge production in research and the limited use of these research results by actors outside the scientific community in policy practices. There is a growing recognition that this gap can be framed as a knowledge production problem (Etzkowitz and Leydesdorff, 2000; Gibbons, 2000; McNie, 2007; Nowotny et al., 2001; Van de Ven and Johnson, 2006). As a means to understand and narrow this gap, several interactive modes of knowledge production have been developed, such as Mode 2 knowledge (Gibbons et al., 1994), post-modern science (Funtowicz and Ravetz, 1993) and engaged scholarship (Van de Ven and Johnson, 2006). These modes are different from the basic mode of knowledge production in research (often referred to as Mode 1 knowledge development). They are characterised by an aim for relevant research in the context of application and the involvement of actors outside the research community, such as decision makers and other societal actors (Hessels and Van Lente, 2008). Interactive modes of knowledge production are promoted for dealing with complex, interdependent environmental problems, as well as dealing with the changes in the relations between science, society and policy (Funtowicz and Ravetz, 1993; Gibbons et al., 1994; Hegger et al., 2012; Hessels and Van Lente, 2008). Challenges of producing relevant knowledge interactively link to 'how to do it?' issues, as participating actors in interactive knowledge development hold different norms, values and criteria for knowledge production (Edelenbos et al., 2011). This complicates processes of interactive knowledge development and can easily result in negotiated nonsense, superfluous knowledge, or unused knowledge (McNie, 2007; Van de Riet, 2003).

Much work has been published already on bringing actors together in environmental issues through interactive modes of knowledge production. In the environmental sciences, many authors focus on the interfaces of science-management (Burbidge et al., 2011; Roux et al., 2006), science-policy (Bremer and Glavovic, 2013; Van der Sluijs, 2005), science-society (Callon et al., 2009; Lane et al., 2011), or on a combination of these interfaces (Buizer et al., 2011; Rogers, 2006). In this paper we study interactive knowledge development at the level of coastal projects. Interactive knowledge development is defined in this paper as a participative form of knowledge production, in which knowledge is shared and developed by obtaining perspectives of key stakeholders (researchers, policy makers, stakeholders) involved in the complex problems that are being studied (Van de Ven, 2007) to develop relevant solutions for the problems defined in the project. Key characteristics are: (1) the development of relevant knowledge for project solutions; (2) the multidisciplinary character; (3) the involvement of researchers, policy makers and stakeholders. The connection between interactive knowledge development and a project's environment is novel and distinguishes this paper from previous research on interactive modes of knowledge production. In this study it is not the researcher (Van de Ven, 2007), nor democratisation (Callon et al., 2009, In 't Veld, 2010), nor an optimal functioning science-policy interface (Bremer and Glavovic, 2013) that is at the forefront of the analysis; but interactive knowledge development is analysed at the level of a project and the setting in which that project develops.

A few descriptive case studies have been published on interactive knowledge development in projects (Edelenbos et al., 2011; Van Buuren and Edelenbos, 2004). Recently, Hegger et al. (2012) developed a conceptual framework to study joint knowledge production in research programs. The aim of this paper is to improve the understanding of interactive knowledge development in a project, taking into account the institutional context of that project, by developing a conceptual framework and describing a longitudinal case study.

We analyse interactive knowledge development in coastal projects. Worldwide, coastal areas are faced with increasing flood risks, expanding cities, land-based and maritime economic activities and threats to the natural environment (Cicin-Sain and Knecht, 1998; Kay and Alder, 1999). Developing relevant knowledge for solutions in such a highly dynamic environment is complicated, because the knowledge developed is often not closely aligned with the demands of stakeholders, policy makers or other researchers of the coastal zone (Blythe and Dadi, 2012; Tribbia and Moser, 2008; Visser, 2004). Three possible consequences of the gap between production and use of knowledge in coastal projects are: (1) involved stakeholders will criticise proposed policies and solutions (Moser, 2005; Mulder et al., 2011); (2) policy makers do not use the knowledge that has been developed (Merkx and Van Den Besselaar, 2008; Van Koningsveld, 2003); or (3) the development of disputes between competing knowledge coalitions (Turnhout et al., 2008). All such consequences may result in delay of the project and solutions that do not meet the demands of policymakers or other stakeholders.

The remainder of this paper is organised in four sections. Section 2.2, introduces the conceptual framework of this paper and the methodology used to study interactive knowledge development in a project environment. Section 2.3, discusses the results of the case analysis: interactive knowledge development in a Dutch dike reinforcement project. Section 2.4, presents a discussion on the derived mechanisms and conceptual framework. Section 2.5, provides the main conclusions.

2.2. Analysing interactive knowledge development in a project's environment

The narratives of key concepts such as Mode 2, post-normal science and engaged scholarship remain fairly general. They are insightful in the sense that they advocate the production of relevant knowledge which can be used in decision making; while taking into account changes in the relations between science, policy and society (Funtowicz and Ravetz, 1993; Gibbons et al., 1994; Nowotny et al., 2001). Yet, they are too general to explain dynamics around knowledge development in a project's environment. Existing studies that focused on the project level point to the problematic interactions between experts, bureaucrats and stakeholders (Edelenbos et al., 2011), to competing knowledge coalitions (Van Buuren and Edelenbos, 2004) and to the power play involved in knowledge development and use (Flyvbjerg, 1998). Obviously, interactive knowledge development in projects represent a social process (Hegger et al. 2012, Roux et al., 2006), which entails more and diverse social dynamics than the classic view of 'researchers speaking truth to power' (Hoppe, 2005).

Little empirical research exists into the involvement of stakeholders, policymakers and researchers in a process of interactive knowledge development within a project (Hegger et al., 2012) Consequently, interactive knowledge development in a project's environment remains a black box. Improving insights in mechanisms of interactive knowledge development is important because the ambitions and benefits of such forms of knowledge production are widely proclaimed, but in practice, the processes appear to be tough, problematic and complex (Edelenbos et al., 2011).

2.2.1 Conceptual framework: project arrangements and knowledge arrangements

The policy arrangement approach (Van Tatenhove et al., 2000) is used to open the black box of interactive knowledge development in projects. The policy arrangement approach was chosen as it is compatible with the project setting. Similar to policy domains, projects have a temporary character and are dynamic over time (Turner and Müller, 2003). Both aspects are explicitly addressed in the policy arrangements approach, as policy arrangements are defined as temporary (Arts et al., 2006) and changes in one dimension may invoke changes in other dimensions (Liefferink, 2006). Furthermore, the approach is inspired by Giddens' notion of duality of structure (Giddens, 1984) offering a solid base for analysing actors in their context. Other multi-actor policy models pay less attention to the institutional context, the content of policy making and power relations between actors involved (Wiering and Arts, 2006). Hegger et al. (2012) also use the policy arrangements approach to study interactive knowledge development, yet they focus on success conditions in research programs and not on the role of interactive knowledge development in the project environment. Hence, they do not provide insight in how interactive knowledge development and project development are intertwined. Understanding the complex interplay between interactive knowledge development and the project environment is needed since interactive knowledge development implies a contextually dependent research process, which is characterised by intensive and contested academic-practitioners negotiation about content and process of the research (Knights and Scarbrough, 2010).

The overall objective of the policy arrangement approach is to link changes in day to day policy practices to broader processes of structural change. In other words, the institutionalisation of policy arrangements is the result of interaction of actors within a certain context. In interaction, actors produce and reproduce the structural properties of the context. A policy arrangement has been defined as "the temporary stabilisation of the content and organisation of a policy domain" (Van Tatenhove et al., 2000) and can be analysed along the following four dimensions:

- Actors and their coalitions;
- The division of resources between actors that lead to variations in power and influence;
- The rules of the game in operation, both in formal procedures and informal routines of interaction;
- Discourses, that entail views and narratives of actors involved.

In interactive modes of knowledge production, various authors have highlighted the importance of the context of application in which knowledge is developed (Hessels and Van Lente, 2008; McNie, 2007; Nowotny et al., 2001; Van Buuren and Edelenbos, 2004). We therefore distinguish *two* types of arrangements which are needed to understand interactive knowledge development within a project: the project arrangement and the knowledge arrangements for solutions. In the project arrangement, problems are defined, solutions proposed and decisions are taken. The knowledge arrangement focuses on the process of knowledge development to develop solutions for the problems defined in the project arrangement. The four dimensions of a policy arrangement described by Van Tatenhove et al. (2000) are applicable for both arrangements. The dimensions are studied through the same indicators. Actors consist of actor involvement, actors relations, actors affected and actor coalitions. We focus on three resources: time, money and information. In rules we distinguish access rules, allocation of responsibilities, legislation and policy rules and interaction rules. We study discourses on the project rationale, the project solutions and coastal defence.

Coastal projects are organised around a central purpose (i.e. combatting erosion, restoring nature) and several activities are employed by actors to achieve the project's purpose. Among others, the activities relate to decision making, the allocation of resources and communication to a broader public. A project arrangement supports a proper analysis into these sorts of activities, as it captures the content and organisation of a project (Korbee, 2010). Another activity in coastal projects is the development of knowledge for solutions that achieve the purpose of the project. Knowledge arrangements conceptualise a process of interactive knowledge development for such a solution[6]. Within a knowledge arrangement, we define four main activities in a process of interactive knowledge development (Van Buuren et al., 2004; Van de Ven, 2007), thereby opening the black box of interactive knowledge development:

- Problem formulation – the scope of a problem is determined and research questions are formulated by the actors involved that address this problem.

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[6] A different interpretation of knowledge arrangements is presented in (Janssen, 2011). She uses knowledge arrangements at the level of a policy domain, by linking both processes of knowledge development and use to a specific policy domain.

- Methods and techniques to be used – discussions focus on the use of methods, techniques, models and theories for data collection.
- Interpretation of results – results are interpreted, after which conclusions are drawn.
- Choice of solution – a solution is chosen to solve the problem under study.

The two arrangements have a distinct scope: the knowledge arrangement focuses on dynamics of interactive knowledge development for a particular solution and the project arrangement on the overall project goals. This may result in different values when the dimensions of the two arrangements are compared within a project. As an example, other actors can be involved in interactive knowledge development than in decision making at the project level, tapping into different resources, with other rules in operation and advocating different discourses. Distinguishing two arrangements has two advantages that enable a better understanding of interactive knowledge development in a project's environment. First, by separating interactive knowledge development from the other project activities, a complex process as interactive knowledge development can be studied more thoroughly through the four activities. Second, through the separation we can derive causal mechanisms that can function as vehicles of explanation (George and Bennett, 2005) for a process of interactive knowledge development.

2.2.2 Methodology

This study has an exploratory character since the conceptual and empirical research into processes of interactive knowledge development in projects is very limited. The case study is selected as research method because it has high construct validity. It gives a researcher the ability to identify and measure the indicators that best represent the theoretical concepts a researcher intends to measure (George and Bennett, 2005). Therefore it allows for an in-depth analysis of complex, uncertain and multidimensional phenomena –such as interactive knowledge development- in their context (Flyvbjerg, 2006). In addition, a case study is able to infer causal mechanism that explain how one variable influences another within the case studied (George and Bennett, 2005). As the case study method suits an in-depth analysis of one or a few cases it can reach a high internal validity, consequently is less suitable for an investigation of a larger range of cases (Flyvbjerg, 2006; Gerring, 2007). Generalisation to a broader class of cases can be achieved through a careful case selection (idem).

The results discussed in this paper are based on three sources of data: semi-structured interviews with project members (see Appendix III for an overview), participant observations of two project meetings and content analysis of more than 300 project documents. Data triangulation (within and across sources) was applied to the main findings to increase the internal validity of this study. Ten interviews were conducted, of which five focused on the project arrangement and five on the knowledge arrangement. Data were analysed qualitatively. Interviews were fully transcribed and coded in a systematic step-by-step procedure using the software package QSR NVivo. Our analysis is based upon a template coding approach (Crabtree and Miller, 1999; Miles and Huberman, 1994). On the basis of the various indicators in our conceptual framework, a list of codes was developed prior to the data analysis. Template coding involves the labelling of text fragments on the basis of these codes. Next, all text fragments were read through and further categorised. Finally, the connections between the different categories and indicators were explored. This resulted in causal mechanisms that explain how interactive knowledge development works within a project.

2.3. The Texel dike reinforcement project

The Texel dike reinforcement project was selected for our analysis, because it represents characteristics of interactive knowledge development within a coastal project: actors outside the research community were involved in knowledge development for a multidisciplinary solution. Data were collected to analyse the project arrangement from 2005 until 2012 and the knowledge arrangement of a sandy seaward solution during 2010-2011.The case is a deviant case (Flyvbjerg, 2006; Gerring, 2007), as the paradigm of traditional dike reinforcements is successfully criticised. The traditional paradigm is based on a 'fighting against the sea' philosophy: building dikes to keep peoples feet dry (Wiering and Arts, 2006). It represents a technocratic water engineering approach and results in 'hard' engineering solutions such as dams, dikes and storm surge barriers. New approaches[7] appear in Dutch water management, but are often constrained by the traditional way in which water management is still organised (Van der Brugge et al., 2005). This case illustrates what can happen when the limits of the traditional paradigm are criticised.

Texel is an island in the north of the Netherlands, protected by dunes and dikes against flooding from the North Sea and the Wadden Sea. Primary flood defences[8] in the Netherlands are tested every five years in a safety assessment against the latest safety norms. In 2005, 17 out of 27 kilometers of the Wadden Sea dike on the island of Texel failed to meet the safety norm of 1/4000 (one failure every 4000 years). As a result, the water board *Hoogheemraadschap Hollands Noorderkwartier* (HHNK), initiated a dike reinforcement project to ensure that the dike on Texel will meet the safety norm. The Texel dike reinforcement project is part of an Environmental Impact Assessment procedure (EIA), a procedure that requires research into alternatives for dike reinforcement[9]. Consequently, knowledge is developed in the project for various solutions for reinforcing the Wadden Sea dike. In June 2009, a Notification of Intent was published by HHNK in which different alternatives for each dike section were presented[10]. The water board plans to present the dike reinforcement plan in 2013.

2.3.1 Project arrangement

The arrangements are described as coherent descriptions to give the reader full understanding of dynamics in the project arrangement and knowledge arrangement. Section 2.3.1 describes the project arrangement, 2.3.2 explains how the knowledge arrangement became part of the project arrangement and 2.3.3 discusses the four activities of interactive knowledge development within the knowledge arrangement. The conceptual framework discussed in the previous section is used to analyse the case. The results are summarised in Tables 2.1 and 2.2.

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7 An example of such a new approach would be the 'Building with Nature' approach, which combines coastal defence with ecosystem services (Van Slobbe et al., 2013)

8 In the Netherlands, primary flood defences provide direct protection against flooding from the sea and the major rivers. Examples of these defences are dunes, dikes, and hydraulic structures.

9 HHNK, 2009. Dijkversterking Waddenzeedijk Texel: Startnotitie m.e.r. (p. 3-9)

10 Idem (p. 44-59)

Table 2.1. Summary of the main elements in the dimensions of the project arrangement and knowledge arrangement in this case study.

	Project Arrangement (2005-2012)	**Knowledge arrangement (2009-2011)**
Scope	Texel dike reinforcement project.	Interactive knowledge development for a sandy seaward solution.
Actors	HHNK, Province Noord-Holland, municipality Texel, FRPP, Dutch Parliament, Witteveen+Bos, NGOs in advisory group.	HHNK, Province Noord-Holland, municipality Texel, PRW (Towards a Rich Wadden Sea), Witteveen+Bos, Vertegaal Ecologisch Advies, NIOZ deputy director, village committees, nature organisations.
Resources	FRPP and HHNK co-finance the project. Delivery deadlines are not met and costs rise over time.	PRW and municipality of Texel finance research.
Rules	Water Act, Nature Protection Act, Environmental Management Act, National Water Management Agreement, Spatial Planning Act.	Nature Protection Act and Water Act.
Discourse	The dike does not meet current safety norms and has to be strengthened. Reinforcements have to be plain, robust and effective.	Sustainable seaward solutions for coastal defence at Texel.

The formal rules form a central dimension in the project arrangement, influencing the inclusion of actors, resources and legitimate discourses. Five national laws apply to the dike reinforcement project and allocate various responsibilities to various actors. The Water Act (2009) describes the prevailing safety norms and an assessment framework for primary flood defences. It makes HHNK responsible for the safety of its flood defences, appoints the *Hoogwaterbeschermingsplan* (Flood Risk Protection Plan (FRPP) as the funding body, and the province as the supervisory body over the water board. The Nature Protection Act (1998) organises the nature protection in Natura 2000[11] areas. The Wadden Sea adjacent to Texel has been declared a Natura 2000 area. The Province of Noord-Holland is responsible for issuing permits for activities in Natura 2000 areas. The Environmental Management Act (1979) defines requirements for an Environmental Impact Assessment procedure. The National Water Management Agreement (2011) discusses financial arrangements for dike reinforcement projects between the various water boards and the Dutch government. Finally, the Spatial Planning Act (2006) states that the municipality is responsible for its own (spatial) zoning scheme in its district. This is relevant as dike reinforcements can require changes to a zoning scheme.

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[11] The Habitats Directive (1992), together with the Birds Directive (1979) forms the cornerstone of Europe's nature conservation policy. It is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection. The Natura 2000 network has to be realised by the designation of Special Protection Areas (SPA, Birds Directive) and Special Areas of Conservation (SAC, Habitat Directive).

The water board created three groups to arrange the involvement of several organisations in the project: a core group, a project group and an advisory group. The core group consists of HHNK and Witteveen+Bos . HHNK is initiator of the dike reinforcement project and has the responsibility to ensure that the Wadden Sea dike meets the safety norms. Witteveen+Bos is an engineering and consultancy company and assists HHNK in the different steps of the EIA procedure and conducts most of the research into the different alternatives for dike reinforcement. The aim of the core group is to coordinate and execute the project. The project group consists of the core group, Province of Noord-Holland and the municipality of Texel. These actors participate in the project group as they have various responsibilities by law. Responsibilities between actors are also allocated in government meetings with administrators from the province, water board and municipality. The advisory group consists of actors who are somehow affected by the dike reinforcement project, such as farmers, inhabitants and nature organisations.

Funding, as an important resource for the dike reinforcement project, comes mainly from the Flood Risk Protection Programme (FRPP). The discourse behind the funding criteria is a frequently repeated statement by respondents: reinforcements should be plain, effective and robust[12]. This discourse structures the feasible solutions for reinforcement as highlighted in the following quote: "*FRPP told us (…) we finance a plain and effective solution, we do not subsidise additional spatial quality*" (HHNK, 15-12-2011). Reports are sent every three months from HHNK to FRPP, discussing the project's progress, risks and planning.

The project has grown considerably in costs and the original delivery deadlines have not been met. The original delivery deadline of 2015[13] has been postponed to 2019. Expected costs have risen over the years from 90 to 223 million euros[14]. New insights have enlarged the scope and the expected impact of the alternatives considered and therefore both delay the dike reinforcement and make it more expensive. Respondents mention three causes for the changing scope and expected impact: (1) uncertainties in proper boundary conditions of water levels and wave heights; (2) new piping[15] calculations; and (3) a more rigorous reinforcement strategy which also addresses potential failure mechanisms once a dike section fails to meet the safety norms (so-called integral dike reinforcement). Those changes are explained in a Revised Notification of Intent that was published in September 2011 by the water board[16]. As FRPP (including the project at Texel) has grown considerably in costs, a report is required every six months by the Dutch House of Representatives about expected costs and progress made.

The central actor in the dike reinforcement project is HHNK, whose role and responsibilities are defined by the formal rules of the Water Act. HHNK cooperates closely with Witteveen+Bos in

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[12] This discourse also returns in Minutes of government meetings. Minutes of government meeting June 3, 2009 (p. 2-3); October 19, 2009 (p. 2)

[13] HHNK, 2011. Planstudie Dijkversterking Waddenzeedijk Texel: Procesplan (p. 27)

[14] Minutes government meeting November 23, 2011 (p. 1)

[15] Piping refers to internal erosion of soil particles within a dike by water that seeps through the dike. This erosion may form a continuous pipe, which undermines the dike and eventually results in dike failure.

[16] HHNK, 2011. Oplegnotitie Startnotite: Aanvulling op de startnotititie (p.7-9)

the core group and involves a range of actors in the project. Access rules for involving other actors are consequently based on formal rules or actors affected.

Scarce resources, such as time and money put the project under strict supervision by FRPP and the Dutch Parliament. The funding criteria of soberness, effectiveness and robustness are a dominant discourse in the project that structure the possible solutions for reinforcement.

2.3.2 How the knowledge arrangement of a sandy seaward solution became part of the project arrangement

Our analysis identified three different knowledge arrangements that focus on solutions for the dike reinforcement at Texel. Each one has a distinct scope, that involves other actors which contribute resources. First, traditional engineering solutions are developed in the core group. These solutions rely on sheet piling and revetments by stones or grassed clay[17]. Second, knowledge is developed for innovative solutions (namely soil improvement and geotextile) that occupy less land than the standard engineering solutions[18]. Knowledge in this arrangement is developed by Witteveen+Bos, HHNK and other water boards. Third, knowledge is developed for a sandy seaward solution involving researchers, policymakers and stakeholders. The solution covers a length of 3.2 kilometer and consists of a sandy reinforcement of the dike, combined with various nature restoration measures (see Figure 2.1).

Initial ideas for a sandy seaward solution were formed during meetings that focused on sustainable transitions for Texel organised by a national sustainability programme in the period 2007-2009[19]. Actors such as the deputy director of NIOZ (Royal Netherlands Institute for Sea Research) and the municipality of Texel drew the link between sustainable transitions and the dike reinforcement project and started to think about sustainable seaward alternatives.

In contrast, the Notification of Intent (June 2009) proposed traditional landward solutions for the 10 dike sections that needed reinforcement[20]. In a written response (September 2009), a group of ten actors –all based on Texel- disagreed with these solutions. The response was signed by the municipality of Texel, NIOZ, three village committees and two nature organisations. This group requested the investigation of alternative, sustainable solutions for 5 dike sections. One proposed solution was a sandy seaward solution for the dike section bordering the Prins Hendrikpolder[21]. Especially the municipality and the NIOZ deputy director[22] were fiercely

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17 HHNK, 2009. Dijkversterking Waddenzeedijk Texel: Startnotitie m.e.r. (p. 40-42, 44-59); HHNK, 2011. Oplegnotitie Startnotitie: Aanvulling op de startnotitie (p. 11-37, 39-41, 43-44)

18 HHNK, 2011. Oplegnotitie Startnotitie: Aanvulling op de startnotitie (p. 9-10)

19 Urgenda, 2009. Texel geeft energie: keuzes & acties voor 2040 (p. 38, 44)

20 HHNK, 2009. Dijkversterking Waddenzeedijk Texel: Startnotitie m.e.r. (p. 40-42, 44-59)

21 Gemeente Texel, 2009. Zienswijze op Startnotitie Dijkversterking Texel (p. 1-5)

22 The case description is written from an institutional perspective. One exception is the NIOZ deputy director as he did not formally represent NIOZ. He functioned as an 'unpaid advisor' to the municipality for the sandy seaward solution (in addition he is also member of a local political party and head of a village committee). We chose to refer to him as the NIOZ deputy director, to both underline his expertise and access to a large professional network.

determined to get this solution into the project. They eventually achieved this in 2010 due to frequent communication with actors within the supporting group, as well as with other actors as the nature recovery programme 'Towards a Rich Wadden Sea' (PRW). PRW became an important financer of research into the technical and legal feasibility of the sandy seaward solution. Such a solution aligns closely with PRW's ambitions to soften the borders between land and sea in the Wadden Sea. During a government meeting (October 2010), HHNK, the municipality of Texel and the Province of Noord-Holland decided to include a sandy seaward solution as one of the alternatives to be studied in the EIA procedure[23].

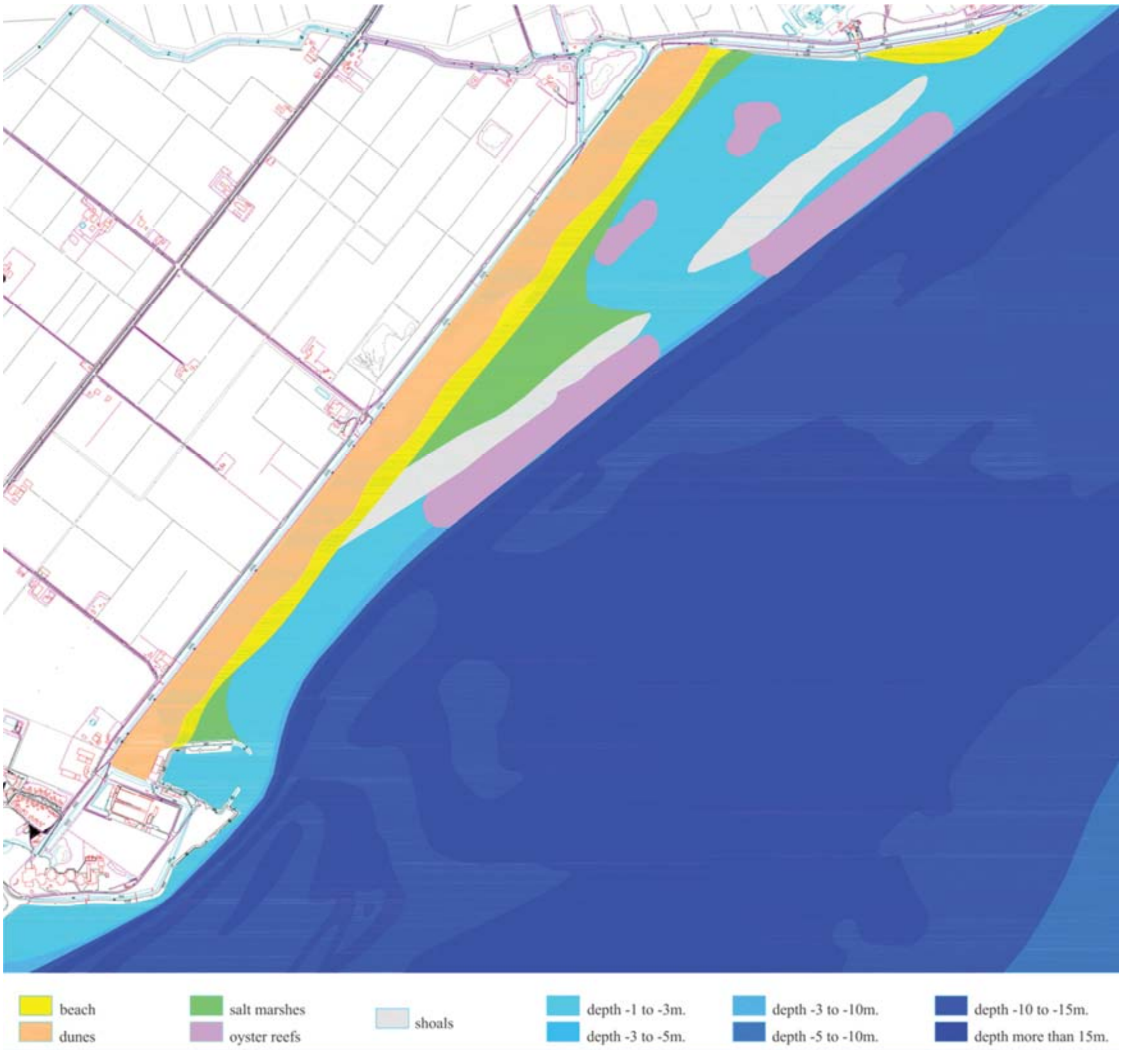

Figure 2.1. Visualisation of the sandy seaward solution at Texel (Source: municipality of Texel).

[23] Minutes of government meeting October 19, 2010 (p. 2)

2.3.3 Interactive knowledge development in the technical study of the proposed sandy seaward solution

The four distinct activities of interactive knowledge development, as defined earlier in this paper to open the black box of interactive knowledge development, are applied to the technical study which was conducted in 2011[24]. The study focused on the technical design and expected costs for construction and maintenance of a sandy seaward solution.

Whereas other technical studies in the project were financed by HHNK, this technical study was financed by PRW (90 %) and the municipality of Texel (10%). The water board refused to finance this study because a sandy seaward solution would be too expensive, thus not meeting the funding criteria of FRPP (sober, effective, robust). The assignment for Witteveen+Bos was formulated in mutual agreement by HHNK, the municipality of Texel and PRW. Witteveen+Bos, under supervision of HHNK, conducted this study and delivered the report[25]. They hired other experts to conduct smaller parts of the study. Deltares modelled sediment transport[26], Arcadis calculated wave conditions[27] and Vertegaal Ecologisch Advies explored the feasibility of the design with respect to the Nature Protection Act[28].

The municipality of Texel and the NIOZ deputy director initated an expert meeting (January 2011) to develop a feasible design for a sandy seaward solution with respect to Natura 2000 legislation. Eleven actors jointly developed a sketch plan for a sandy seaward solution. Among them were representatives from a nature organisation (Staatsbosbeheer), research institutes (SOVON and IMARES) and actors already previously mentioned (i.e. HHNK, Witteveen+Bos, municipality, NIOZ deputy director, PRW, Vertegaal Ecologisch Advies)[29]. Because the sketch plan received the support of all the actors involved, it was used as the point of departure for the technical study by HHNK and Witteveen+Bos[30]. The technical study was affected by severe time pressure of the project arrangement as the following quote demonstrates: "*The study is conducted under severe time pressure. A sandy seaward solution may not distort the planning of the overall dike reinforcement project, this planning is already under pressure*" (Witteveen+Bos, 20-01-2012)

Methods used in the technical study are the sketch plan as point of departure, a qualitative description of the morphological system and quantitative models for wave conditions, sediment

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24 Another study in this knowledge arrangement dealt with a broader interpretation of the Nature Protection Act, in which a sandy seaward solution served as one of the case studies. In: Eelerwoude, 2011. Een ruimere jas binnen N2000: de mogelijkheden voor een ecosysteembenadering voor de vergunningverlening onder de Nb-wet

25 Witteveen+Bos, August 2011. Planstudie dijkversterking Waddenzeedijk Texel: zandige oplossing Prins Hendrikpolder.

26 Idem (Annex II, 24 p.)

27 Idem (Annex IV, 2 p.)

28 Vertegaal Ecologisch Advies, February 2011. Verkenning haalbaarheid zandige variant versterking Prins Hendrikpolder i.r.t. Natuurbeschermingswet/Natura 2000

29 Gemeente Texel, January 2011. Besprekingsverslag Workshop ecologische meerwaarde zandige variant versterking Prins Hendrikdijk (p. 1-5).

30 Witteveen+Bos, August 2011. Planstudie dijkversterking Waddenzeedijk Texel: zandige oplossing Prins Hendrikpolder (p. 7)

transport and erosion[31]. In June 2011, a technical meeting took place which was attended by HHNK, Arcadis, Witteveen+Bos, the municipality and the NIOZ deputy director. The research approach and initial modelling results were discussed[32]. The question of whether there is net erosion or sedimentation in the proposed area of the seaward solution was hotly debated. Models predicted net erosion, whereas the NIOZ deputy director observed sedimentation in the area. These discussions resulted in the incorporation of a qualitative historical analysis and the input of additional monitoring data into the quantitative models.

The results of the technical study were interpreted by Witteveen+Bos and HHNK. An expert of Arcadis reviewed the report. Perspectives differ upon the input of the municipality, PRW and the NIOZ deputy director. *"We discussed draft versions with them* (red. municipality, PRW, province). *Final versions have been discussed extensively and we discussed it in the project group"* (HHNK, 24-01-2012). However, the next quote shows a different perspective: *"If they would have contacted the municipality of Texel (…) They were not involved in-between, how steps have been elaborated and what the costs would be. The outcomes were suddenly presented and that was it.* (NIOZ deputy director, 20-02-2012)

Both respondents of the province and the municipality mentioned the limited time they were given to comment on the report. Conclusions have been formulated solely by HHNK and Witteveen+Bos and were presented in the project group. This is explained by one respondent of HHNK as follows. *"PRW, The municipality and other parties consider the report as a product of the water board (…) it is our report. Therefore, we have to support it 100% before we send it to others* (HHNK, 24-01-2012)

The municipality, PRW and the NIOZ deputy director heavily criticised the report they had funded. Especially the final design and estimated costs of 90 million euros for a sandy seaward solution were criticised, as the following quote illustrates " *I am really disappointed by the lack of a search for a cheaper design. Everybody knew that the costs would be a decisive factor. I find it disappointing"* (Municipality of Texel, 12-01-2012). However, HHNK and Witteveen+Bos refer to the earlier agreement: it was decided by all actors involved that the sketch made in January 2011 was the point of departure for the technical study. As the sandy seaward solution is one of the alternatives being studied in the EIA procedure, a solution for the Prins Hendrikpolder was not chosen after the technical study was completed.

Actors such as PRW, the NIOZ deputy director and the municipality demanded a follow-up study with an optimised design that would lower the costs significantly. During a meeting in December 2011 which was facilitated by PRW, all actors (HHNK, Witteveen+Bos, Vertegaal Ecologisch Advies, province, municipality, NIOZ deputy director) agreed that the technical study did not deliver the optimal design for a sandy seaward solution and that major cost reductions were possible[33]. Therefore, a follow-up study was initiated by the actors involved, which indeed resulted in a more cost-effective design. The final decision of how to strengthen the dike in the Prins Hendrikpolder will be made in the dike reinforcement plan, based on conclusions from the various knowledge arrangements.

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[31] Idem (p. 7-58, Annex I, II, III,IV)

[32] Minutes of expert meeting June 16, 2011 (p. 1-3)

[33] Minutes of follow-up meeting sandy seaward solution (p. 1, 3)

In conclusion, by focusing on seaward solutions a different discourse of seaward thinking is advocated in this arrangement in comparison to the project arrangement (plain, effective, robust, landwards). Attached to this discourse are actors who are not necessarily involved in the project arrangement such as PRW and the NIOZ deputy director. The knowledge arrangement of a sandy seaward solution does not fit smoothly in current legislation of the Water Act and Natura 2000 policies. Consequently, the knowledge arrangement shows an adaptive approach towards funding, design and legislation. After describing the project arrangement and knowledge arrangement, we can now derive the causal mechanisms that explain a process of interactive knowledge development for a sandy seaward solution within the Texel dike reinforcement project.

Table 2.2 Important events in the project arrangement and knowledge arrangement, to which effects of interactive knowledge development are linked.

Project arrangement Texel dike reinforcement project	Knowledge arrangement Sandy seaward solution	Main activity of interactive knowledge development	Effect of interactive knowledge development
2005: 17 kilometers of Wadden Sea dike do not meet safety norms			
Jun 2009: Notice of Intent is published by HHNK			
	Sep 2009: 10 actors request research into seaward solution	Problem formulation	Ten actors express and support an alternative view on dike reinforcement
Oct 2010: Government meeting HHNK, municipality, province. A sandy seaward solution becomes part of EIA			
	Dec 2010: assignment and research questions are formulated for technical study	Problem formulation	Agreement between HHNK, municipality and PRW
	Jan 2011: sketch plan is developed in expert meeting	Methods and techniques	Agreement on sketch design by actors involved in the meeting
	Jun 2011: technical meeting	Methods and techniques	Incorporation of new data and methods

Sep 2011: Revised Notification of Intent is published by HHNK	Sep 2011: technical study is completed	Interpretation of results	Disagreement between HHNK and other actors on design and costs sandy seaward solution
	Dec 2011: discussion on optimisation possibilities	Choice of solution	Agreement for further research among all actors involved

2.3.4 Mechanisms explaining interactive knowledge development

Based on the analysis of the interplay of, and the dynamics in the project and knowledge arrangement, we derive eight causal mechanisms that explain the process of interactive knowledge development within the Texel dike reinforcement project. A causal mechanism is defined by George and Bennett (2005, p. 137) as *"a social process through which agents with causal capacities operate, but only in specific contexts or conditions, to transfer energy, information, or matter to other entities. In so doing, the causal agent changes the affected entity's characteristics, capacities, or propensities in ways that persist until subsequent causal mechanisms act upon it."* Causal mechanisms give within a case insight in the way a knowledge arrangement relates to a project arrangement, they explain the enabling and constraining conditions for a process of interactive knowledge development, thereby offering strategies for understanding and managing processes of interactive knowledge development in a coastal project's environment. The mechanisms can be linked to a specific dimension of an arrangement (shown in italics). They operate at two levels: within a knowledge arrangement, and between a project and knowledge arrangement.

Within a knowledge arrangement, we consider three mechanisms that explain dynamics in a process of interactive knowledge development:

Mechanism 1: Diverse perspectives in knowledge arrangement

Diverse perspectives of *actors* are involved in the distinct activities of knowledge development in the technical study of a sandy seaward solution. Perspectives mix and views are exchanged. This resulted in broad support among actors for the sketch plan; altered insights in which methods and techniques to be used; broad agreement for a follow-up study. In contrast, activities in which multiple perspectives were hardly involved (interpretation of results) resulted in critical feedback on the estimated costs and design of the seaward solution (see also Table 2.2, effects of interactive knowledge development).

Mechanism 2: Limited technical knowledge in knowledge arrangement

Actors such as PRW and the municipality of Texel have limited technical knowledge and find it difficult to comment on the technical study. This creates challenges to a process of interactive knowledge development because actors lack technical knowledge but understand that the study resulted in an unacceptably expensive design. By consulting an expert within their coalition – the NIOZ deputy director - they were able to jointly formulate opportunities to optimise a sandy seaward solution. These opportunities eventually resulted in a follow-up study with a more cost-effective design.

Mechanism 3: Facilitation in knowledge arrangement

Financial resources of PRW were used to fund three studies about the sandy seaward solution. These studies improved the feasibility of a sandy seaward solution as they removed barriers regarding legal and technical feasibility. In addition, PRW facilitated a discussion between actors when there was strong disagreement about the outcomes of the technical study (December 2011).

Between the project arrangement and knowledge arrangement we consider the following five mechanisms that affect interactive knowledge development in a project's environment:

Mechanism 4: Trusted partners in both arrangements

Witteveen+Bos is a trusted partner of HHNK. The two *actors* cooperate closely in the project arrangement and in other knowledge arrangements of landward and innovative solutions. As HHNK is content about the functioning of Witteveen+Bos, it also conducts the technical study. Witteveen+Bos involves other actors for smaller sub-parts of the study. This limits a process of interactive knowledge development because the study is subdivided into smaller parts for various actors.

Mechanism 5: Scope demarcation in both arrangements

The scope for knowledge development is demarcated at different levels through the *discourses* expressed. Through scope demarcation, boundaries are drawn as to what can and cannot be investigated. The project scope "reinforcing the dike within limits of time and money" has already set initial boundaries for knowledge development. During a joint government meeting in the project arrangement, the scope for knowledge development in the technical study was formulated, being a sandy seaward solution that will replace the existing primary flood defence[34]. Within the knowledge arrangement, Witteveen+Bos demarcates the scope for actors who conduct sub-parts of the study.

Mechanism 6: Time pressure in both arrangements

Time serves as a pressing *resource* in the project arrangement and results in time pressure in the knowledge arrangement. The technical study has a general character; respondents state they had limited time to comment on the study; and there was no time for an optimisation discussion until the study was finished. Paradoxically, this may have caused additional delay as an optimisation study was conducted after the technical study was finished.

Mechanism 7: Not sharing responsibilities in both arrangements

Current *legislation* (*rules)* makes HHNK responsible for the overall dike reinforcement project. HHNK considers itself to have full responsibility for the technical study, as it is one of the alternatives studied in the EIA procedure. Consequently, the report and conclusions are written

[34] Minutes of Government Meeting October 29, 2010 (p.2)

by HHNK and Witteveen+Bos. This results in little opportunity for the involvement of other actors during the interpretation of results and formulation of conclusions.

Mechanism 8: Interdependency in both arrangements

Besides HHNK, the municipality and province have *formal responsibilities (rules)* in relation to the dike reinforcement project. The province has a supervisory function over HHNK and the municipality has to approve changes in their zoning plan for planned reinforcements. Therefore, it is important for HHNK to continuously ensure the approval of both actors for the dike reinforcement project. This also affects interactive knowledge development, as it is an important motive for HHNK to involve those parties in the various activities of knowledge development to ensure their continuing support.

The causal mechanisms explain a process of interactive knowledge development in the Texel dike reinforcement project. The mechanisms have varying impacts upon interactive knowledge development. Four mechanisms constrain (trusted partners, scope demarcation, time pressure, sharing responsibilities); three enable (involving multiple perspectives, facilitation, interdependency); and one both constrains and enables (limited technical knowledge) a process of interactive knowledge development in this case. In this project environment, mechanisms have an internal or external origin. External mechanisms have a structuring impact on interactive knowledge development (not sharing responsibilities, scope demarcation FRPP program). Yet, there are also enabling internal project factors, such as facilitation and diverse perspectives, which counteract these structuring factors.

2.4. Discussion

Each of the mechanisms can be linked to different bodies of knowledge. Mechanisms 1 and 2 are reflected in the literature of social learning and different types of knowledge (Eshuis and Stuiver, 2005; Ison et al., 2007). Mechanism 3 is one of the characteristics of boundary organisations (Pietri et al., 2011). Mechanism 4 is an illustration of trust between two actors and shares with mechanisms 7 and 8 a connection with research on trust and inter-organisational collaboration in networks (De Bruijn and Ten Heuvelhof, 2008; Koppenjan and Klein, 2004). Mechanism 5 represents one of the main phenomena in the field of discursive analysis and boundary work (Metze, 2010), whereas mechanism 6 has already been reported in project management literature (Keegan and Turner, 2001). A key contribution of this paper is that the case study both shows how these mechanisms can coexist within one coastal project and how they affect a process of interactive knowledge development.

The four dimensions of the policy arrangement approach are able to serve a diversity of research purposes (Liefferink, 2006). The adapted conceptual framework of project arrangements and knowledge arrangements provides a lens for understanding interactive knowledge development in a project's environment. The added value of this conceptual framework is an improved understanding of a Mode 2 type of knowledge production in a project's environment. An abstract and complex process as interactive knowledge development (Edelenbos et al., 2011; Hegger et al., 2012) becomes analysable through knowledge arrangements. The causal mechanisms are a first effort of explaining the 'indirect and hard to discern' mechanisms (Hegger et al., 2012) involved in interactive knowledge development in a project's environment. Through the combination of project arrangements and knowledge arrangements, the attention is drawn to structural (external) and internal factors within a project environment that both explain *and* affect a process interactive knowledge development in a coastal project. Such insights on this particular scale have, for as far as we know, not been published in studies on interactive modes of knowledge production in the environmental sciences. However, not all dynamics are explained through the conceptual framework. Partly because they were not the main focus of this study (i.e. the power play between HHNK and other actors, the formation and changes in actor coalitions), and partly because the policy arrangements approach focuses on the institutional level (Arts et al., 2006). Therefore it does not account for dynamics on the individual level, or on different perspectives within one organisation. Some dynamics were difficult to describe due to the collected data. For example the informal interaction rules were hard to examine, due to the small share of participant observations in our data collection.

2.5. Conclusion

In this paper a conceptual framework is developed to improve the understanding of interactive forms of knowledge development in a project's environment. The policy arrangement approach was further developed by distinguishing project arrangements and knowledge arrangements. The case study illustrates how a diverse group of actors criticised the traditional technocratic solutions in the Texel dike reinforcement project. This resulted in interactive knowledge development for an alternative, seaward solution. By analysing the interplay between the Texel dike reinforcement project arrangement and the sandy seaward solution knowledge arrangement, eight causal mechanisms were derived that affect and explain a process of interactive knowledge development in a project's environment. Based on this analysis we draw the following conclusions that contribute to an improved understanding of interactive knowledge development in a project's environment:

- The case study illustrates how a strict project arrangement fuels the development of a new knowledge arrangement. Over time, this new knowledge arrangement became embedded in the strict project arrangement, thereby broadening its scope and transferring responsibility from the initiating actors to the water board.
- The causal mechanisms explain a process of interactive knowledge development in the Texel dike reinforcement project. Both the number of mechanisms as well as their varying impact (constrain, enable, or both), reveal the complex character of interactive knowledge development in a coastal project.
- A gap between theory and practice may be narrowed through interactive knowledge development in all four activities of knowledge development. Much interaction in three activities resulted in agreement and broad support among participating actors in interactive knowledge development for a sandy seaward solution. Yet, when there was little interaction (interpretation of results), the effect was strong disagreement among participating actors. More interaction across the participating actors in this particular activity might have prevented the strong disagreement.

Developing relevant knowledge in coastal projects is a lengthy process. Coastal project organisations have to manage many diverse challenges. They deal with biophysical and social-economic dynamics of the coastal zone while following legislation, schedules and budgets. Organising a process of interactive knowledge development may be perceived as another burden for a project organisation. Yet, as this paper illustrates, interactive knowledge development may result in more relevant knowledge. Our case showed that interactive knowledge development resulted in a solution that receives broad support from the actors involved, due to consensus about the problem formulation and the methods applied.

Acknowledgements

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Chapter 3. Responding to coastal problems: Interactive knowledge development in a US nature restoration project[35]

Photo II. Constructing restoration measures in the South Bay Salt Pond Restoration project. An excavator creates a breach in a levee of a salt pond. The breach marks the completion of restoration works in two salt ponds that cover an area of 52 hectares. The breach supports a transformation of these –former- industrial salt ponds to tidal marsh and pond habitat. A new environment can be created for birds, fish and other marsh-species since the tide can flow in and out of the ponds. The South Bay Salt Pond restoration project is in this study the second case study. This chapter discusses how knowledge is interactively developed for nature restoration solutions within this project. (Source: photo taken on October 31, 2012 by Chris Seijger)

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[35] This chapter has been published as: Seijger, C., J. Van Tatenhove, G. Dewulf and H.S. Otter (2014). Responding to coastal problems: Interactive knowledge development in a US nature restoration project. Ocean & Coastal Management 89: 29-38.

Abstract

Coastal decision-making is impacted by global climate change and region-specific changes related to population growth, economic activities and the natural environment. This results in complex and interdependent problems. Addressing these problems requires the involvement of decision-makers, researchers and other societal actors in knowledge production. However, such means of knowledge production are poorly understood when it comes to coastal regions. Using a conceptual framework that makes a distinction between project arrangements and knowledge arrangements, this paper analyses interactive knowledge development in a nature restoration project on the US West Coast. The project adopted a collaborative approach, and involved diverse organisations in developing knowledge for reaching its restoration solutions. The case study analysis results in seven causal mechanisms. The mechanisms are divided into two groups. One group discusses processes that affect interactive knowledge development, such as the need for public support. The other group explains how interactive knowledge development functions, for example through facilitation and the creation of safe environments for researchers and regulators. Through identifying these mechanisms, this paper contributes to an improved understanding of interactive knowledge development in coastal regions.

3.1. Introduction

Coastal regions face various environmental and spatial problems. In seeking solutions to these problems, decision-makers have to deal with all kinds of uncertainties, ranging from knowledge uncertainties related to global climate change (Hanger et al., 2013) to the competing interests of nature protection, expanding cities and economic activities (Cicin-Sain and Knecht, 1998; Kay and Alder, 1999). Responding to these issues in coastal decision-making processes requires the involvement of researchers, decision-makers and stakeholders in knowledge production (Clarke et al., 2013; Hanger et al., 2013; Schmidt et al., 2012; Tribbia and Moser, 2008). A critical assumption is that their involvement is essential in coming to robust solutions for the coastal region. The involvement of actors outside the research community in producing knowledge is essential for knowledge uptake (Van Koningsveld, 2003), for identifying effective solutions (Clarke et al., 2013) and for anchoring these solutions within society (Schmidt et al., 2012). The aim of this paper is to increase understanding of such knowledge production in coastal regions.

The involvement of researchers, decision-makers and stakeholders is necessary to produce socially robust knowledge: knowledge that is relevant in the context of its application (Gibbons et al., 1994; Nowotny et al., 2001). Relevant criteria such as legitimacy, credibility and salience (Cash et al., 2003) also emphasise the need to involve actors outside the research community. Indeed, the latest perspectives on knowledge production and uptake in coastal decision-making highlight the need to include a diversity of actors in knowledge production (Bremer and Glavovic 2013; Bruckmeier, 2012; Clarke et al., 2013). Nevertheless, research shows the difficulty of organising such interactive modes of knowledge production. For example, Bruckmeier (2012) reports limited attention to knowledge integration in three Swedish EU research projects. Tribbia and Moser (2008) discuss a disconnect between scientists and decision-makers in California's coastal zone management. Clarke et al. (2013) conclude that a more collaborative coastal governance structure is required for sustainable decision-making and knowledge generation in

Australia. These cases demonstrate the difficulties in reaching interactive modes of knowledge production between researchers, stakeholders and decision-makers.

This paper focuses on processes for interactive knowledge production in coastal projects. To date, coastal-related research on this topic has focused on research partnerships (McFadden and Schernewski, 2012; Schmidt et al., 2012), coastal policies (Bremer and Glavovic, 2013; Clarke et al., 2013) or the relationship between climate science and decision-makers (Tribbia and Moser, 2008; Shaw et al., 2013). Coastal projects represent a distinct domain for understanding the production of socially robust knowledge as projects seek multi-million dollar solutions with a lifespan of several decades. Solutions concentrate for example on nature restoration, coastal protection or waterfront expansion. Consequently, projects have to respond to the global and regional changes in their area, and this requires socially robust knowledge. Research shows that this becomes a challenging process if the project organisation adopts a hierarchical approach towards other organisations (Seijger et al., 2013). Although collaborative settings are deemed necessary for effective coastal science-policy interfaces (Bremer and Glavovic, 2013; Clarke et al. 2013), there remains a gap in the literature on how interactive knowledge development functions in such a collaborative setting.

The objective of this paper is to understand the role of interactive knowledge development in a collaborative coastal project. The central question is how does a process of interactive knowledge development function in a collaborative coastal project? Collaboration refers to the way organisations jointly manage a project. Interactive knowledge development is defined as a participative form of knowledge production in which knowledge is shared and developed by using the perspectives of key stakeholders (researchers, decision-makers, stakeholders) involved in the complex problem being studied to develop relevant solutions for the problems defined in the project (Seijger et al., 2013). This paper analyses interactive knowledge development in a large-scale nature restoration project - the South Bay Salt Pond Restoration Project - located in South San Francisco Bay. The project aims to restore 60 km^2 of former industrial salt ponds to nature while providing flood control and public access. The project organisation adopted a collaborative approach, giving significant attention to the involvement of researchers, stakeholders and regulators. This resulted in interactive knowledge development in seeking restoration solutions.

The remainder of this article has four sections. Section 3.2 outlines the methodology applied. Section 3.3 presents the results of the analysis of our restoration project case study, and these results are placed in a wider scientific context in Section 3.4. Section 3.5 presents the main conclusions of this study.

3.2. Methodology

As argued by Van de Ven (2007), there is a knowledge production problem in the limited use of research knowledge. In response, we analyse the process of interactive knowledge development to arrive at socially robust knowledge. Rather than focusing on knowledge transfer (Carlile, 2004; Vinke-de Kruijf et al., 2012) or distinct types of knowledge (Edelenbos et al., 2011; Maiello et al. 2013), we argue that the process of knowledge production itself holds important clues for creating socially robust knowledge. This revolves around questions of who is involved, in which phases and what is their contribution? These questions relate to various phases in the process of knowledge production for environmental decision-making: formulating the problem (Hommes et al., 2009); identifying methods and using them to generate knowledge (Norgaard et al. 2009, Van Buuren and Edelenbos 2004;); and interpreting the results (Eshuis and Stuiver, 2005; Lane et al., 2011).

3.2.1 Conceptual framework: project arrangements and knowledge arrangements

In studying interactive knowledge development in a project environment, we apply the framework developed by Seijger et al. (2013) to analyse project arrangements and knowledge arrangements. With the use of this framework, we are able to analyse, through a longitudinal approach, how knowledge is interactively produced within an evolving project setting. Here, we summarise the main elements of the framework presented in Seijger et al. (2013). The framework builds on the policy arrangement approach of Van Tatenhove et al. (2000). A policy arrangement is defined as 'the temporary stabilisation of the content and organisation of a policy domain' and is analysed in terms of four dimensions:

- Actors and their coalitions;
- The division of resources among actors that lead to variations in power and influence;
- The rules of the game in operation, both in formal procedures and informal routines of interaction;
- Discourses, that entail the views and narratives of the actors involved.

Seijger et al. (2013) adapted the policy arrangement approach to study interactive knowledge development within a project by analysing the project arrangement and the knowledge arrangement. The *project arrangement* focuses on the overall project goals: how problems are defined, solutions are proposed and decisions are taken. The *knowledge arrangement* focuses on the process of knowledge development to find solutions for the problems defined in the project arrangement.

The four dimensions of a policy arrangement apply to *both* the project arrangement and the knowledge arrangement. Indicators for the four dimensions are shown in Table 3.1.

Table 3.1. Indicators of the project arrangement and knowledge arrangement

Dimension	Indicator
Actors	actor involvement, actors' relationships, actors affected, actor coalitions
Resources	time, money, information
Rules	access rules, allocation of responsibilities, legislation and policy rules, interaction rules
Discourses	project rationale, the project solutions, nature restoration

The project and the knowledge arrangements have distinct scopes. The project arrangement focuses on the overall project goals; the knowledge arrangement on the dynamics of interactive knowledge development for a particular solution. In a knowledge arrangement, four main activities define the process of interactive knowledge development (Van Buuren et al., 2004; Van de Ven, 2007):

- Problem formulation – the scope of the problem is determined and research questions are formulated by the actors involved to address that problem;
- Methods and techniques to be used – discussions focus on methods, techniques, models and theories to be used in data collection;
- Interpretation of results – results are interpreted after which conclusions are drawn;
- Choice of solution – a solution is chosen to solve the problem under study.

Both arrangements can be studied longitudinally in order to analyse how a project develops over time, and how knowledge is developed for solutions. Insights are gained both on project decisions that impact interactive knowledge development, and on the functioning of interactive knowledge development.

3.2.2 Method

Our goal was to gain empirical insights into interactive knowledge development in collaborative coastal projects. A case study approach was selected as this enables an in-depth analysis of complex, uncertain and multidimensional phenomena in their context (Flyvbjerg, 2006), a description that fits our subject. While a case study can achieve high internal validity, it is less appropriate for investigating a large range of cases (Flyvbjerg, 2006; Gerring, 2007). Nevertheless, generalisation to a broader class of cases can be achieved through careful case selection (Flyvbjerg, 2006; Gerring, 2007).

The findings of this paper rely on four sources of data: semi-structured interviews (19), observations of meetings (6), field trips (5) and project documents (numerous). Appendix IV provides more information on these sources. The interviews were qualitatively analysed in three rounds through a template-coding approach (Crabtree and Miller, 1999; Miles and Huberman, 1994; Seijger et al., 2013). In the first round, text fragments were coded on the basis of the indicators in the conceptual framework. In the second round, all the coded fragments were further categorised. In the third round, links between the various categories and indicators were explored. Based on this coding process, causal mechanisms can be derived that explain interactive knowledge development in the coastal project. Findings were triangulated both within and across sources to increase the internal validity of this study.

3.3. Interactive knowledge development in South Bay Salt Pond Restoration Project

San Francisco bay covers an area of 1200 km^2 and is located in California between the mouth of the Sacramento-San Joaquin river system and the Pacific Ocean. The sea level has been rising with 2 mm/year between 1897 and 2006[36]. San Francisco Bay is heavily modified since the 1850s

[36]Measured by the San Francisco tide station near the Golden Gate bridge. Data were obtained from the NOAA website http://co-ops.nos.noaa.gov/sltrends/sltrends_station.shtml?stnid=9414290 (website accessed on December 3rd, 2013)

due to hydraulic mining, land reclamation, waste disposal, and farming (Nichols et al., 1986). The South Bay is one of the four sub-systems of San Francisco Bay[37]. The South Bay floor is dominated by mud-sized sediments, and has been accreting sediment (11million m3) between 1983 and 2005 (Barnard et al., 2013). The shoreline is prone to flooding due to extensive groundwater pumping in the adjacent region. This pumping led to subsidence ranging from 1 meter near the southern shoreline up to 4 meters in San José (Poland and Ireland, 1988).

We selected the South Bay Salt Pond Restoration Project (SBSPR project) for our analysis as it represents a typical case (Gerring, 2007) of a collaborative, coastal project. We consider this case as typical in that various levels of governmental organisations (federal, state, local) collaborate with non-governmental organisations to restore the salt ponds. Further, organisations share resources and make decisions on a consensual basis. During the period of data collection, between September 2012 and March 2013, knowledge was interactively developed for a new set of restoration solutions. Interactive knowledge development actually started in 2010 and, hence, the knowledge arrangement covers the period 2010-2013. However, to understand the origins of these restoration solutions, as well as the functioning of the project organisation, we consider the project arrangement to cover the period from land acquisition in 2003 until 2013 (see also Table 3.2).

Table 3.2. SBSPR project phases and their relationship to the conceptual framework

([p] = part of project arrangement, [k] = part of knowledge arrangement).

<table>
<tr><td>2003</td><td>2004</td><td>2005</td><td>2006</td><td>2007</td><td>2008</td><td>2009</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td></tr>
<tr><td colspan="5">interim stewardship plan (p): change management of industrial salt ponds to prepare them for nature restoration</td><td colspan="8"></td></tr>
<tr><td></td><td colspan="5">phase 1 planning (p): programmatic restoration including an adaptive management plan, phase 1 restoration actions</td><td colspan="7"></td></tr>
<tr><td colspan="6"></td><td colspan="6">building phase 1 restoration actions</td><td></td></tr>
<tr><td colspan="6"></td><td colspan="7">phase 1 studies: informed by the adaptive management plan</td></tr>
<tr><td colspan="7"></td><td colspan="4">phase 2 planning (p, k): restoration alternatives</td><td colspan="2"></td></tr>
</table>

37 Other sub-systems are San Pablo Bay, Central Bay and West-central Bay

Section 3.3.1 provides an analysis of the project arrangement in terms of the four dimensions outlined earlier. The analysis starts with the project history, the formal project discourse and the actors that are mobilised by this discourse. It continues with the structuring impact of environmental regulation on the planning process, the various sub-discourses, and how collaboration serves as an interaction rule in dealing with these sub-discourses. Section 3.3.2 discusses the knowledge arrangement. The four dimensions of the two arrangements are summarised in Table 3.3. Section 3.3.3 then presents the mechanisms that explain interactive knowledge development in the SBSPR project.

3.3.1 Project Arrangement South Bay Salt Pond Restoration Project

In 2003, 66.8 km^2 of salt ponds in San Francisco Bay were purchased from Cargill for USD 100 million. The State of California contributed USD 72 million, the US federal government USD 8 million, and four private foundations USD 20 million. Since the 1850s, 83% of the original South San Francisco Bay marshland has been lost to dyked habitat (~60%, mostly salt ponds) and bay fill. This dramatic loss of tidal mudflats and marshlands is problematic: marsh-dependent fish and wildlife stocks have dwindled, risks of local flooding have increased and the water quality decreased. The South Bay Salt Pond Restoration (SBSPR) project is responsible for the restoration of three salt pond complexes covering 60.7 km^2 in the South Bay (see Figure 3.1). The formal discourse of the SBSPR project is 'to restore and enhance wetlands in South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation' (discourse, Table 3.3).

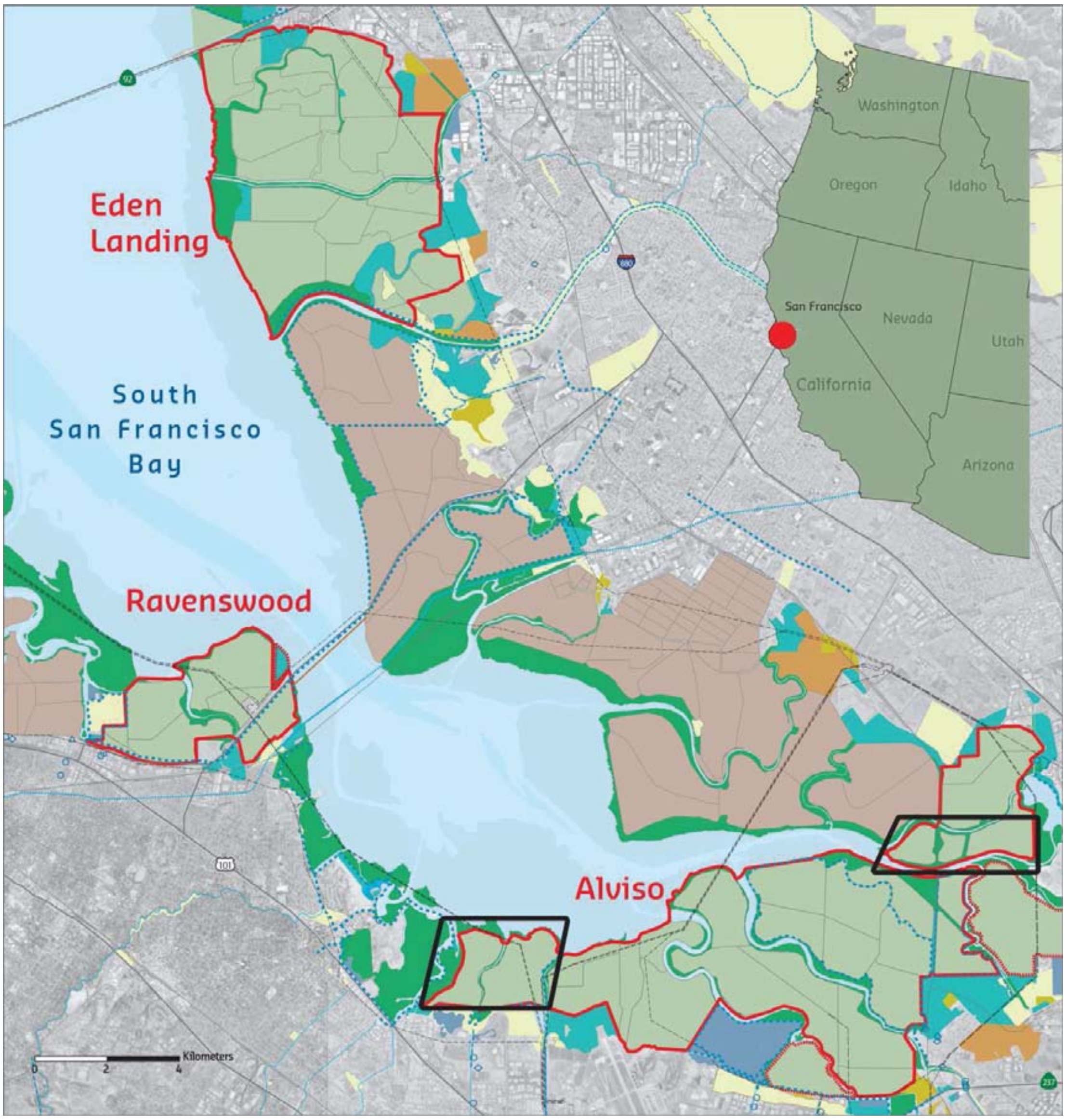

Figure 3.1. The three salt pond complexes: Eden Landing, Ravenswood and Alviso in South San Francisco Bay (total 60.7 km^2). The black quadrangles mark the areas that are considered for restoration in the Alviso phase 2 knowledge arrangement (Section 3.3.2.): the Mountain View ponds (left) and Island ponds (right).

The project area comprises three salt pond complexes which are managed by state and federal landowners. CDFW[38] owns and manages the Eden Landing complex, and USFWS the Ravenswood and Alviso complexes. The SCC supervises the project and oversees the two landowners. The project management team (PMT) is the key decision-making body of the project. The PMT consists of governmental and non-governmental agencies who jointly manage the project (see Figure 3.2 and the actors in Table 3.3). The project has a time horizon of 50 years, and all the restorative actions should be completed by 2058 (resources, Table 3.3). The first restorative actions focused on creating tidal and pond habitats, trails and viewing access points.

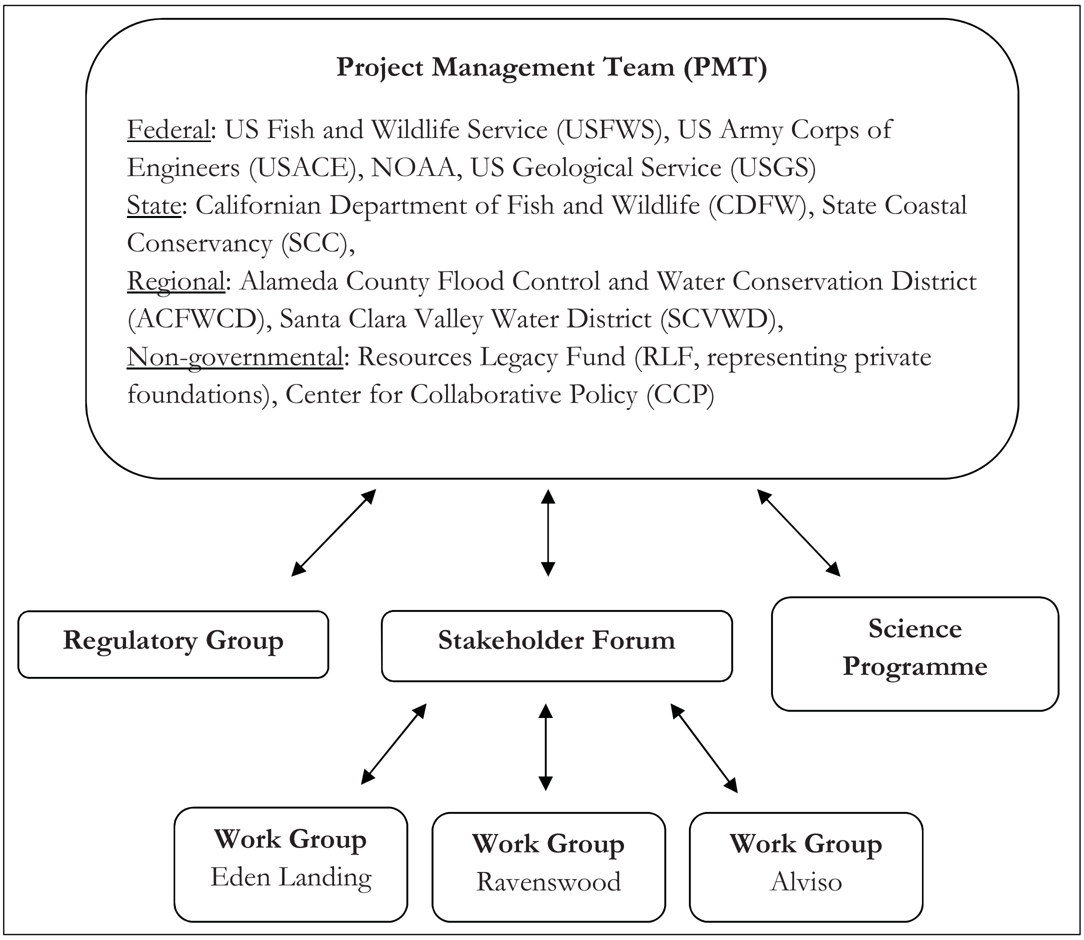

Figure 3.2. Organisational project structure: SBSPR project. The figure omits the Executive Leadership Group. This group has not met in recent years as there have not been any major conflicts or challenges that have required addressing by the executive leaders of the governmental organisations.

The existing environmental legislation is a key 'rule' in the project arrangement as it provides a framework for project planning (legislation, Table 3.3). The project has to comply with federal

38 Such acronyms are explained in Figure 3.2.

and state environmental regulations (NEPA and CEQA respectively[39]) given the federal and state landowners. The plans, proposed in a NEPA/CEQA procedure, are impacted upon by various acts. Permits have to be obtained under acts that might cover proposed actions (i.e. Endangered Species Act, Clean Water Act, Migratory Bird Treaty Act). The potential environmental impacts of the project are evaluated in an Environmental Impact Statement / Environmental Impact Report (EIS/EIR). During the phase 1 planning, the PMT developed a programmatic EIS/EIR [40] (responsibilities, Table 3.3). The EIS/EIR evaluated three restoration scenarios with a fifty-year period: no action, 50-50 tidal-pond habitat and 90-10 tidal-pond habitat.

Two key decisions have been made in the programmatic EIS/EIR that affect phase 2 planning. The first was to acknowledge the uncertain outcomes of the project given the fifty-year time horizon. As a result, the project does not work towards a defined end-state. Rather, the project adopts a phased approach, and relies on researchers and adaptive management to adjust management decisions and the future restoration of the salt ponds. A lead scientist, positioned within USGS, is part of the PMT and is responsible for the link between project managers and researchers. Studies in the science programme (totalling 4.8 million USD[41]) address key uncertainties that were identified during phase 1 planning in the adaptive management plan (information, Table 3.3). Researchers work for various types of organisations, ranging from a university as UC Davis to a research organisations as USGS to a private company.

The second key decision that affects phase 2 planning was to consider restoring 50% of the tidal marshes as the minimum. This decision was informed by the Baylands Ecosystem Habitat Goals report (1999) (information, Table 3.3). That report led to a hard-fought consensus between researchers and resource managers in the bay area. The report provided guidance on two topics: the types of habitat to consider, and the minimum amount of marsh restoration. The SBSPR project adopted their findings and, consequently, a 50-50 split between tidal and pond habitats became the lower boundary for restoration in the programmatic EIS/EIR (information, Table 3.3). This constraint was maintained in phase 2.

The actors interpret the three objectives of the formal project discourse differently. The PMT considers nature restoration to be the prime goal of the project, for which flood control is a prerequisite, and public access should be compatible with wildlife and restoration efforts. This is reflected in the narrow discourse for phase 2 where the two guiding principles are ‘to do no harm relative to flood impacts, and to progress towards the 50-50 managed pond – tidal marsh habitat equilibrium’ (discourse, Table 3.3). The sequence of actors joining the PMT also reflects this priority: flood control agencies joined the PMT in August 2004, whereas a public access organisation did not formally join the PMT until 2012. In addition to these unequal priorities, there are multiple perspectives within each sub-discourse. In terms of nature restoration,

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[39] NEPA = National Environmental Policy Act, CEQA = California Environmental Quality Act.

[40] Phase 1 restoration alternatives were also evaluated in this EIS/EIR.

[41] SBSP overall project costs (20 Aug 2012)

conflicts exist as to whether the salt ponds should be restored as marsh or as pond habitat[42]. In terms of flood control, large areas of the Alviso and Eden Landing complexes need improvement before the salt pond levees can be breached for tidal restoration. Here, the project is reliant on the willingness and procedures of regional flood agencies and the USACE to improve flood control. Public access is only planned in areas where the expected impact on nature will be small. This conflicts with various public access organisations such as The Bay Trail that want to maximise public access opportunities. The PMT developed a collaborative style in an attempt to accommodate these perspectives.

This collaborative style is a formal PMT consensus-based interaction rule[43]. Non-governmental organisations (the private foundations and the CCP) initiated this collaborative style. Prior to the land acquisition, the private foundations were already pushing the dealmakers to organise a transparent and inclusive process once they acquired the land. The public support that would arise from such a collaboration would be crucial for the future of the project as public support and funding are coupled. Californians vote for tax measures, so-called state bonds, which require a majority vote to be accepted. These state bonds cover more than half of the project costs[44]. Thus, without this public support, funding for the project would be heavily impacted, especially as new state bonds were needed after phase 1 construction work is finished. The foundations insisted that the SCC supervise the project and oversee the two landowners. Further, the private foundations introduced the CCP to the dealmakers. The CCP has participated in the PMT since 2003 and is responsible for outreach, conflict mediation and facilitation. In 2003, the CCP developed a collaborative project management structure that remains largely in place for phase 2 of the project.

Collaboration primarily occurs at two levels, among PMT members and between the PMT and other groups. The monthly PMT meetings are where all the organisations meet (interaction, Table 3.3). In these meetings, members inform each other and take decisions. Each organisation has specific responsibilities and areas of expertise. In the meetings, PMT members provide updates on topics under their responsibility (i.e. public outreach, science programme, finance, progress in pond complexes). As members value and respect each other's expertise, there is not necessarily much discussion on each topic. Alongside this collaboration within the PMT, the PMT collaborates with stakeholders, regulators and researchers through frequent formal and informal meetings. Nevertheless, maintaining the project's collaborative capacity is not easy. For example, many PMT members regard collaboration with others as difficult due to conflicting interests, organisation-specific procedures and limited responsibilities. One respondent saw the collaborative capacity of the PMT weakening due to shrinking state budgets and a fading project memory: successors of PMT members do not share the initial project spirit, and tend to forget

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42 Although the project addresses the historic loss of marshland, pond habitat is also needed for the migrating and overwintering birds that have become regular visitors to the salt ponds since the 1900s.

43 Memoranda of Understanding in 2003, 2004, and 2009 state that 'The Parties agree to seek consensus among themselves prior to taking actions that may significantly impact the Project'.

44 SBSP overall project costs (20 Aug 2012).

the project has three objectives: restoration, flood control and public access. Instead, they tend to focus on their own interests.

Table 3.3 summarises for the project arrangement the primary elements of each dimension during phase 1 and phase 2 planning[45]. Changes occurred in the arrangement's four dimensions between the two planning phases. A change in the core responsibility of the PMT steered the changes: during phase 1 planning they had to develop a programmatic plan for restoration, whereas in phase 2 they had to implement restorative actions. This resulted in a narrower discourse in phase 2 planning. The financial resources also dried up once the phase 1 restorative actions are carried out. Therefore, there is no budget for phase 2 construction, and no strict deadlines placed on phase 2 planning. To summarise, the PMT's approach to salt pond restoration is to restore them through a collaborative and science-driven process, by building upon decisions made in the phase 1 planning phase.

Table 3.3. Main elements in the project arrangement and knowledge arrangement dimensions of the SBSPR project.

Dimension	Project arrangement phase 1 planning (2003-2008)	Project arrangement phase 2 planning (2010-2013)	Knowledge arrangement Alviso phase 2 (2010-2013)
Discourse	Restore and enhance wetlands in South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation	Do no harm to flood impacts and ensure progress towards the 50-50 managed pond – tidal marsh habitat equilibrium	Tidal marsh restoration where there is a backside levee
Actors	Formal project management structure (see Figure 2)		Executive project manager, USFWS, consultant team, City of Mountain View
Rules (legislation)	Environmental regulations (NEPA-CEQA structure planning process)		Charleston Slough mitigation permit[46] and environmental regulation
Rules (interaction and responsibilities PMT)	PMT meets twice a month: responsible for developing a restoration plan	PMT meets once a month: responsible for implementing restoration actions	PMT meets once a month: responsible for developing restoration alternatives

45 The period between phases 1 and 2 is excluded from Table 3.3 as this consisted primarily of applying for permits and construction activities that did not affect phase 2 planning.

46 The permit is only relevant to the Alviso pond complex

Resources (time and money)	Project has fifty years to complete implementation (2008-2058), full project budget is spent when planning for phase 2 ends		No strict deadline, costs for Alviso ~ USD 300,000
Resources (information)	Bayland Habitat Goals Report	Phase 1 studies, programmatic EIS/EIR	Programmatic EIS/EIR, phase 1 studies, research summaries, information from City of Mountain View

3.3.2 Alviso phase 2 knowledge arrangement

Our analysis of phase 2 planning[47] revealed two distinct knowledge arrangements with different discourses. First, knowledge was developed in the science programme to reduce the uncertainty in planning and management of the SBSPR project. Supervised by the lead scientist, 15 principal investigators, each with their own research team, analyse issues that could potentially halt the restoration work such as mercury contamination or changes in fish and bird populations. Second, knowledge is developed for the phase 2 restoration alternatives under two guiding principles: solutions should do no harm to flood impacts, and should ensure progress towards the 50-50 pond-tidal marsh habitat. The latter resulted in a focus on tidal marsh restoration. We chose to study interactive knowledge development for phase 2 of the Alviso pond complex. Of the three pond complexes, this provided the best opportunity to study interactive knowledge development as there was considerable interaction between the PMT and other organisations. In the other pond complexes there was either little interaction between the PMT and other organisations (Ravenswood), or the production of phase 2 alternatives were postponed (Eden Landing).

Links between project arrangement and knowledge arrangement

The Alviso phase 2 knowledge arrangement is closely linked to the project arrangement. Both arrangements are subject to the same project management structure, with the same rules and resources (see Table 3.3). Knowledge is developed for various restoration ideas as environmental regulations demand the development of three alternatives. Various restoration actions have been discussed for two sets of ponds, covering 5.3 km^2, in the Alviso complex: the Mountain View ponds and the Island ponds (see Figure 3.1). The alternatives include actions in response to the three project goals including breaching the salt pond levees for tidal restoration, establishing ecotone transition areas, improving levees and establishing trails and viewing platforms. The City of Mountain View became a restoration partner due its own marsh restoration requirements for Charleston Slough, adjacent to the Mountain View Ponds (actors and rules, Table 3.3).

Table 3.4 provides an overview of important events in this knowledge arrangement. The remainder of this section discusses the findings in terms of the four interactive knowledge

47 Knowledge was also developed during phase 1 planning on various topics: the adaptive management plan, restoration scenarios in the programmatic EIS/EIR and possible phase 1 restoration actions. These topics are excluded from this analysis as this section focuses on phase 2 planning and the related knowledge development.

development activities identified in Section 3.2.1 (problem formulation, methods and techniques, interpretation of results, choice of solution).

Table 3.4. Key events in the Alviso phase 2 knowledge arrangement.

Date	Event	Purpose	Characterising interaction	Interactive knowledge development activity
May 2010	Design workshop	What to consider for Alviso phase 2	Among PMT members	Problem formulation
Oct 2010-Nov 2011	First set of meetings with stakeholder forum, researchers and regulators	Present results of design workshop and obtain feedback	Consensus and preparation by PMT, then others	Interpretation of results
Sept 2011	Request for Services for Phase 2 consultants	What to consider for Alviso phase 2	SCC and City of Mountain View	Problem formulation
June 2012	Opportunities and Constraints Report (OC Report)	Explore opportunities and constraints	Consultants and SCC, review by some PMT members and by City of Mountain View	Interpretation of results
Sept-Nov 2012	Second set of meetings with stakeholder forum, researchers and regulators	Present results of OC report and obtain feedback	Consensus and preparation by PMT, then others	Interpretation of results
Feb 2013	Alternatives Report	Compare the alternatives and select three for environmental review	Consultants and PMT	Choice of solution

Problem formulation

The topic requiring knowledge development for Alviso phase 2 is the possibilities for achieving the three project objectives: nature restoration, flood control and public access. Research questions were not formulated as such for this process. The problem formulation was guided by the programmatic EIS/EIR and the two guiding principles for phase 2: no harm to flood impacts and progress towards the 50-50 pond - tidal habitat equilibrium. These guiding principles were translated into 'tidal marsh restoration where there is a backside levee[48]'

[48] If solid levees are present at the landside of the salt ponds, then the bayside levees of these ponds can be breached for tidal marsh restoration. Salt ponds between the Mountain View ponds and Island ponds lack a solid backside levee, and were therefore excluded from phase 2 restoration (see also Figure 3.1). A

(discourse, Table 3.3). During the design workshop, the PMT explored various phase 2 restoration options. Many ponds were rejected either because they were identified as pond habitat in the programmatic EIS/EIR or because there were issues linked to mercury or flood control. A major finding of the design workshop was that only two sets of ponds were suitable for tidal restoration: the Island ponds and the Mountain View ponds.

Methods and techniques

The methods used to develop knowledge for the Alviso phase 2 restoration alternatives mostly relied on expert opinions. The PMT reduced the number of options through a design workshop and a multi-criteria analysis. Consultants developed qualitative descriptions of the opportunities and constraints offered by these options. In an alternatives report, these options were evaluated using a multi-criteria analysis. Scientific studies, mostly conducted under the science programme, informed the Alviso alternatives. The PMT established a deliberated method to involve stakeholders, researchers and regulators in knowledge production for phase 2. This method involves making only small steps in the phase 2 planning process, and then presenting the same message to the various groups and gathering their feedback in two sets of meetings. Similar to the two levels of collaboration in the project arrangement[49], the deliberated method manifested itself on two levels: within the PMT and in meetings between the PMT and other actors. Methods are discussed and decided upon within the PMT. The meetings with the other groups are carefully prepared, with PMT members discussing the topics for the meeting, the kinds of questions they want to ask and how to frame certain issues.

Interpretation of results

An Opportunities and Constraints Report was developed primarily by the consultancy team and the executive project manager. The report identified the opportunities and constraints arising from the options discussed in the design workshop, while taking into account the feedback from the first set of meetings with stakeholders, researchers and regulators. The report's contents were reviewed by several PMT members (USFWS, SCC, lead scientist, SCVWD) and the City of Mountain View. Comments focused on both the implications of the scientific studies for the restoration alternatives, and location-specific considerations such as mercury contamination and levee strength. Changes in the restoration alternatives reflect the knowledge developed: levee improvements would be required in an adjacent flood basin, trails and an interpretive platform were added, and the nesting islands and ecotone transition areas were modified.

In 2012, the PMT discussed the opportunities and constraints in separate meetings with researchers, regulators and stakeholders. Researchers were asked to provide input for Alviso

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parallel project, the South San Francisco Bay Shoreline Study, explores feasible options for flood control in this area.

[49] Collaboration refers more generally to how organisations interact with each other in the project arrangement, whereas the deliberated method refers specifically to interactive knowledge development. The discussion on possible funding strategies with the stakeholder forum (November 15, 2012) amounts to collaboration. In the same meeting, as part of interactive knowledge development, stakeholders provided input for phase 2 restoration alternatives (see Section 3.3.2 Interpretation of results)

phase 2. This resulted in fewer breaches in the Island ponds, and changes to the sizes and shapes of nesting islands in the Mountain View ponds. Regulators were asked for input on allowable strategies for creating ecotone areas from dredged material. However, the regulators asked questions about the restoration alternatives, and gave little feedback on allowable strategies. Stakeholders were able to ask questions about the restoration plans and many questions had a clarifying character. Generally, the stakeholder forum approved the plans with the notable exception of the planned restoration of Charleston Slough. Here, a bird protection organisation (Audubon) criticised plans to restore this area to tidal marsh. In addition to the meetings, findings in this knowledge arrangement are communicated in multiple ways. Various reports are posted on the project website (memo design workshop, Opportunity and Constraints Report, updated maps). More informally, the executive project manager discussed findings in personal meetings with various actors: the consultant team, regulators, USFWS staff, concerned stakeholders and the City of Mountain View.

Choice of solution
An agreed solution for Alviso phase 2 had not been identified by the time of our data collection in 2012. The PMT later selected three alternatives for the Alternatives Report (February 2013) that will be evaluated in an EIS/EIR procedure.

To conclude, the degree of interaction among the organisations involved varied across the four interactive knowledge development activities. The PMT directed the problem formulation, the selection of methods and techniques and the solution choosing process. During the interpretation of results stage, other actors could share their knowledge. Researchers contributed new knowledge on restoration alternatives with their studies and observations from field visits. Stakeholders were less significant in terms of contributing knowledge in this phase as they had already shared their knowledge in earlier stakeholder forum meetings. By involving the regulators, the project ensured that only permissible restoration actions would be developed. Involving all these groups was not easy: scientists felt neglected during the first round of meetings in 2011 and developed a highly critical approach to the PMT; stakeholders represented multiple interests that had to be continuously addressed; and regulators were reluctant to engage early in the planning process.

Having discussed the project and knowledge arrangements, we derive in the next section the causal mechanisms that explain the process of interactive knowledge development for restoration alternatives for Alviso phase 2.

3.3.3 Causal mechanisms explaining interactive knowledge development in SBSPR project

From the analysis of the project and knowledge arrangements, we can derive causal mechanisms that are rooted in the empirical data of this case study. These mechanisms show how elements of a causal process contribute to the process of interactive knowledge development in the SBSPR project. By describing both these elements, as well as their effect on the process of interactive knowledge development, the mechanisms improve understanding of interactive knowledge development in an evolving project setting. As causal mechanisms reflect the causal processes responsible for the observed outcomes, they specify the spatial and temporal context in which they operate (Hedström and Ylikoski 2010; Beach and Pedersen 2013). The mechanisms are derived on the basis of our template-coding approach (see Section 3.2.2). The mechanisms are numbered for referencing purposes within this paper and do not signify a dominance of one mechanism over the other. Mechanisms 1-3 outlined below operate within the project arrangement and have an effect on the knowledge arrangement, whereas mechanisms 4-7 operate within the knowledge arrangement. The arrangement dimension in which each mechanism originates is highlighted in italics.

Mechanism 1. Public support - The need for public support results in a process of interactive knowledge development.

The case studied shows that public support was of the utmost importance for the project by fostering funding and project progress. The project management team adopted a collaborative approach *(interaction rule)* to ensure support from communities and organisations in the bay area. This collaborative approach was translated into a deliberate and transparent method of interactive knowledge development for Alviso phase 2. Deliberation occurred at the PMT level and also between the PMT and other groups. Documents of meetings and intermediate reports are posted on the project website, resulting in a transparent process.

Mechanism 2. Project memory - The project memory of actors structures the roles of others in a process of interactive knowledge development.

Individual PMT members *(actors)* of CDFW, SCC, USFWS and CCP were involved from the land acquisition in 2003. They carried the project through the planning phase, saw the rise of the adaptive management plan and the phase 1 studies and then supervised construction activities. As such, they have intimate knowledge of the possibilities in future restoration of the salt ponds. This affected their relationships with the consultant team that was hired for phase 2. As a newcomer to the project, the consultants added details under the PMT's directions.

Mechanism 3. Resources - Resources narrow the scope for interactive knowledge development.

In the case studied, the programmatic EIS/EIR (*information*) supported the option of establishing tidal marshlands, and other resources (limited *time* and *money*) prioritised the type of solutions sought for Alviso phase 2. This resulted in a retrenchment from a formal equal discourse (restoration, flood control and public access) to tidal restoration where a backside levee was present. In rejecting other options, PMT members referred to these limited resources when explaining their decisions.

Mechanism 4. Type of knowledge – The type of knowledge supports a process of interactive knowledge development.

In this case, the restoration alternatives for Alviso phase 2 were understandable by non-experts (*actors*). Stakeholders, researchers and regulators commented on the qualitative results in the form of maps and descriptions. Further, contributions by organisations such as Audubon, a bird protection organisation, were easy to incorporate when a set of alternatives were developed for the Alternatives Report.

Mechanism 5. Creating a 'safe environment' – A safe, confidential, environment results in extra valuable knowledge.

In this project, researchers needed a meeting with the PMT, independent of other stakeholders, in which they could share knowledge that was not strictly based on their findings. Regulators met one-on-one with the executive project manager, and shared more information than they would in a meeting with other actors. The PMT created these 'safe environments' (*interaction rules)* on purpose so that actors could share more knowledge than they would in public. In this way, the PMT received valuable knowledge that they might otherwise lack. This helped the PMT in developing good and allowable alternatives for Alviso phase 2.

Mechanism 6. Professional facilitation - Professional facilitation smoothes the process of interactive knowledge development.

The CCP had no formal responsibilities in the project, and focused on its tasks of facilitation and conflict mediation. During phase 2 meetings, the CCP facilitated dialogues *(interaction rules)* between decision-makers, researchers, stakeholders and regulators. The CCP ensured that each meeting was carefully prepared, that each voice was heard, that the scope of a discussion was clear and that vague expressions were clarified. This resulted in better understanding among the actors involved in the meetings.

Mechanism 7. Diverse perspectives - Including diverse perspectives broadens support among the actors involved.

In the case studied, the method of deliberately involving *actors* early and frequently in the process ensured that concerns were detected early. During the various meetings, criticisms were explored and potential drawbacks were discussed. This resulted in changes in some of the restoration alternatives, for example in the proposed nesting islands. The meetings offered distinct platforms for discussion between the PMT and stakeholders, researchers, and regulators leading to a shared understanding.

The mechanisms discussed above are closely connected (see also Figure 3.3). Mechanisms in the first group (1 to 3) connect the project arrangement to the knowledge arrangement. These mechanisms *affect*, or have an effect on, the process of interactive knowledge development. Mechanisms in the second group (4 to 7) operate within the knowledge arrangement. These mechanisms e*xplain*, or provide more detail on, the process of interactive knowledge development. In addition, the mechanisms have either an enabling (1, 4 -7) or constraining (2, 3) impact.

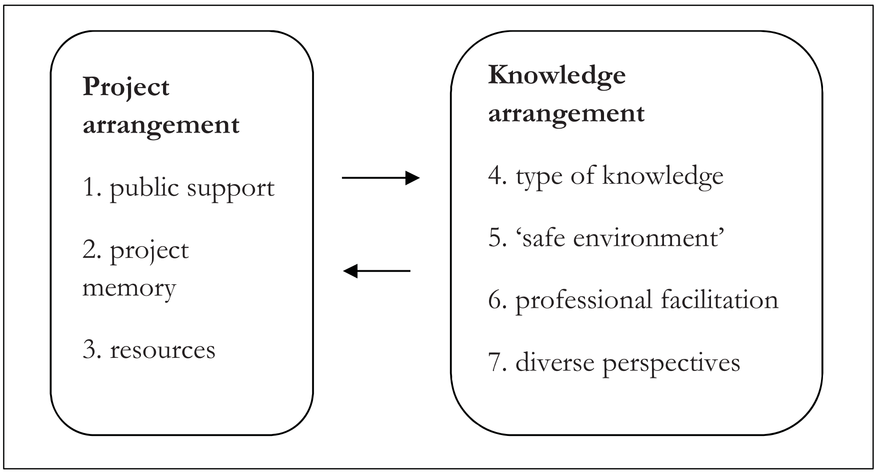

Figure 3.3. Characteristics of the project and knowledge arrangement that influenced interactive knowledge development in the South Bay Salt Pond Restoration project.

3.4. Discussion

The causal mechanisms represent the key findings of our analysis. The uncovered mechanisms enrich the current understanding of interactive knowledge development in coastal regions. The entire set reveals how mechanisms coexist and influence interactive knowledge development. The mechanisms are rooted in a collaborative coastal project that integrates knowledge from researchers, stakeholders, regulators and decision-makers. As such, this paper suggests how to integrate the knowledge held by such diverse groups for various management purposes such as: sustainable coastal zone management (Bremer and Glavovic, 2013; Bruckmeier, 2012; Clarke et al. 2013), adaptation to climate change (Schmidt et al. 2012; Tribbia and Moser 2008) or adaptive management (Folke et al., 2005; Walters and Holling 1990). The mechanisms highlighted represent diverse processes that influence interactive knowledge development: the availability of resources (mechanisms 1 and 3) the contribution of actors (mechanisms 2, 5, 6 and 7) and the type of knowledge developed (mechanism 4).

Two mechanisms illuminate relationships that have not been previously reported in scientific literature on interactive knowledge development for environmental decision-making. The first mechanism is the strategy of actively creating safe environments. This results in additional knowledge from researchers and regulators that would otherwise have been difficult to obtain. This mechanism seems to contradict with the idea of a common space in which stakeholders, decision-makers and researchers convene together to share and develop knowledge (Schmidt et al., 2012). The second mechanism is the strong link established among public support, funding and interactive knowledge development. As discussed earlier, drivers, or arguments for interactive knowledge development, are often referred to in abstract terms such as sustainable development, broadly accepted solutions or adaptation to climate change. This case study adds an additional driver: public support as a catalyst for funding.

In this paper, we used the conceptual framework of project arrangements and knowledge arrangements (PAKA) (Seijger et al., 2013). This framework served our research interests, and by applying it in a longitudinal approach, the framework effectively unravelled the process of interactive knowledge development in the project domain. A different, but related framework has been developed that supports an analysis of joint knowledge production projects (Hegger et al., 2012). This so-called JNP framework provides seven success conditions for joint knowledge production. Both frameworks have been published recently, thereby showing the significance of understanding interactive modes of knowledge production. To enhance conceptual understanding of such knowledge production in a project domain, we compare the two frameworks with each other in the remainder of this section. The frameworks share similar conceptual foundations: they perceive the production of knowledge as a social process, rely on the policy arrangement approach (Van Tatenhove et al., 2000) and study interactive knowledge development within a project domain.

The frameworks differ in three aspects. First, the JNP framework derives success conditions from literature, whereas the PAKA approach roots mechanisms in real-life projects. The mechanisms and success conditions overlap (i.e. in terms of actor involvement, problem formulation), but also focus on different aspects such as reward structures (Hegger et al., 2012; Hegger et al., 2014) or the type of knowledge developed (Seijger et al., 2013; this paper). Second, the JNP framework consists of a single arrangement whereas the PAKA approach has two types of arrangements. By distinguishing project arrangements and knowledge arrangements in the PAKA framework it becomes possible to analyse how the project environment affects the process of interactive knowledge development. This results in additional insights, for example on project drivers of interactive knowledge development or on project-level actor relationships. (Seijger et al., 2013, this paper). Third, the frameworks cover different purposes of knowledge production. JNP assesses the success of research programmes that aim to produce policy-relevant knowledge whereas PAKA assesses knowledge production for solutions that are constructed within coastal projects. These different purposes, and the different foci of the two frameworks, suggest that the production of socially robust knowledge differs between science-policy interfaces and implementation projects.

3.5. Conclusions

To address the need to produce socially robust knowledge for coastal solutions that respond to global and regional changes, this paper's aim was to understand the role of interactive knowledge production in collaborative coastal projects. The analysis of the South Bay Salt Pond Restoration (SBSPR) project has contributed to a thorough understanding of interactive knowledge development by focusing on the interplay between the project and knowledge arrangements, and by deriving and developing causal mechanisms that influence the process of knowledge development.

The SBSPR project shows that establishing a collaborative project and a process for interactive knowledge development does not guarantee an all-encompassing solution for complex problems in coastal regions. The initially equal goals of nature restoration, flood control and public access were reduced in the Alviso complex to tidal restoration where adequate flood controls were present. An existing lack of adequate flood controls served as a rigid boundary condition that restricted the possible solutions for restoring nature in Alviso phase 2. Collaboration failed to overcome such boundaries in phase 2 planning.

Moreover, the case study highlights how difficult it is to organise interactive knowledge development. Every actor requires careful handling in a lengthy process, and it took almost three years to develop alternative restoration options. The study identified seven mechanisms that both affect and explain the process of interactive knowledge development in this project. This set of mechanisms reflects a novel step in understanding interactive knowledge development: a step that enriches current understanding by making explicit the elements, structure and effects of a causal process in interactive knowledge development.

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Chapter 4. Socially robust knowledge in coastal projects[50]

Photo III. The Schermdijk and industry at the seaport of Delfzijl. The Schermdijk protects the port's navigation channel (right) from waves of the Ems estuary (left). The liveability of Delfzijl is threatened by strong population decline and mono-functional planning. The Marconi project aims to improve the liveability of Delfzijl through spatial developments in the maritime zone. In this study, the Marconi project is the third, and last, case study. This chapter discusses how knowledge is developed interactively for coastal protection alternatives at the Schermdijk that combine flood control with beach expansion and salt marshes. (Source: photo taken on May 16, 2013 by Chris Seijger)

[50] This chapter is currently under review by Environmental Science & Policy as: Seijger, C., H.S. Otter, J. Van Tatenhove and G. Dewulf. Socially robust knowledge in coastal projects.

Abstract

Interactive modes of knowledge production offer a strategy for seeking solutions to complex environmental problems. The outcome of such knowledge production is socially robust knowledge. Social robustness refers to knowledge that is relevant and accepted by actors in the context of its application. To date, only limited research has focused on how social robustness is achieved. As coastal problems are characterised by conflicting interests and major uncertainties, the coastal zone represents a relevant domain for studying socially robust knowledge. This paper analyses and presents three conditions that need to be in place if one is to achieve socially robust knowledge in coastal projects. The conditions are based on theories related to socially robust knowledge, boundary spanning, project arrangements and knowledge arrangements. The conditions specify how social robustness can be achieved through knowledge testing by boundary spanners, the involvement of diverse actors and a close connection between knowledge production and the evolving project. In a case study, these conditions are compared to developments in a Dutch coastal project involving spatial developments near the Ems estuary. The comparison highlights the need to meet the three conditions in order to achieve socially robust knowledge. In addition, a fourth aspect is empirically uncovered: the role of boundary spanning among project partners prior to producing knowledge. These four conditions clarify how social robustness may be achieved in coastal solutions. As such, this paper contributes to the theoretical and empirical understanding of socially robust knowledge.

4.1. Introduction

Interactive modes of knowledge production, such as Mode 2 knowledge and post-normal science, offer strategies for seeking solutions to complex, interdependent environmental problems (Funtowicz and Ravetz, 1993; Gibbons et al., 1994). Such means of knowledge production aim to achieve relevant research and produce socially robust knowledge as an outcome by involving researchers and non-researchers (Gibbons et al., 1994; Nowotny et al., 2001; Hessels and Van Lente, 2008). Although some authors are critical of the concept of Mode 2 knowledge (Hessels and Van Lente, 2008; Weingart, 2008), many such applications can be found in diverse areas of environmental decision-making including nature conservation, climate change, natural resources management, agriculture, water management and coastal issues (Aeberhard and Rist, 2009; Bruckmeier, 2012; Edelenbos et al., 2011; Giller et al., 2008; Gross, 2006; Vogel et al., 2007).

A key goal of Mode 2 knowledge production is to deliver socially robust knowledge. Social robustness refers to the societal acceptance of knowledge, achieved by knowledge becomming relevant in the 'context of application' (Gibbons et al., 1994; Nowotny et al., 2001; Nowotny, 2003). These authors specify how social robustness may be achieved through combining three closely related aspects. First, robustness should be tested outside the research arena so that social, economic, cultural and political factors can influence the developed knowledge. Second, social robustness is achieved through involving an extended group of experts, users and laypersons. Third, robustness results from repeatedly testing, modifying and expanding the developed knowledge (Nowotny et al., 2001; Nowotny, 2003). Cash et al. (2003) proposed three criteria to evaluate the relevance of knowledge for environmental decision-making: knowledge should be credible to important actors, relevant to the needs of the decision-makers (salience) and produced in a legitimate way (legitimacy).

It follows that social robustness demands the involvement of diverse actors, such as researchers, policymakers and stakeholders. This diversity complicates the production of knowledge. In general, experts, bureaucrats and stakeholders have differing norms when it comes to producing knowledge (Edelenbos et al., 2011). More specifically, the criteria of salience, credibility and legitimacy are normative (Hegger et al., 2012; Vogel et al., 2007;) and actors therefore interpret them differently. Further, these criteria involve trade-offs and are therefore difficult to achieve simultaneously (Cook et al., 2013; White et al., 2010). Consequently, achieving social robustness is not easy and, instead, knowledge may become irrelevant to the end-users (McNie, 2007; Sarewitz and Pielke, 2007).

The objective of this paper is to improve understanding on how to achieve socially robust knowledge. To date, only limited research has focused on achieving socially robust knowledge in the context of environmental decision-making. The criteria suggested by Cash et al. (2003) are evaluative and provide some insight into how to achieve social robustness. Seijger et al. (2013; 2014) focus on the process of Mode 2 type knowledge production, but do not address social robustness as an outcome of knowledge production. There have been two case studies in nature restoration that have focussed on social robustness and these show that involving many parties, ranging from scientific experts to policymakers and stakeholders, can result in socially robust solutions (Gross, 2006; Van Der Windt and Swart, 2008). As a context for applying social robustness (Gibbons et al., 1994; Nowotny et al., 2001), we focus on coastal projects. The problems addressed in coastal projects tend to be complex and interdependent due to conflicting interests and large knowledge uncertainties in a coastal zone (Coffey and O'Toole, 2012; Weinstein et al., 2007). As such, coastal projects represent a relevant context in which to study socially robust knowledge.

The novelty of this paper is in reporting the development of a set of theoretical conditions that specify how social robustness may be achieved in coastal projects. The conditions relate to the concept of boundary spanning since socially robust knowledge implies an interrelatedness between knowledge production and the context of its application. Consequently, boundary spanning is needed while producing knowledge such that knowledge travels across the organisational boundaries of participating actors (Pemsel and Widén, 2011; Pülzl and Rametsteiner, 2009;). Further, the actors who span boundaries will be enabled or constrained by other factors such as resources, rules and discourses (Van Tatenhove et al., 2000). We therefore position the conditions in a framework that not only analyses actors within an arrangement but also links the production of knowledge to the context of application. The set of conditions forms a theoretical pattern that will be compared with the empirical pattern found in a case study. The case study is of the Dutch Marconi project that addresses spatial developments in Delfzijl, a seaport located near the Ems estuary.

The remainder of this paper is divided into four sections. Section 4.2 outlines the concepts, the theoretical conditions for socially robust knowledge and the applied method. Section 4.3 presents the empirical pattern of social robustness found in a multifunctional solution in Delfzijl and this is then compared to the developed theoretical conditions. The implications for social robustness in coastal projects of this comparison are discussed in Section 4.4. Finally, Section 4.5 draws important conclusions on achieving social robustness in coastal solutions.

4.2. Specifying socially robust knowledge in coastal projects

Achieving social robustness in coastal projects first requires specification due to ambiguity in the concepts of socially robust knowledge and in the 'context of application' (Hessels and Van Lente, 2008; Weingart, 2008). Further, the previous case studies merely point to the involvement of a diverse group of actors (Gross 2006; Van der Windt and Swart 2008), and this is only one of the three aspects of socially robust knowledge (Nowotny et al., 2001; Nowotny, 2003). To address the three aspects in an integrated way we draw on the literature related to boundary spanning and policy arrangements.

4.2.1 Boundary spanning

As knowledge production and the context of application are interrelated, it is necessary to span organisational boundaries between actors if one is to achieve social robustness. Boundaries between actors become blurred as they produce knowledge (Gibbons et al., 1994; Guston, 2001; Nowotny et al., 2001; Turnhout et al., 2007). Researchers, policymakers and stakeholders need to understand each other while they develop knowledge, and need to span boundaries such that concepts and ideas can travel across organisational boundaries (Pemsel and Widén, 2011; Pülzl and Rametsteiner, 2009). Various boundary-spanning concepts have been developed, ranging from boundary objects (Star and Griesemer, 1989) to boundary organisations (Guston, 2001) and boundary spanners (Aldrich and Herker, 1977). Given our interest in how knowledge travels across organisational boundaries, and agreeing with Lejano and Ingram (2009) that boundary objects and organisations do not themselves span boundaries, we are not focussed on these theoretically defined concepts. Rather, we will focus on boundary spanning practices to explore how actors develop socially robust knowledge.

Organisational theorists use boundary spanning in describing activities that occur at organisational boundaries (Aldrich and Herker, 1977). Boundary spanners generally engage in three main activities: they connect different people and processes on both sides of the boundary, select relevant information on both sides of the boundary, and translate this information to both sides of the boundary (Leifer and Delbecq, 1978; Tushman and Scanlan, 1981; Van Meerkerk and Edelenbos; 2013). We focus on what people actually do to span boundaries: so-called boundary spanners in practice (Levina and Vaast, 2005). Boundary spanners in practice are engaged in building a new shared field between organisations. They rely on boundary spanning to negotiate meaning and terms of relationships in this new shared field between organisations (idem).

Thus, boundary-spanning activities are a precondition for developing socially robust knowledge. If boundary-spanning efforts fail, social robustness decreases because concepts and ideas cannot travel across the organisational boundaries of participating actors. Nevertheless, exclusively focusing on boundary spanning does not resolve the aforementioned ambiguity in the 'context of application' and socially robustness. The question remains as to how to analyse this context of application? Further, when is knowledge socially robust – for example, which actors need to accept the developed knowledge for a coastal solution? To address these issues, this paper will apply the framework of project arrangements and knowledge arrangements (Seijger et al., 2013;

Seijger et al., 2014) to analyse knowledge production within a specific institutional and organisational context.

4.2.2 Project arrangements and knowledge arrangements

The framework of project arrangements and knowledge arrangements builds on the policy arrangement approach developed by Van Tatenhove et al. (2000). They define a policy arrangement as a temporary stabilisation of the content and organisation of a policy domain. A policy arrangement is analysed in terms of four dimensions: actors and their coalitions; the division of resources among actors; the formal and informal rules of the game in operation; and the discourses of the actors involved. A tetrahedron is used to symbolise the arrangement by illustrating the interconnectedness of the four dimensions (Liefferink, 2006).

Seijger et al. (2013; 2014) adapted the policy arrangement approach to develop a project arrangement and a knowledge arrangement in order to study Mode 2 type knowledge production in a coastal project. The project arrangement represents the context of the application in achieving social robustness. The project arrangement focuses on the overall project goals: how problems are defined, how solutions are proposed and how decisions are taken. The knowledge arrangement focuses on producing knowledge to seek solutions for the problems defined in the project arrangement. The four dimensions of a policy arrangement (actors, resources, rules and discourses) apply to *both* the project arrangement and the knowledge arrangement (Figure 4.1). Table 4.1 lists the indicators of the four dimensions.

Table 4.1. Indicators of project arrangement and knowledge arrangement.

Actors	actor involvement, actors' relationships, actors affected, actor coalitions
Resources	time, money, information
Rules	access rules, allocation of responsibilities, legislation and policy, interaction rules
Discourses	project rationale, project solutions, project scope

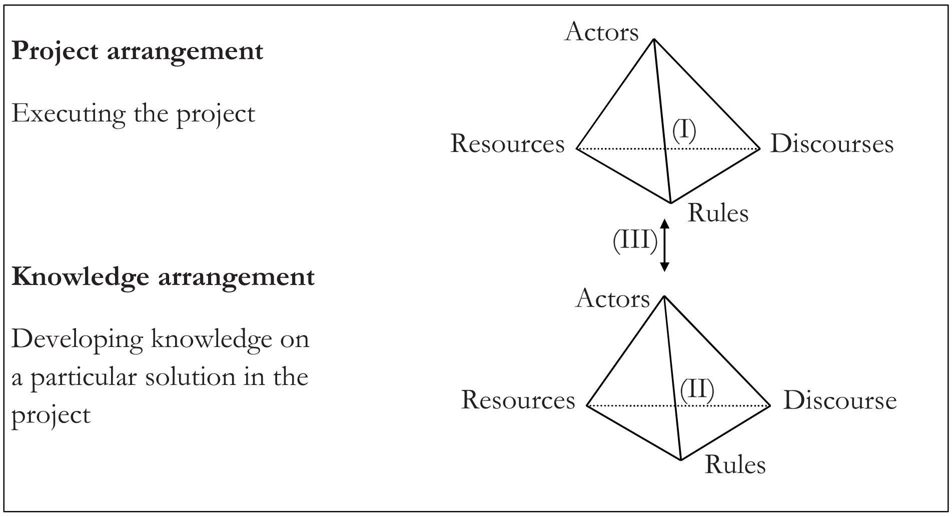

Figure 4.1. Conceptual framework for the project and knowledge arrangements. Boundary spanning between actors may occur on various levels (I-III).

Linking the framework of project arrangements and knowledge arrangements with the concept of boundary spanning (Figure 1) results in three forms of boundary spanning: between actors in the project arrangement (I), between actors in the knowledge arrangement (II) and between actors in the knowledge arrangement and those in the project arrangement (III). The double arrow emphasises the interconnectedness between knowledge production and the project arrangement as context of application.

4.2.3 Conditions for socially robust knowledge

The analysis of the literature enabled us to introduce three conditions that need to be in place for socially robust knowledge to be achieved in coastal projects. The starting points for establishing these conditions are the three aspects of socially robust knowledge (Nowotny et al., 2001; Nowotny, 2003). Translated to our project-knowledge arrangement framework, this results in three conditions for socially robust knowledge in coastal projects. Since the project arrangement represents the context of application, we argue that social robustness will be achieved when all the actors in the project arrangement accept the developed knowledge.

Condition 1: Boundary spanners test knowledge developed from knowledge arrangements in other arenas.

A knowledge arrangement does not function in isolation from the project arrangement as boundary spanners frequently test the developed knowledge in other arenas. A major test is whether the developed knowledge is credible, salient and legitimate to key actors in the project arrangement. Further, social robustness increases through testing the knowledge with other actors such as governmental administrators, influential stakeholders and regulators. Spanning boundaries with these actors may improve robustness in terms of political decision-making, permit procedures and societal acceptance.

Condition 2: Diverse actors participate in the knowledge arrangement.

Knowledge production is not restricted to researchers. Rather, relevant policymakers and other societal actors also participate in knowledge production. To develop socially robust knowledge within a knowledge arrangement requires contributions from all the participating actors. This could be organised by formulating interaction rules that acknowledge the importance of every contribution. Otherwise, if the contributions of some actors are set aside, social robustness may decrease as the knowledge developed is no longer credible or legitimate to the ignored actors. Boundary spanning is therefore needed among the actors such that they understand each other and come to a shared understanding. In practice, all the participating actors could be boundary spanners if they relate practices from one organisation to another, and negotiate terms and meanings of relationships with others.

Condition 3: A knowledge arrangement is strongly connected to the project arrangement during the process of knowledge production.

The developed knowledge is repeatedly tested while actors produce knowledge. Knowledge may be modified and adapted during the various phases from problem formulation through to the selection of solutions. Such an iterative knowledge-production process demands a close connection between the project and knowledge arrangements. This iterative characteristic also highlights the difficulty of achieving knowledge that is credible, salient and legitimate to all participating actors. The robustness will be frequently challenged by actors in both the project and the knowledge arrangements. Consequently, the boundaries of the knowledge and project arrangements should be frequently spanned.

These conditions provide the theoretical foundation for achieving social robustness in the context of coastal projects. Condition 1, testing by boundary spanners, and Condition 3, a good connection between the knowledge and project arrangements, emphasise type III boundary spanning (Figure 4.1). In comparison, Condition 2, having diverse actors in the knowledge arrangement, focuses on type II boundary spanning (Figure 4.1). Type I boundary spanning, between actors in the project arrangement, is not included in the conditions since such spanning was not addressed in the three aspects of Nowotny et al. (2001) and Nowotny (2003). Together, the three conditions represent a theoretical pattern (Yin, 2003). Since Nowotny et al. (2001) and Nowotny (2003) interrelate their aspects of socially robust knowledge, we view our conditions as necessary ones. Consequently, social robustness will not be achieved if any one of these three conditions is not met. In the second half of this paper, we explore whether this theoretical pattern existed in a coastal project for which a proposed solution achieved social robustness.

4.2.4 Method

We conducted a case study to explore how knowledge becomes socially robust in a specific coastal project. The case-study method is well equipped for such a research objective as it has high construct validity. This allows us to identify and measure those indicators that best represent the theoretical concepts that we are interested in (George and Bennet, 2005). It enables an in-depth analysis of complex, uncertain and multidimensional phenomena in their context (Flyvbjerg, 2006), such as socially robust knowledge in coastal projects. Moreover, theoretical patterns can be compared to empirical ones (Yin, 2003). The case-study method can achieve a high internal validity through one, or a few, cases but is less appropriate for a study with many cases (Flyvbjerg, 2006; Gerring, 2007). Nevertheless, it is possible to generalise to a broader range of situations through carefully selecting one or a few cases (idem).

For our study, we selected the Marconi project in Delfzijl, the Netherlands, as a range of diverse actors are involved in knowledge production for a multifunctional solution in the maritime zone of the Ems estuary. Boundaries are spanned among six project partners, three research organisations and numerous environmental organisations. We consider this case as positively deviant (Flyvbjerg, 2006; Gerring, 2007) from other coastal projects because (1) knowledge became socially robust rather than irrelevant or heavily criticised, and (2) a large group of diverse actors was involved. As such, this case is useful in exploring how social robustness can be achieved in a coastal project.

We built the case analysis on fifteen semi-structured interviews, observations of four project meetings, two field trips and numerous project documents (see Appendix V). We transcribed the interviews and analysed them in three rounds through a template-coding approach (Miles and Huberman, 1994; Crabtree and Miller, 1999). Coding refers to the labelling of text fragments. We first coded text fragments on the basis of indicators in the project and knowledge arrangements. Next, we categorised all the coded fragments. Finally, we explored links between the categories and the indicators. Based on this coding process, an analysis emerged of the dynamics in, and between, the project arrangement and the knowledge arrangement. We triangulated findings from the coding process both within and across sources to increase the internal validity of this analysis. The case analysis formed an empirical pattern for achieving socially robust knowledge. We compared this empirical pattern to the theoretical pattern (Yin, 2003) created from the conditions specified in Section 4.2.3.

4.3. Socially robust knowledge in the Marconi project

Delfzijl is a Dutch seaport located on the banks of the Ems estuary. The Marconi project aims to improve the liveability of Delfzijl through spatial developments in the maritime zone (see Figure 4.2). In the case analysis, we discuss how, within the Marconi project, social robustness is achieved for a multifunctional solution in the Schermdijk locale. Section 4.3.1 discusses the Marconi project's project arrangement and Section 4.3.2 the Schermdijk knowledge arrangement. Section 4.3.3 compares the case analysis with the theoretical conditions developed in Section 4.2.3.

Figure 4.2. The maritime zone of Delfzijl at the Ems estuary. The beach and salt marsh areas form part of proposed Marconi spatial developments in the maritime zone. (adapted from: Ecoshape, 2013. Ecodynamische variantenanalyse: Kustontwikkeling Delfzijl)

4.3.1 Marconi project arrangement

In 2009, the municipality of Delfzijl initiated the Marconi project to respond to the strong population decline in the region (predicted at 33% over 1990-2040). This decline threatens the liveability of Delfzijl as young people leave the region and citizens abandon houses and shops[51]. The project partners (see Figure 4.3) had further acknowledged that mono-functional planning, especially in flood control, had worsened liveability in Delfzijl. The Marconi project's partners are focussing on a range of topics to improve the liveability in the maritime zone, including flood control, surface water drainage, recreation and nature. Solutions should strengthen the connections between the city centre, the harbour and the coastline.

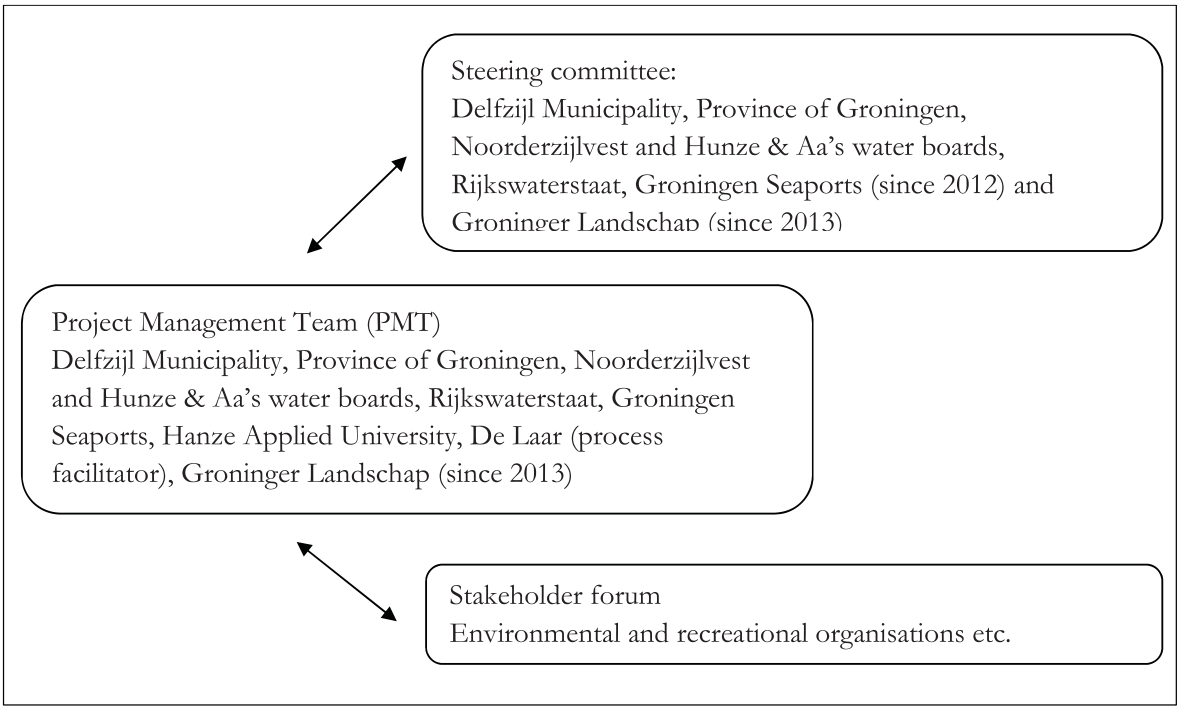

Figure 4.3. Project management structure of Marconi

An informal discourse along the lines of 'we have to do spatial planning differently' accompanied the formal project discourse of 'improving the maritime character of Delfzijl'. The municipality needed this change in planning practices to move from an infeasible situation with mono-functional planning and ambitious but unrealistic plans, to solutions that could improve the liveability in Delfzijl. In 2009, the municipality conducted an inventory in which ambitious but infeasible plans[52] were permanently removed. Instead, the Marconi project would focus on two flood control alternatives: the traditional option of reinforcing existing dikes and a municipality-

[51] The municipality coordinates plans designed to improve the liveability of Delfzijl. Measures include demolishing flats and houses, redeveloping the city centre and transforming surrounding villages. The budget for this programme totals €50 million, funded by the national government, the province (Groningen) and the municipality.

[52] Such plans included reopening the old harbour entrance and closing off the Ems estuary.

preferred alternative that assigned a flood control function to the Schermdijk[53]. Tables 4.2 summarises the timelines of these arrangements.

Table 4.2. Timelines of the Marconi project arrangement and the Schermdijk knowledge arrangement. The highlighted cells cover the analysed period.

Marconi project arrangement	Time line	Schermdijk knowledge arrangement
	Jan 2009	
Inventory by the Delfzijl municipality of plans for the maritime zone.		Flood control combined with salt marshes.
	Jan 2010	
Project partners identified sub-projects: the Schermdijk, surface water drainage and a multifunctional flood defence.		
	Jan 2011	
Reorientation of the project. Project partners developed a spatial vision for Delfzijl's maritime zone.	Jan 2012	
		Flood control combined with urban planning, recreation and nature restoration.
Project partners signed a notice of intent to realise the spatial vision		
	Jan 2013	
Project partners decided to develop a request to the Wadden fund for the preferred solution.		
	April 2013 – onwards	New hydraulic boundary conditions.

In order to be able to implement solutions in the maritime zone, the municipality realised they would have to collaborate with governmental and non-governmental organisations due to formal responsibilities and competing interests in flood control, urban development, and port and coastal management. Five governmental organisations participated in both the steering committee and the project management team (PMT). In addition, three non-governmental organisations participated in the project from the start (see Figure 4.3). A process facilitator manages the steering committee, the PMT and the stakeholder forum. The other two are Groningen Seaports, the relevant port authority that owns the Schermdijk, and Hanze Applied University that contributes ecological knowledge. The steering committee is responsible for the decision-making process and supervises the PMT. In the PMT, representatives of steering committee organisations work together on the development and implementation of solutions for

53 The Schermdijk is 5 km long and is owned by Groningen Seaports. The Schermdijk protects the harbour from waves but does not offers a flood control function.

the Marconi project. Other stakeholders, such as enviornmental and recreation organisations, are consulted and informed about the project's progress through the stakeholder forum.

The 'we have to do spatial planning differently' discourse affected the project's interaction rules. Project communication is reasonably transparent, with meeting notes and reports posted on the project website. Meetings of the steering committee and the PMT are scheduled regularly. The process facilitator links the output of the PMT to the steering committee, and transfers steering committee advice to the PMT. Despite their intentions to do spatial planning differently, the municipality failed to reach consensus among the project partners. During a PMT meeting in 2011, the water boards expressed displeasure that their concerns on funding and feasibility were being overlooked. The project's partners realised that they lacked a shared analysis of the problem and that this reduced the commitment of involved actors to implementing solutions. Later in 2011, the municipality initiated a reorientation phase to regain commitment. The reorientation emphasised the need for boundary spanning between the project partners to ensure that all partners supported the concepts and ideas.

The reorientation phase marked an important turn in the project arrangement, which is emphasised in three changes made. First, the PMT meetings no longer took place in Delfzijl but in offices of other Marconi partners. Second, the discourse broadened from flood control at the Schermdijk to a spatial vision for the maritime zone. The resulting vision aligned urban planning ambitions with flood control, surface water drainage, nature and shipping navigation. Third, partners agreed formally – through a Notice of Intent – to collaborate and implement the spatial vision. The Notice of Intent laid down the shared and individual responsibilities of the project's partners and gave formal roles to Groningen Seaports and Groninger Landschap (an environmental organisation) in the steering committee.

To summarise, the project arrangement illustrated how governmental and non-governmental organisations could collaborate to improve liveability in Delfzijl. Project partners were connected to one another during many meetings in the offices of the various project partners. During these meetings, they interacted and negotiated a shared spatial vision for the maritime zone of Delfzijl. Through such boundary spanning, commitment was regained from the project partners and they signed a Notice of Intent to implement the shared vision. However, the project partners could not directly implement the spatial vision as the envisaged solutions were not sufficiently detailed and the partners lacked funds for implementation. The knowledge arrangement in the next section discusses how the project partners developed knowledge for a solution at the Schermdijk. Table 4.3 summarises both these arrangements.

Table 4.3. Main elements of the project arrangement and the knowledge arrangement.

	Marconi Project Arrangement (2009-2013)	Schermdijk Knowledge Arrangement (2012-2013)
Discourse	Formal: Improve the maritime character of Delfzijl to improve liveability. Informal: We have to do spatial planning differently.	Feasible coastal protection options for the Schermdijk that contribute to urban planning, recreation and nature restoration ambitions.
Actors	See Figure 4.3 for project management structure.	Marconi project partners, Ecoshape researchers, nature coalition*, process facilitator.
Rules (formal interaction)	Steering Committee meets four times a year and is responsible for decision-making and advising the PMT. PMT meets five times a year and is responsible for implementing the Marconi Stakeholder forum that meets once a year.	Interaction among actors is embedded in the Marconi interaction rules.
Rules (legislation)	Nature Protection Act, Water Act.	
Resources (time and money)	Funding for project implementation is lacking.	Ecoshape study co-funded by Ecoshape (50%) and Marconi partners(50%).
Resources (information)	Opportunities for improving the maritime character of Delfzijl (2009). Spatial vision for Delfzijl's maritime zone (2012).	Studies on the Schermdijk, industrial dumping site, Ems estuary. Vision for Ems estuary restoration.

*This coalition is itself made up of two coalitions: a coalition for a natural Wadden Sea and the nature restoration programme Towards a Rich Wadden Sea. We refer to them as 'the nature coalition' as many environmental organisations participated in both coalitions and they share an interest in estuary restoration.

4.3.2 Schermdijk knowledge arrangement

In 2009 and 2010, studies by Hanze Applied University and Deltares indicated that flood control at the Schermdijk could be combined with salt marshes (for timeline, see Table 4.2). The spatial vision included such a solution and the project partners decided to explore its feasibility. The process facilitator connected the Ecoshape consortium to the Marconi project as the former had the required expertise and held opportunities for co-funding. The Ecoshape consortium is a research and innovation programme that consists of private parties, governmental organisations, universities and research institutes. The consortium focuses on 'building with nature' solutions[54] in hydraulic engineering projects. The Ecoshape consortium and Marconi project partners each funded half of the Schermdijk study.

Three Ecoshape organisations (Arcadis, Royal HaskoningDHV and Imares) formed a research team (hereafter called 'the Ecoshape researchers') for a study (hereafter referred to as 'the Ecoshape study') into feasible coastal protection alternatives for the Schermdijk. Table 4.3 summarised the actors, resources, legislation and interaction rules for this knowledge arrangement. The remainder of this section explores how social robustness was achieved for a multifunctional solution at the Schermdijk. This will be discussed through four knowledge-production activities: problem formulation; selection of methods and techniques; interpretation of results; and choice of solution (Van Buuren et al., 2004; Van de Ven, 2007).

Problem formulation

During the first half of 2012, the Ecoshape and Marconi coalitions struggled with the research proposal due to their differing interests. The Ecoshape researchers were interested in identifying 'building with nature' solutions whereas the Marconi partners wanted to implement their spatial vision for the Schermdijk. For example, while the Ecoshape researchers wanted to study the former industrial dumping site in the Ems and include it in the project (indicated in Figure 4.2), the Marconi Steering Committee tried to exclude the dumping site from the Marconi project as there were associated clean-up costs of EUR 10 to 20 million. Further, the municipality was pushing for an expanded city beach to be included in the study, whereas Ecoshape researchers were not interested in such a simple, traditional solution. During a six-month debate, the Marconi project partners and Ecoshape researchers negotiated the meanings and terms of the research questions. This resulted in a shared research proposal that balanced the contrasting interests. In this boundary-spanning process, generic research questions (for example about hydro- and morpho-dynamics in the Ems estuary) were combined with local demands related to flood control, beach expansion and salt marshes at the Schermdijk. The industrial dumping site was included as a research topic. However, the Marconi partners failed to involve the 'nature coalition' in this research proposal. The result of this was that the nature coalition's critical discourse of "the Marconi project as a 'green cover-up' for engineered expansion into the Ems estuary" was excluded from the project.

Methods and techniques

While developing the research proposal, the researchers selected the methods to be used. These were discussed during a PMT meeting in April 2012. The methods consisted of a hydrodynamic model of the Ems estuary, a literature review on salt marsh creation, an assessment framework for the developed alternatives and a field study into the former industrial dump.

Interpretation of results

By the end of 2012, the study had produced two central insights. First, the now-preferred solution, involving salt marshes, beach expansion and flood control at the Schermdijk, was a

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[54] Utilising natural processes and providing opportunities for nature as part of the infrastructure development process (www.ecoshape.nl/en_GB/philosophy.html)

feasible alternative to reinforcing the existing dikes. Second, removing the dumping site (covering 0.22 km^2) would be inevitable in this preferred solution to achieve sufficient nature benefits. The resulting 'nature inclusive' solution had sufficient nature benefits for the Ems estuary to fulfil the requirements of the Nature Protection Act.

The nature coalition critically assessed the outcomes of the study in November 2012. Backed by a vision and research synthesis for restoring the Ems, the nature coalition opposed the preferred solution as it would hamper estuary restoration. The process facilitator sensed that this criticism could obstruct the implementation of the preferred solution and swiftly organised a series of meetings with representatives of the nature coalition. Their concerns were translated into additional hydrodynamic modelling to relate the preferred alternative to the larger scale of the Ems estuary. This additional research indicated that the preferred solution had a minor but positive impact on restoring the Ems estuary.

The Ecoshape researchers coordinated the writing process for reporting the study. They discussed a draft during a PMT meeting in February 2013. The Marconi process facilitator reviewed the report to ensure that the main messages would be acceptable to all the involved actors, requiring organisational boundaries to be spanned between the project partners and the environmental coalition. In addition, the findings were also communicated online. An Ecoshape researcher blogged about the field visit to the industrial dumping site, the municipality posted the Ecoshape study on the Marconi project website and the nature coalition posted hydrodynamic modelling simulations on their website.

Choice of solution

The Ecoshape study resulted in a preferred solution that provides flood control at the Schermdijk, constructs a beach and salt marsh (both open to the public), creates conditions for pioneering marsh vegetation and removes the dumping site (see Figure 4.2). All the Marconi partners supported this solution during a steering committee meeting in March 2013. The earlier boundary spanning efforts with the nature coalition, exploring their concerns and conducting follow-up research, resulted in the nature coalition now supporting the preferred solution. Moreover, they were willing to develop a funding request for its implementation (see timeline, Table 4.2). Flood control was excluded from this funding request as the Schermdijk area would not need major dike reinforcements for several decades.

In conclusion, we can say that social robustness was achieved for a multifunctional solution at the Schermdijk because *all* the actors in the project arrangement accepted and supported the solution. Project partners and researchers successfully spanned boundaries with the nature coalition by connecting the Schermdijk solution to the scale of the Ems estuary through additional hydrodynamic research. Furthermore, regular meetings involving Marconi partners with formal responsibilities (such as the province, water boards and Rijkswaterstaat) and major commercial interests (Groningen Seaports) resulted in support from a broad group of actors that might otherwise have opposed the preferred solution. Thus, boundaries with all actors in the project arrangement were effectively spanned such that all the actors accepted the preferred solution.

4.3.3 Achieving socially robust knowledge in the Marconi project

The Marconi case analysis of project and knowledge arrangements provides an empirical template on achieving socially robust knowledge in a coastal project. This empirical pattern is now compared to the theoretical pattern described in Section 4.2.3. We end the section by addressing factors that constrained socially robust knowledge in the Marconi project.

The first condition, referring to boundary spanners testing the developed knowledge in other arenas, is demonstrated by the activities of the process facilitator as he spanned various boundaries. He checked the key outcomes with the nature coalition, which eventually resulted in their support for the preferred solution. In addition, he linked the steering committee to the project management team, which resulted in political support evidenced by the steering committee funding 50% of the study and supporting its outcomes. Finally, he explored permit issues related to the preferred solution with relevant regulators. As a result, the study was developed as a legitimate source for future permit-seeking procedures[55]. Thus, through such boundary spanning activities, knowledge gained in the Ecoshape study became robust in the Marconi project.

The second condition, having diverse actors in the knowledge arrangement, was evidenced by the involvement of the nature coalition, Ecoshape researchers and Marconi project partners. The interaction rules emphasised how the actors valued each contribution. This is exemplified by the boundary spanning activities that addressed the concerns of the nature coalition. Knowledge was made credible and salient for them through additional hydrodynamic research that related the preferred Schermdijk solution to the Ems estuary. The Ecoshape consortium functioned as a scientific authority, thereby ensuring that credible and legitimate knowledge was produced. Social robustness was thus enhanced as diverse actors supported the developed knowledge.

The third condition, that the knowledge arrangement is well connected to the project arrangement, is illustrated by the knowledge arrangement being embedded in the project arrangement. This was achieved through regular PMT meetings in which the Ecoshape researchers discussed the research proposal, the preliminary design and research findings with the project partners. Further, ensuring the knowledge was easily comprehensible facilitated understanding between actors in the project and the knowledge arrangements. The weblog created by an Ecoshape researcher was used to convince the steering committee that addressing the dumping site was an essential component of the preferred solution. Another example is the assessment framework that structured PMT discussions about the positive and negative impacts of potential solutions. Further, knowledge was tested several times, modified and expanded such that it became credible and salient to participating actors. This is illustrated by the negotiated research proposal, the additional hydrodynamic research that was undertaken and the inclusion of the dumping site in the preferred solution.

The boundary spanning efforts between the project partners prior to the Ecoshape study are not covered by the proposed conditions. In practice, actors were connected to one another in the

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[55] The Ecoshape study covered the research needs for an Appropriate Assessment, a legal requirement in such a project.

offices of project partners as they negotiated a spatial vision for Delfzijl. This vision was supported by the project partners and contained a multifunctional solution for the Schermdijk, one that combined flood control with beach expansion and nature restoration. Through this, the project partners structured the scope for knowledge production. This amounts to type I boundary spanning (Figure 4.1). Although this is not represented in the conditions, it was essential to the Marconi project. Thus, at least in the case studied, this constitutes a fourth case-specific condition for achieving socially robust knowledge, i.e.: boundary spanning among actors in the project arrangement to structure the scope of problems and solutions prior to developing knowledge for a coastal solution.

Although social robustness was achieved in the Marconi project, there were three factors that hampered this process. First, the nature coalition was rather fragmented. Various representatives of the involved actors attended different meetings in which research questions and initial results were discussed. These representatives disturbed the iterative process of making knowledge socially robust as they had not participated in previous discussions. Second, the interests of the participating actors did not spontaneously align as each actor tended to focus on their own interests: Ecoshape researchers did not always translate results to the specific Delfzijl situation; water boards were critical of flood control aspects as these were their formal responsibilities; the nature coalition was only interested in the results of the hydrodynamic modelling. Third, developing socially robust knowledge cost more than many had expected. One research organisation spent 40% more time on the Ecoshape study than they had budgeted for due to the many meetings and additional research required.

4.4 Discussion

In this paper, we have developed a set of interrelated conditions for achieving social robustness in coastal projects. The comparison of this theoretical pattern with the empirical pattern discerned from the Marconi case study improves understanding on how to realise social robustness in coastal projects. The case study supports the assumption that the three theoretically derived conditions are necessary preconditions for achieving social robustness. Other empirical research on socially robust knowledge shows that these conditions may also apply to other complex environmental projects. For example, Gross (2006) analysed solutions in a restoration project and showed the existence and necessity of conditions 2 (diversity of actors in the knowledge arrangement) and 3 (knowledge arrangement well connected to project arrangement). Moreover, the analysis of the Marconi project highlighted a fourth condition: boundary spanning between actors in the project arrangement prior to producing knowledge. Further research is needed to explore whether this condition is specific to our case or a more general condition for robust knowledge production. Hanssen et al. (2009) describe such boundary spanning as a facilitation strategy: consensus must be reached on ambitions and the directions for potential solutions before uncertainties are reduced by research.

Interpreting boundary spanning from the perspective of organisational sciences enabled us to focus on the main challenge of how to span boundaries between actors such that knowledge travels across organisational boundaries. This revealed that social robustness was achieved in the studied case through a combination of boundary objects and boundary spanning practices. The assessment framework functioned as a boundary object (Star and Griesemer, 1989) that contributed to a shared understanding. Spanning practices were crucial, including the reorientation of the project by the project partners. Such boundary spanning by actors from several policy domains is needed when environmental problems cut across several policy areas (Bressers and Lulofs, 2010; Jochim and May 2010). Despite this importance, this aspect receives little attention in the science-policy interface literature which mainly focuses on boundary spanning between researchers and policymakers within a single policy domain (Cook et al., 2013; Turnhout et al., 2007).

We also identified constraints on achieving social robustness. A fragmented coalition disturbed the iterative process of achieving social robustness and the costs were higher than expected due to the many meetings and additional research involved. Further, while developing knowledge, each actor tended to focus on their own interests despite their agreement on the scope and type of solution needed. This emphasises the need for continuous boundary spanning activities among actors. Finally, all these interests have to be balanced without compromising the legitimacy or credibility of the developed knowledge (Cash et al., 2003). If the latter is not achieved, the knowledge may be accepted but amount to no more than negotiated nonsense lacking scientific credibility (Van de Riet, 2003). In the project studied, Ecoshape researchers retained their scientific authority by joining discussions on the research proposal, selecting appropriate research methods, interpreting the results and coordinating the writing process of the study's outputs.

4.5 Conclusions

The objective of this paper has been to improve understanding on how to achieve socially robust knowledge in coastal projects. We therefore addressed boundary spanning, the framework of the project and knowledge arrangements, and developed a theoretical pattern specifying how social robustness can be achieved. We then analysed socially robust knowledge in the Marconi coastal project being undertaken in the Netherlands. This resulted in an empirical pattern, which we compared to the theoretical pattern. From this, we can draw the following conclusions on achieving socially robust knowledge in coastal projects.

The three theoretically developed conditions proved necessary for social robustness in the analysed case. That is, the robustness improved as the developed knowledge was tested by a boundary spanner in other arenas. Second, robustness was strengthened by diverse actors participating in the knowledge arrangement. Third, the boundary between knowledge production and project decision-making was frequently bridged while actors produced knowledge. This ensured that the knowledge was relevant for the context in which it was developed.

A fourth, possibly case-specific, aspect was uncovered through the empirical study. The problem regarding which knowledge had to be developed was strongly structured by the project partners. This resulted in a clear scope for knowledge production activities. Further, although the problem became well structured, the participating actors did not stick closely to one course or perspective in responding to that problem. Rather, they frequently modified and expanded the developed knowledge to ensure that participating actors such as the nature coalition supported the knowledge.

These four conditions clarify the concept of socially robust knowledge by stipulating how social robustness can be achieved in coastal projects. In coastal projects, the ultimate test of societal support comes at crucial formal events: when formal project decisions are communicated, permits requested or construction is about to start. Clearing such hurdles becomes easier if the proposed solutions are socially robust. In that sense, the ultimate final test is replaced by smaller informal tests earlier in the process as reflected in the conditions outlined in this paper.

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Chapter 5. Sustainable coastal development: Turning knowledge into action[56]

Abstract

Turning scientific knowledge into action for sustainable development is a major challenge for sustainability science. In order to turn knowledge into action, researchers and practitioners should be aiming to develop knowledge in an interactive way. Few studies have systematically analyzed how interactive knowledge development functions in practice. This paper presents a cross-case analysis of interactive knowledge development in coastal projects. Three cases are analyzed through the framework of project arrangements and knowledge arrangements. The projects are located in the Wadden Sea, San Francisco Bay and the Ems estuary and address issues of flood control, nature restoration and liveability. The cross-case analysis revealed eleven causal mechanisms that help explain how project decision-making impacts on interactive knowledge development, how a process of interactive knowledge development functions and what its outcomes are. The mechanisms reveal gaps in the theoretical understanding of interactive knowledge development. Nevertheless, interactive knowledge development remains relevant for turning knowledge into action since it enhances feasibility and societal support for developed solutions. As such, this paper contributes to a practice-oriented understanding of turning knowledge into action for sustainable coastal development.

Significance statement

To turn knowledge into action for sustainable development, knowledge should be developed in interaction between researchers and practitioners. Since interactive knowledge development has been little studied in settings where practitioners address problems of sustainable development, it remains unclear how practitioners develop the knowledge required to balance human needs with environmental concerns. This study provides such an understanding for coastal zones, by presenting a cross-case analysis of coastal projects in the Wadden Sea, San Francisco Bay and the Ems estuary. The cross-case analysis reveals that interactive knowledge development enhances societal support and the feasibility of the developed coastal solutions. As such, this paper reveals how interactive knowledge development is of value to practitioners trying to balance human needs with environmental concerns.

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5.1. Introduction

Sustainability science seeks to facilitate a transition towards sustainability (Clark, 2007; Kates et al., 2001; Weinstein and Turner, 2012). In recent decades, views have converged on the central challenges facing sustainable development (Board on Sustainable Development NRC, 1999; Kates, 2010; Kates, 2012; WCED, 1987). Nevertheless, sustainability science has been slow in contributing to effective and feasible solutions for sustainable development (Kates, 2012; Van der Leeuw et al., 2012; Van Kerkhoff, 2013; Wiek et al., 2012a). Turning knowledge into action for sustainable development therefore remains a major challenge for sustainability science (Cornell et al., 2013; Kates et al., 2001; Kates, 2012; Van Kerkhoff and Lebel, 2006). Only a few studies have analyzed how the knowledge required for sustainable development is produced in practice. Sustainability scientists agree that knowledge should be interactively developed between researchers and practitioners (Cash et al., 2003; Cornell et al., 2013; Kates et al., 2001; Kates, 2010; Lang et al., 2012; Van Kerkhoff and Lebel, 2006). This knowledge production, in this paper labelled as 'interactive knowledge development'[57], has been addressed theoretically in various concepts (Burbidge et al. 2011; Callon et al., 2009; Coffey and O'Toole, 2012; Gibbons et al., 1994; Hegger et al., 2012; Lang et al., 2012; Nowotny et al., 2001; Van de Ven, 2007). Descriptive case studies have provided empirical understanding of interactive knowledge development (Edelenbos et al., 2011; Hegger et al., 2012; Lane et al., 2011; Rogers, 2006; Roux et al., 2006) but are not able to identify underlying mechanisms (Hegger et al., 2012) or to separate case-specific insights from generic ones. Studies involving multiple cases indicate that sustainability science studies have had only a limited real-world impact (Wiek et al., 2012b) and that knowledge needs to be credible, salient and legitimate to the actors involved (Cash et al., 2003).

Given the significance of interactive knowledge development in turning knowledge into action, the objective of this paper is to contribute to a systematic understanding of interactive knowledge development. We therefore present a cross-case analysis of interactive knowledge development in three coastal projects. This paper responds to pleas for comparative analyses related to interactive knowledge development (Van Kerkhoff, 2013; Lang et al., 2008; Hegger et al., 2014) as well as to calls for research that engages with practitioners addressing real-world problems related to sustainable development (Clark and Dickson, 2003; Kates, 2012).

Coastal zone projects offer examples of practitioners dealing with place-based problems of sustainable development. The world's coasts are deteriorating, while human dependence on coastal space and resources continues to increase (Burke et al., 2001; UNEP, 2006; U.S. Commission on Ocean Policy, 2004; Weinstein et al., 2007). Coastal projects respond to

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[57] We use the term 'interactive knowledge development' to emphasise the interactive character of knowledge production while trying to avoid creating expectations regarding collaboration between researchers and practitioners. Concepts such as knowledge co-production (Clarke et al., 2013; Cornell et al., 2013; Lane et al., 2011) and joint knowledge production (Hegger et al., 2012; Van Buuren and Edelenbos, 2004) emphasise only the collaborative setting, ignoring the possibility that actors might be excluded or only partially involved during processes of knowledge production.

problems in the coastal zone by trying to balance human needs with environmental concerns. Around the world, there are projects showing the difficulty of taking action that amounts to sustainable coastal development. For example, controversies exist around land reclamation activities, dredging operations near expanding harbours and exploitation of coastal resources by the oil and gas industry. Moreover, the feasibility of many solutions that are implemented around the world, such as protected marine areas and conventional coastal engineering, are questioned in the scientific community (Edgar et al., 2014; Temmerman et al., 2013). Solving coastal problems is thus a complicated undertaking due to conflicting interests and major knowledge uncertainties (Cicin-Sain and Knecht, 1998; Kay and Alder, 1999). Given this reality, responding to coastal issues requires the involvement of both researchers and practitioners in knowledge production (Clarke et al., 2013; Hanger et al., 2013; Schmidt et al., 2012; Tribbia and Moser, 2008).

This paper presents a cross-case analysis of interactive knowledge development in three coastal projects. In each case, project managers have attempted to involve researchers, policymakers and stakeholders in producing knowledge for a sustainable coastal solution. The cases are located in the Netherlands (Wadden Sea and Ems estuary) and the USA (San Francisco Bay) and deal with issues of flood control, nature restoration and liveability. The cross-case analysis reported here investigates how interactive knowledge development enhances societal support and boosts the feasibility of developed coastal solutions. Case-specific findings have been published elsewhere (Seijger et al., 2013; Seijger et al., 2014).

5.2. Conceptual framework of project and knowledge arrangements

In analyzing interactive knowledge development in coastal projects we have applied the framework of project arrangements and knowledge arrangements (Seijger et al., 2013; Seijger et al., 2014). This framework builds on the policy arrangement approach (Arts et al., 2006; Van Tatenhove et al., 2000). A policy arrangement is defined as the temporary stabilisation of the content and organisation of a policy domain. Four dimensions make up the policy arrangement: actors and actor coalitions; the division of resources among actors; the rules of the game in operation; and the discourses of actors involved. These dimensions are interconnected and frequently illustrated in the form of a tetrahedron (Liefferink, 2006).

In order to study interactive knowledge development in coastal projects, Seijger et al. (2013; 2014) adapted the policy arrangement approach by dividing and extending it into a project arrangement and a knowledge arrangement (Figure 5.1). The four dimensions of the policy arrangement apply to both the project arrangement and the knowledge arrangement, with the indicators for the dimensions listed in Table 5.1. The project and knowledge arrangements differ in scope (see Figure 5.1). The project arrangement focuses on the evolving coastal project and analyses the context for knowledge production: how actors define problems, allocate resources, propose solutions and take decisions. The knowledge arrangement focuses on the knowledge production process for the defined problems and is analyzed through four activities: problem formulation, selection of methods, interpretation of results and choice of solution. The double-ended arrow in Figure 5.1 emphasises the interconnectedness of the two arrangements.

In the project and knowledge arrangement framework used here, three aspects of interactive knowledge development are analyzed: structuring factors impacting on interactive knowledge development (Manuel-Navarrete and Gallopín, 2012; Van Kerkhoff, 2013), dynamics during interactive knowledge development (Cornell et al., 2013; Edelenbos et al., 2011; Manuel-Navarrete and Gallopín, 2012; Van Kerkhoff, 2013), and consequences of interactive knowledge development for uptake in decision-making (Cash et al., 2003; McNie, 2007; Nowotny et al., 2001; Sarewitz and Pielke, 2007). Integrating these three aspects into one framework is an innovative approach to analyzing interactive knowledge development since most studies focus on either one or two aspects.

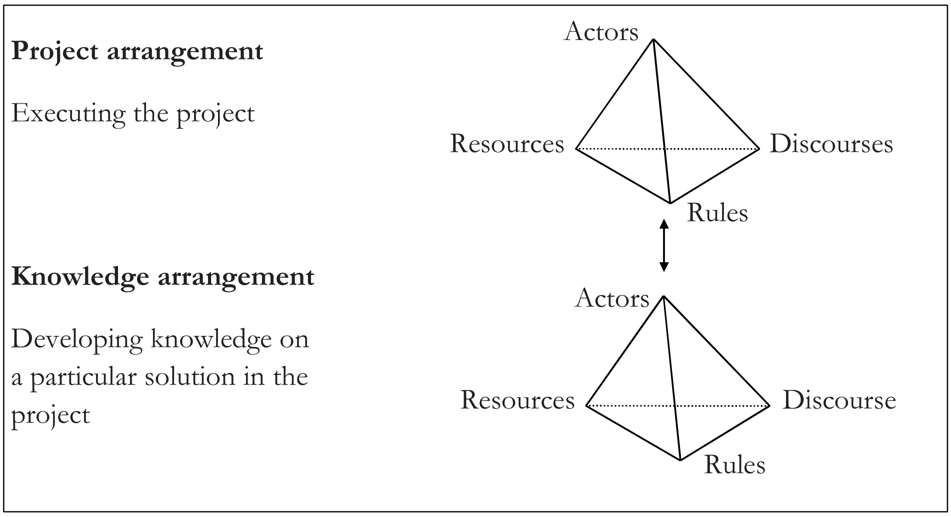

Figure 5.1. Conceptual framework of project and knowledge arrangements

Table 5.1. Indicators for the project and knowledge arrangements

Actors	Actor involvement; Actors' relationships; Actors affected; Actor coalitions
Resources	Time; Money; Information
Rules	Access rules; Allocation of responsibilities; Legislation and policy; Interaction rules
Discourses	Project rationale; Project solutions; Project scope

5.3. Method

5.3.1 Multiple case study

A multiple case study was undertaken to enrich and broaden the empirical understanding of interactive knowledge development in coastal projects. A case study approach makes it possible to identify and measure the indicators that best represent the theoretical concepts one wants to measure (George and Bennet, 2005). As such, case studies enable an in-depth analysis of complex, uncertain and multidimensional phenomena in their context (Flyvbjerg, 2006). Given the depth of the analysis, only a few cases can be studied but this results in a high internal validity (Flyvbjerg, 2006; Gerring, 2007). A cross-case comparison can deepen the understanding on the phenomena of interest (Miles and Huberman, 1994). In addition, the ability to generalise findings to a broader range of situations improves through appropriate case selection and case comparison (George and Bennet, 2005; Gerring, 2007; Miles and Huberman, 1994).

Three cases were selected: two coastal projects in the Netherlands (Wadden Sea and the Ems estuary) and one in the US (San Francisco Bay). These choices reflect a 'most different' research design (George and Bennet, 2005; Gerring, 2007; Landman, 2008) in that they share a number of key characteristics and a similar outcome, yet differ in terms of other possible explanatory factors. The shared characteristics of the selected cases reflect our research interest: coastal area projects that address local, place-based, problems. The selected projects are characterised by a diversity of actors involved in knowledge production, indicative of a process of interactive knowledge development. The cases differ in three aspects of project management, namely how they manage time, manage costs and project scope (Atkinson, 1999; Morris and Geraldi, 2011). A fourth defining aspect is the institutional context in which a project is embedded. The prevailing institutional structure both enables and constrains the practices of actors in projects (Grabher, 2002; Morris and Geraldi, 2011). Table 5.2 shows how the three cases differ in terms of these four aspects.

Table 5.2. Similarities and Differences identified in the most different research design

	Wadden Sea: dike-reinforcement project	San Francisco Bay: nature restoration project	Ems estuary: spatial development project
Similarities			
Coastal zone	Dikes protecting Texel from the Wadden Sea.	Salt ponds between Silicon Valley and South San Francisco Bay.	Delfzijl's maritime zone adjacent to the Ems estuary.
Local place-based problem	17 km of dikes no longer meet safety norms.	The project owns 60.7 km^2 of salt ponds that could be restored.	The liveability of Delfzijl is seen as problematic, the project focuses on options in the maritime zone (35 km^2).
Interactive knowledge development actors	Government (regional and local), experts (mainly consultants), nature organisations.	Government (federal, state and local), experts (scientists and consultants), stakeholder forum.	Government (regional and local), experts (scientists and consultants), port authority, nature organisations.
Differences			
Scope	Provide flood control.	Restore tidal marsh.	Improve liveability.
Financial	Funding for project solutions is largely covered by a national	Funding for project solutions is organised for each phase of	The project lacks funding to implement solutions.

	program.	implementation.	
Time	Considerable time pressures as original delivery deadlines were not met.	Little time pressure as final implementation phase should be completed by 2058.	No time pressure due to absence of funding for implementation.
Institutional context	The Netherlands.	California, USA.	The Netherlands.

5.3.2 Data collection and data analysis

Each case was analyzed longitudinally using the framework of project arrangements and knowledge arrangements. Data were collected from semi-structured interviews, project documents, observations of project meetings and field visits to project areas. Table 5.3 provides an overview of the data sources in each project.

Table 5.3. Overview of collected data in each case

	Wadden Sea: dike-reinforcement project	San Francisco Bay: nature restoration project	Ems estuary: spatial development project
Period analyzed	2005-2011	2003-2013	2009-2013
Interviews project arrangement	5	9	9
Interviews knowledge arrangement	5	10	6
Project meetings	2	6	4
Field trips	2	5	2
Project documents (number of files)	373	842	107

The interviews were fully transcribed and qualitatively analyzed using a template coding procedure (Crabtree and Miller, 1999; Miles and Huberman, 1994). Coding involves the labelling of text fragments, which was carried out in QSR NVivo. The template coding procedure consisted of three rounds. First, fragments were coded on the basis of indicators in the project and knowledge arrangements. Second, all the coded fragments were further categorised in order to enhance our understanding of the indicators. Third, links between the categories and indicators were explored by integrating the dimensions of the project arrangement and of the knowledge arrangement. This final third step provides the key findings for the project and knowledge arrangements based on the transcribed interviews. To improve the internal validity of the analysis, findings were triangulated in two ways. Firstly, during the coding, findings were compared across interviews. Following this, the findings from the coding procedure were validated against project documents and observations of project meetings.

The within-case analysis covered the project arrangement, the knowledge arrangement and case-specific causal mechanisms. Causal mechanisms specify the causal processes responsible for observed outcomes (Beach and Pedersen, 2013; Hedström and Ylikoski, 2010). Causal mechanisms, due to their structure, contribute to systematic understanding since they reveal how a set of causes contribute to interactive knowledge development outcomes. The mechanisms were derived and developed within the three individual case studies and specify the functioning of interactive knowledge development. Elsewhere, we published two case studies and their associated case-specific mechanisms (Seijger et al., 2013; Seijger et al., 2014). The cross-case analysis presented in this paper focuses on generic mechanisms. That analysis is informed by a variable-oriented strategy where variables are compared across cases (Miles and Huberman, 1994). The case-specific mechanisms serve as variables that are compared with each other to arrive at generic mechanisms. These generic mechanisms are developed iteratively by completing cross-case tables and re-examining the single case analyses.

5.4. Project and knowledge arrangements in individual projects

This section summarises the case-specific arrangements and causal mechanisms.

5.4.1 Wadden Sea: dike-reinforcement project

Project arrangement - In 2005, 17 km of the 27 km of Wadden Sea dikes on the Dutch island of Texel failed to meet existing safety norms. The water board responsible for flood control initiated a dike-reinforcement project to ensure that the dikes would then meet the safety norms. Funding mainly came from the national flood risk protection program. This program determined the project discourse through their funding criteria: reinforcements should be sober, effective and robust. The water board collaborated with an engineering firm in following the environmental impact analysis procedure. The water board regularly met with the province and the municipality authorities due to their formal responsibilities. In 2009, the water board announced that they would investigate traditional, landward, alternatives to reinforcing the dikes.

Knowledge arrangement – A group of ten actors, all based on Texel, disagreed with the proposed landward alternatives. They called for research on alternative, more sustainable, solutions. One option would be a seaward solution entailing a sandy flood defence in the Wadden Sea, supplemented with salt marshes and oyster reefs. The water board refused to fund a study into this since such a solution would not meet the funding criteria of soberness and robustness. However, the municipality and a nature recovery program decided to fund the study. An outline of a seaward solution was jointly developed and this served as a starting point for the study. The engineering firm and the water board interpreted the results and formulated the conclusions. Others were excluded from this process as the water board took full responsibility for the study. The nature recovery program and the municipality (backed by an unpaid scientific advisor) heavily criticised the study and especially the cost estimates for a seaward solution. In response, the water board conducted a follow-up study in 2012 that indeed resulted in a more cost-effective design.

5.4.2 San Francisco Bay: nature restoration project

Project arrangement - In 2003, a restoration project acquired 60.7 km^2 of industrial salt ponds in the south of the bay. Since the 1850s, 83% of the South San Francisco Bay marshland has been lost and the project discourse was to restore and enhance wetlands in South San Francisco Bay while providing flood management and wildlife-oriented public access and recreation. The project management team (PMT) consisted of governmental and non-governmental organisations. The aim was that restorative actions should be completed by 2058. Given this time horizon, the PMT relied on researchers and adaptive management to adjust management decisions. The project discourse for Phase 2 planning (2010-onwards) was narrowed to tidal marsh restoration of the salt ponds. PMT members sought consensus among themselves prior to decision-making. Future funding was strongly linked to public support, and this was a key driver for collaboration with researchers and with governmental and non-governmental organisations.

Knowledge arrangement – Alternative restorative ideas for Phase 2 were developed in this arrangement. The alternatives included breaches in salt pond levees, ecotone transition areas, trails and viewing platforms. In 2010, the PMT identified ponds suitable for tidal marsh restoration. They presented their findings to the stakeholder forum, to researchers and to the regulators. In 2011, the PMT hired consultants to develop qualitative descriptions of the opportunities and constraints of the various alternatives. Their findings were reported in separate meetings to researchers, regulators and stakeholders. Based on the inputs from the researchers, the number of breaches was altered as well as the sizes and shapes of the proposed nesting islands. The regulators shared valuable permit-related knowledge in one-on-one meetings with the executive project manager. In February 2013, the PMT selected three alternatives for environmental impact analyses.

5.4.3 Ems estuary: spatial development project

Project arrangement - Delfzijl is a Dutch seaport, located on the banks of the Ems estuary. In 2009, the municipality initiated a spatial development project to improve the liveability of Delfzijl. This liveability was being threatened by a sharp population decline and the previous mono-functional planning. The project partners focused on solutions that would strengthen connections between the city center, the harbour and the coastline. To implement such solutions, the municipality realised it would have to collaborate with the regional government and with non-governmental organisations. Despite this, as of 2011, the municipality had failed to reach a consensus on a proposed solution for flood control and tidal marshes. This resulted in a reorientation phase with the project partners realizing that they lacked a shared problem analysis. The project partners regained a shared commitment through a spatial vision for the maritime zone. However, the project partners lacked funding for its implementation.

Knowledge arrangement – In 2012, the project partners decided to explore the feasibility of a seaward solution that had been outlined in the spatial vision. The solution combined expanding the city's beach with tidal marsh, recreation and flood control aspects. This study was conducted by a research consortium that was interested in 'building with nature' solutions in hydraulic engineering projects. The consortium and the project partners each funded 50% of the study. Their contrasting interests of generic building with nature research versus implementing an envisioned solution resulted in a six-month struggle over the research proposal. In November 2012, a coalition of nature organisations opposed the findings of the study on the basis that the proposed solution might hamper estuary restoration. The facilitator considered their criticisms leading to additional research. This additional research turned the nature coalition from opponents into advocates who then helped to develop a funding request for implementation.

For each case, we developed causal mechanisms that could explain the interactive knowledge development (Seijger et al., 2013; Seijger et al., 2014). These mechanisms are case-specific and reveal different interactive knowledge development processes (Table 5.4). These mechanisms have been positioned in the project and knowledge arrangements framework. This results in two types of mechanisms: ones that cross from the project arrangement to the knowledge arrangement; and mechanisms that operate within the knowledge arrangement. In Section 5.5, we transform the case-specific understandings of interactive knowledge development to a systematic, generic, understanding.

Table 5.4. Case-specific causal mechanisms for interactive knowledge development.

Orientation of causal mechanisms	**Wadden Sea: dike-reinforcement project**	**San Francisco Bay: nature restoration project**	**Ems estuary: spatial development project**
From project arrangement to knowledge arrangement	1a. The formal responsibilities of other actors were a key motive for involving them in the knowledge arrangement.	2a. The need for public support resulted in interactive knowledge being developed in the knowledge arrangement.	3a. Project partners realised they needed to collaborate over Delfzijl's maritime zone and this resulted in collaboration in the knowledge arrangement.
	1b. Time pressures in the project resulted in time pressures in the knowledge arrangement.	2b. Limited resources (information, time and money) narrowed the scope of the knowledge arrangement.	3b. Limited financial resources impacted on the actors and type of solutions in the knowledge arrangement.
	1c. The engineering firm became a trusted partner of the water board and they therefore conducted the study for a sandy seaward solution.	2c. The project memory of the actors structured the role of the consultancy team in the knowledge arrangement.	3c. The project discourse structured the problem-formulation knowledge arrangement.
	1d. Discourses in the project and in the knowledge arrangement determined the scope for knowledge development.		3d. The interaction rules of the project arrangement applied to the knowledge arrangement, ensuring that the knowledge arrangement was well embedded.

	1e. Legislation meant that the water board was responsible for the project and, therefore, they did not involve other actors in the interpretation of results and the formulation of conclusions.		
Within knowledge arrangement	1f. Involving a diversity of perspectives resulted in support from the actors involved.	2d. Including a diversity of perspectives broadened support among the actors involved.	3e. The interests of project partners, researchers and the nature coalition had to be bridged during the interactive knowledge development to achieve broadly accepted solutions.
	1g. Actors with limited technical knowledge found it difficult to comment on the study.	2e. The type of knowledge present (qualitative restoration alternatives) supported a process of interactive knowledge development.	3f. Easily understood knowledge facilitated understanding among participating actors.
	1h. The nature recovery program facilitated interactive knowledge development through funding and conflict mediation.	2f. Professional facilitation smoothed the process of interactive knowledge development.	3g. Facilitation by the facilitator ensured a smooth process of interactive knowledge development.
		2g. A safe, confidential environment resulted in additional knowledge.	3h. One actor from the research consortium was excluded from this knowledge arrangement for budgetary reasons.
			3i. It was difficult to engage with the fragmented nature coalition.
			3j. The costs of interactive knowledge development were higher than expected.

5.5. Mechanisms in interactive knowledge development in coastal projects

5.5.1 Deriving generic mechanisms

The generic mechanisms are developed iteratively, by comparing the mechanisms across the cases and re-examining the individual case analyses. Table 5.4 reveals four generic mechanisms that *affect* interactive knowledge development in the project arrangement. First (1): initiating actors are pressed to involve others in knowledge production (mechanisms 1a, 2a, 3a). Second (2): resources structure the knowledge arrangement and narrow the scope of what can and what cannot be investigated (mechanisms 1b, 2b, 3b). Third (3): actor relationships in the project arrangement affect the role of the main knowledge producer: either because the main knowledge producer is already a trusted partner (mechanism 1c), or because they are new to the project (mechanism 2c), or because they are an attractive partner in the sense they bring funding to the project (mechanism 3b).

Re-examining the data resulted in a fourth generic mechanism (4): sharing responsibilities supports interaction rules for interactive knowledge development. This mechanism was derived from the role of responsibilities (mechanism 1e) and interaction rules (mechanism 3d). In both the San Francisco Bay and the Ems estuary projects, actors shared decision-making responsibilities. This resulted in consensus-based interactions through which actors moved forward in small steps in the knowledge arrangement. In contrast, in the Wadden Sea project, a single actor was responsible and consequently less willing to involve other organisations. Other case-specific mechanisms in the project arrangement point to structuring impact of discourses (mechanisms 1d, 3c). As discussed in the second generic mechanism, this structuring impact on the scope of knowledge production occurs especially through resources.

In the knowledge arrangement, we could also identify four generic mechanisms that *explain*, or provide more detail, on interactive knowledge development. First (1): actors hold different perspectives on issues for which knowledge needs to be developed, and this results in differing contributions during interactive knowledge development (mechanisms 1f, 2d, 3e). Second (2): easily understood knowledge supports contributions by non-experts (mechanisms 1g, 2e, 3f). Third (3): facilitation smoothes the process of interactive knowledge development (mechanisms 1h, 2f, 3g). Further, mechanism 3h on exclusion appeared to represent another generic mechanism (4): actors were excluded in each case during one or more activities in the knowledge arrangement development. Other case-specific mechanisms in the knowledge arrangement point to barriers (mechanisms 3h, 3i), strategy (mechanism 2g) and the additional costs of interactive knowledge development (mechanism 3j).

The remaining generic mechanisms reflect the *consequences* of interactive knowledge development for actors in the projects. These were included in the case-specific mechanisms as broad support (mechanisms 1h, 2f, 3e) and high costs (mechanism 3j). Re-examining the data for outcomes related to interactive knowledge development resulted in three mechanisms. First (1): interactive knowledge development broadens societal support for solutions since involved organisations eventually support the developed solutions. Second (2): the proposed solutions become more feasible as actors make valuable contributions that change the design, reduce costs, or improve the permitability. Finally (3): significant time is consumed through this process due to all sorts of meetings being required plus additional follow-up research.

5.5.2 Key findings

Table 5.5 summarises the generic mechanisms identified. These mechanisms reveal how interactive knowledge development functions in the studied coastal projects. The mechanisms are positioned within the framework of project and knowledge arrangements. They cover three sorts of processes (affect, explain, consequences) as discussed in Table 5.5. These mechanisms were operating in all three cases (the empirical evidence is presented in Appendix VI).

Table 5.5. Generic mechanisms identified in interactive knowledge development in coastal projects.

Type of causal mechanism	Description
From project arrangement to knowledge arrangement: mechanisms that *affect* interactive knowledge development.	Project partners are pressed to involve other actors in knowledge production.
	Project resources structure interactive knowledge development resulting in a narrowed scope for interactive knowledge development.
	Project-level actor relationships affect the actor that is the main knowledge producer.
	Sharing responsibilities at the project level supports interaction rules for interactive knowledge development.
Within knowledge arrangement: mechanisms that *explain,* or provide more detail on, interactive knowledge development.	Actors hold different perspectives, which results in differing contributions during the process of interactive knowledge development.
	Easily understood knowledge supports contributions by non-experts.
	Professional facilitation smoothes the process of interactive knowledge development.
	Actors are excluded during one or more interactive knowledge development activities.
From knowledge arrangement to project arrangement: mechanisms that specify the *consequences* of interactive knowledge development.	Support for solutions broadens through interactive knowledge development.
	Feasibility of solutions improves through interactive knowledge development.
	Interactive knowledge development consumes more time than expected.

The mechanisms include three main findings. First, how a project is organised affects the process of interactive knowledge development. The resources of key actors narrow the scope for knowledge production. When responsibilities are shared between project partners, a setting is created in which knowledge can be interactively developed. Second, the differing perspectives of participating actors require a particular process for knowledge development. Facilitation is needed to ensure that differing contributions are heard and clarified. Easily understood knowledge ensures that non-experts can also participate in interactive knowledge development. The partial exclusion of some actors is not fatal as long as they can voice their concerns and criticisms regarding the developed knowledge. Lastly, it is vital to address such concerns and criticisms if one is to come to a shared understanding. Addressing concerns requires additional meetings and research. However, this may result in changes that improve the feasibility of the developed solutions and may also increase societal support since critical actors may come to accept the developed knowledge. This requirement for additional meetings and research results in interactive knowledge development consuming more time and budget than 'basic' research.

5.6. Discussion

Given the importance of interactive knowledge development in turning knowledge into action, the objective of this paper was to provide a systematic understanding of interactive knowledge development. The cross-case analysis resulted in eleven mechanisms that explain how knowledge is interactively developed in coastal projects. The question then is, to what range of scenarios do the mechanisms apply? In the studied projects, knowledge was interactively developed for coastal solutions that were attempting to balance human needs, in terms of flood control and public access, with environmental concerns linked to nature restoration. The mechanisms would therefore seem likely to apply to situations where knowledge is being interactively developed for sustainable, multifunctional coastal solutions. As such the mechanisms are applicable to coastal zones where a high human dependency on the coastal space and resources (Weinstein et al., 2007) puts pressure on coastal projects to combine various functions in sustainable solutions. Further research could provide greater insight into the range of institutional contexts where the mechanisms might apply. This paper has shown that the mechanisms function in the institutional contexts of the Netherlands and the USA. The remainder of this section discusses the implications of our study for turning knowledge into action for sustainable coastal development.

The generic mechanisms provide three key contributions to the debate on interactive knowledge development. The contributions focus on the motive to organise interactive knowledge development, the role of exclusion as an intrinsic characteristic and the absence of boundary organisations. Together, these three contributions reveal gaps in the idealised arguments for interactive knowledge development.

First, we saw that practitioners involved a diversity of actors in knowledge production because of their goal of implementing coastal solutions. This contrasts with theoretical arguments for incorporating knowledge that is widely distributed across society (Cornell et al., 2013; Gibbons et al., 1994; In 't Veld, 2010), or motives that address conflicting coastal interests and major knowledge uncertainties (Clarke et al., 2013; Hanger et al., 2013; Schmidt et al., 2012; Tribbia and Moser, 2008). Thus, these theoretically promoted motives neglect the practical considerations of project managers who involve other actors since they might otherwise obstruct the implementation of developed solutions.

Second, the cases show that exclusion is intrinsic to interactive knowledge development since only a limited group of actors is involved. These are the policymakers who hold relevant formal responsibilities, other well-organised stakeholders who can attend the many meetings during the process of knowledge production and researchers who are hired to conduct research in relation to the project. Moreover, a dependency on the resources of key actors structures what can, and cannot, be investigated. These exclusions seen in practice contrast with theoretical arguments about involving the broadest possible coalition of actors and using collective problem framing (Cornell et al., 2013; Hegger et al., 2012; Lang et al., 2012; Roux et al., 2006). This paper shows that while exclusion can result in fierce criticism, that this criticism can be addressed through additional research. Thus, the role of exclusion cannot be ignored in processes of interactive knowledge development.

Third, in all the three projects studied, the boundaries between research and decision-making were spanned by individuals in their roles as project managers and facilitators. This contrasts with the literature that considers the use of boundary organisations as an effective approach for mediating between research and decision-making (Cash et al., 2003; Guston, 2001; McNie, 2007). Rather, this paper has shown that facilitation is also needed among policymakers and stakeholders to ensure that participating actors support the developed knowledge. Consequently, key boundary spanning individuals might be better equipped for this task than boundary organisations, at least in the setting of coastal projects.

Although the previous three paragraphs question the accepted theoretical perspective, we are not disputing that interactive knowledge development is an effective approach for turning knowledge into action. The three projects studied show how interactive knowledge development enhances societal support and the feasibility of developed solutions. Consequently, potential barriers to implementation are lowered or removed and the cases therefore confirm the significance of interactive knowledge development for turning knowledge into action (Cash et al., 2003; Cornell et al., 2013; Lang et al., 2012; Van Kerkhoff, 2013; Van Kerkhoff and Lebel, 2006). Further, our analysis supports the view that interactive knowledge development consumes time (Hanssen et al., 2009; McNie, 2007; Roux et al., 2006) since differing perspectives have to be bridged and criticisms addressed. Although this might consume significant time, it still represents an effective approach when seeking solutions that balance human needs with environmental concerns in a coastal zone. An alternative approach to this consensus-seeking process is to develop knowledge in a polarised setting with competing knowledge coalitions. However, knowledge will then be developed for vested interests (Turnhout et al., 2008; Van Buuren and Edelenbos, 2004) resulting in contested knowledge claims and public controversies (Martin and Richards, 1995). Such a setting is less effective for turning knowledge into action than interactive knowledge development because differences are reinforced rather than bridged.

The generic mechanisms identified contain four recommendations for creating a setting in which knowledge can be interactively developed. First, the project partners should share responsibility for project outcomes since this encourages a setting in which consensus is sought during knowledge production. Second, a professional facilitator should be hired, to ensure that the differing views and contributions are heard and clarified. Third, although coastal zones are complex from the physical, biological and social perspectives, knowledge should be made easily understandable so that non-experts can contribute to interactive knowledge development. This participation of non-experts can be eased through using visualisations and qualitative analyses of coastal systems and the impacts of proposed solutions. Finally, although actors may become excluded, their concerns and criticisms should be actively addressed. Thus, overall, interactive knowledge development requires additional resources and careful project management to ensure that relevant actors can participate since this will lead to developed solutions with wider support.

Based on this study, we propose further research that functions as opportunities for sustainability scientists to engage with practitioners in addressing real-world problems related to sustainable development. The practice-oriented understanding of interactive knowledge development can be strengthened by testing the identified generic mechanisms in other coastal projects and in differing institutional contexts. Do they still function in accordance with Table 5.5, or do different mechanisms contribute to similar outcomes? In addition, the requirements and limits of interactive knowledge development could be further studied by focusing on the requirements for and outcomes of interactive knowledge development. How much more time and costs are consumed in meetings and additional research through developing knowledge interactively compared to 'basic' research? Are these investments repaid through a quicker implementation, or does it merely result in muddling through? Further, domains other than coastal zones could be studied to explore how interactive knowledge development functions elsewhere. This research could study projects that are focused on local transitions to sustainability in areas such as water management, agriculture, energy, nature conservation, health and poverty reduction.

We started this paper by linking interactive knowledge development with turning knowledge into action for sustainable development. A major implication of our study is that we reveal gaps in the theoretical understanding of interactive knowledge development, although we do show that interactive knowledge development is effective in informing actions for sustainable coastal development. Thus, interactive knowledge development still represents a valuable approach for practitioners and researchers seeking sustainable development solutions. Through this study, we hope to reshape current thinking on turning knowledge into action by encouraging research that focuses on and contributes to, practitioners addressing the day-to-day challenges of sustainable development.

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Chapter 6. Conclusions and discussions

The prime motivation for this study has been the limited understanding of interactive knowledge development and more specifically interactive knowledge development as an approach to respond to complex coastal problems. A sustainable future of the coastal environment is severely at risk since the world's coasts are deteriorating while human dependence on coastal space and resources continues to increase. Seeking solutions for coastal development is challenging as coastal problems are complex. The problems evolve around multiple interests, are difficult to understand and become even more complicated due to knowledge uncertainties in climate change and sea level rise. Given this complex reality, the knowledge of researchers is not sufficient to respond to complex coastal problems. Instead, various researchers have argued that knowledge should be developed in interaction between researchers, policy makers and other societal actors. Such interactive knowledge development may produce research that is relevant to coastal decision-makers (Van Koningsveld, 2003), anchor coastal solutions in society (Schmidt et al., 2012) and develop the coastal zone more sustainably (Weinstein et al., 2007).

Worldwide, coastal projects attempt to address complex coastal problems by constructing solutions that range from flood protection to port expansion and nature restoration. However, conceptual and empirical research is limited on interactive knowledge development in the engineering project environment (e.g. Edelenbos et al., 2011; Van Buuren and Edelenbos, 2004; Hartmann and Dewulf, 2011). In addition, various knowledge production concepts have been developed such as Mode 2 knowledge and post-normal science. Yet these concepts are too general and prescriptive. Consequently, interactive knowledge development in coastal projects remains a black box. This is problematic since it is seen as an approach to deliver relevant knowledge for solving complex coastal problems. Therefore, it remains unclear how interactive knowledge development functions in coastal projects and to what extent it may result in improved solutions for coastal problems. As a result, the objective of this study has been to explore how interactive knowledge development functions in the setting of coastal projects.

This study explores how interactive knowledge development functions in coastal projects in the Wadden Sea (Chapter 2), San Francisco Bay (Chapter 3) and the Ems estuary (Chapter 4). The cross-case analysis (Chapter 5) integrates the empirical findings of these case studies. The insights of the entire study are integrated in this chapter, which is organised in six sections. Section 6.1 presents the conclusions on the formulated research questions. Section 6.2 discusses the contributions to science and Section 6.3 contains the contributions to methodology. Section 6.4 covers the limitations of this study. Section 6.5 provides an outlook for further research on interactive knowledge development. Section 6.6 presents recommendations for practitioners to facilitate interactive knowledge development.

6.1. Conclusions

In Chapter 1 two questions are posed about the analysis and functioning of interactive knowledge development in coastal projects. I will now discuss the main conclusions for these questions.

6.1.1 Analysis of interactive knowledge development in coastal projects

The first research question is 'How can a process of interactive knowledge development be analysed in coastal projects?'

I have introduced and developed the concept of interactive knowledge development. Interactive knowledge development was defined as a participative form of knowledge production in which knowledge is shared and developed by using the perspectives of key actors (researchers, policy makers, stakeholders) involved in the complex problem being studied to develop relevant solutions for the problems defined in the project. Interactive knowledge development was analysed through the framework of project arrangements and knowledge arrangements in coastal projects in the Wadden Sea, San Francisco Bay and the Ems estuary. By analysing the interplay of a project and knowledge arrangement, case-specific mechanisms were developed that explained interactive knowledge development. These mechanisms were transformed into generic mechanisms in the cross-case analysis. In addition to the mechanisms, theoretical conditions were developed for achieving socially robust knowledge in coastal projects. Based on this analysis of interactive knowledge development the following conclusions are drawn.

The operationalisation of interactive knowledge development has developed from a conceptual framework to a set of eleven mechanisms that explain how interactive knowledge development functions in the setting of coastal projects. The project and knowledge arrangements separate the context of application from the process of knowledge production. The project arrangement focuses on the coastal project that aims to implement a solution whereas the knowledge arrangement captures the process of interactive knowledge development for a particular solution. Both the concept and the framework are developed to analyse interactive knowledge development without specifying who should be involved in which activity or how actors should interact with each other while developing knowledge. These specifications are created through practices of interactive knowledge development in the case studies. Consequently, the case studies define the concept of interactive knowledge development by analyses of the project and knowledge arrangement and case-specific causal mechanisms. The cross-case analysis has produced a set of eleven generic mechanisms that explain how interactive knowledge development functions in coastal projects.

The conceptual framework and the inductively derived causal mechanisms supplement each other in the analysis, resulting in a 'deeper' understanding of interactive knowledge development. The framework breaks down the process of interactive knowledge development into the arrangement dimensions -actors, rules, resources and discourses- and the activities in knowledge production –problem formulation, selection of methods, interpretation of results and choice of solution. These dimensions and activities provide structure in the analysis of interactive knowledge development in coastal projects, resulting in descriptions of the project and knowledge arrangements. The causal mechanisms provide a deeper explanation about the functioning of interactive knowledge development. For instance, the arrangements in the Texel case discuss who were involved in the interactive knowledge development for a seaward solution. The set of mechanisms explains why some actors were included and others excluded during knowledge production. Consequently, the conceptual framework is used to structure the analysis of interactive knowledge development into project and knowledge arrangements. The mechanisms are inductively derived from the case-specific project and knowledge arrangements.

The causal mechanisms open the black box of interactive knowledge development in coastal projects. The abstract and complex process of interactive knowledge development is decomposed into a set of mechanisms that explain how interactive knowledge development functions in coastal projects. The mechanisms reveal linkages between causes and effects that contribute to the process of interactive knowledge development. The mechanisms-based explanations have improved over the course of this study. The mechanisms in Chapter 2 and 3 are case-specific whereas Chapter 5 provides case-generic mechanisms. In addition, the explanations offered by the mechanisms became more accurate. The case-specific mechanisms offer two types of explanations, whereas the generic mechanisms offer three types of explanations. These are the structural factors in the project that impact interactive knowledge development, the actor dynamics that explain how differing contributions are aligned during a process of interactive knowledge development and the consequences of interactive knowledge development for the coastal project.

The theoretical conditions for achieving socially robust knowledge (developed in Chapter 4) provide a different type of analysis than the causal mechanisms. The conditions explain interactive knowledge development from the theory on socially robustness and boundary spanning whereas the mechanisms explain interactive knowledge development through practices in coastal projects. The theoretical conditions stipulate how social robustness can be achieved through boundary spanning activities in the project and knowledge arrangement. The conditions and mechanisms are both linked to the conceptual framework of project and knowledge arrangements. Therefore, the conceptual framework of project and knowledge arrangements can be employed for theory-based and practice-based research on interactive knowledge development in the engineering project environment.

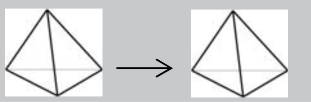
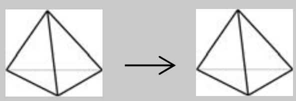
Lastly, the framework of project and knowledge arrangements provides an understanding about interactive knowledge development in terms of actors and their coalitions, rules of the game, allocation of resources and discourses. By applying the framework, an understanding arises on how to organise interactive knowledge development in terms of actors, interaction rules and required resources. This arrangement-based understanding provides clear recommendations to those who want to organise interactive knowledge development. Section 6.6.1 presents such recommendations for coastal projects.

6.1.2 Functioning of interactive knowledge development in coastal projects

The second research question is ‘How does a process of interactive knowledge development function in coastal projects?’

This study has provided case-specific and case-generic answers to this research question. The Texel case demonstrates how a process of interactive knowledge development could lead to different solutions then originally proposed. The South Bay salt pond case indicates that interactive knowledge development requires a careful separation of researchers, regulators and stakeholders. The Delfzijl case emphasises the iterative character of interactive knowledge development since researchers, project partners and stakeholders have differing interests and contributions. The common, deeper explanation for the functioning of interactive knowledge development is given by the generic mechanisms. They are derived in the cross-case analysis and explain the functioning of interactive knowledge development (see Table 6.1).

Table 6.1. Generic mechanisms explain the functioning of interactive knowledge development as an interplay between the project and knowledge arrangement.

Type of causal mechanism	Description
From project arrangement to knowledge arrangement: mechanisms that *affect* interactive knowledge development.  project arrangement → knowledge arrangement	Project partners are pressed to involve other actors in knowledge production.
	Project resources structure interactive knowledge development resulting in a narrowed scope for interactive knowledge development.
	Project-level actor relationships affect the actor that is the main knowledge producer.
	Sharing responsibilities at the project level supports interaction rules for interactive knowledge development.
Within knowledge arrangement: mechanisms that *explain,* or provide more detail on, interactive knowledge development.  knowledge arrangement	Actors hold different perspectives, which results in differing contributions during the process of interactive knowledge development.
	Easily understood knowledge supports contributions by non-experts.
	Professional facilitation smoothes the process of interactive knowledge development.
	Actors are excluded during one or more interactive knowledge development activities.
From knowledge arrangement to project arrangement: mechanisms that specify the *consequences* of interactive knowledge development.  knowledge arrangement → project arrangement	Support for solutions broadens through interactive knowledge development.
	Feasibility of solutions improves through interactive knowledge development.
	Interactive knowledge development consumes more time than expected.

The generic mechanisms provide a rich and detailed understanding on the functioning of interactive knowledge development in coastal projects since they explain how a range of processes contribute to interactive knowledge development. As they operate in all three cases (see Appendix VI), they are key in explaining the functioning of interactive knowledge development in coastal projects. Based on these mechanisms the following four conclusions are drawn about the functioning of interactive knowledge development in coastal projects.

(1) Interactive knowledge development is characterised by a close connection between the project arrangement and knowledge arrangement. Both the project and knowledge arrangement contribute to a process of interactive knowledge development. The mechanisms show that decisions in the project arrangement directly impact a process of interactive knowledge development. Resources of key-actors structure the scope for knowledge production, actor relations in the project affect the main knowledge producer and the interaction rules for interactive knowledge development are set in the project arrangement. In addition, the consequences of interactive knowledge development clarify why the process of knowledge production impacts project decision-making. When the developed knowledge results in difficulties in terms of societal support or feasibility, actions are undertaken by actors in the project since criticism and unfeasible solutions may hinder the construction of coastal solutions.

(2) Interactive knowledge development requires specific measures to align the contributions of participating actors. Project partners are pressed to involve other actors in interactive knowledge development. Such actors are involved as they may otherwise hinder the implementation of a coastal solution due to their formal responsibilities or their connection to funding. Responsibilities between project partners are shared to create a setting in which knowledge can be developed interactively. Facilitators and easily understood knowledge contribute to a shared understanding between researchers, policy makers and stakeholders. Yet conflict and exclusion might hinder the shared understanding. For instance, the Texel and Delfzijl case reveal how conflicts arise because actors are excluded and hold different values to what is important in the developed coastal solution. Conflict makes these values explicit and the differences might be overcome by additional meetings and follow-up research.

(3) Interactive knowledge development results in a specific type of knowledge, namely a feasible, broadly supported solution to solve a structured coastal problem. Although coastal problems are complex, they are narrowed down in a process of interactive knowledge development such that knowledge can be developed for a solution that solves the structured coastal problem. To ensure implementation, solutions should receive support from key actors that can hinder or facilitate construction of the coastal solution. Furthermore, solutions have to be feasible from a technical, regulatory and financial perspective. Interactive knowledge development enables a diversity of actors to contribute to these different aspects of feasibility. During interactive knowledge development, actors can share their criticism and concerns for the developed solution. Societal support and feasibility increase when they are addressed. For instance in the South Bay salt pond case, the regulators had concerns about permitting dredging operations for nature restoration. The project partners addressed these concerns and changed the proposed dredging operations such that the feasibility for the restoration solutions improved.

(4) The improvements in feasibility and societal support come at a price of consuming substantial more time and financial resources since the improvements are generated by additional meetings and follow-up research. These additional investments are needed to respond to concerns and criticism of participating actors in interactive knowledge development.

Consequently, interactive knowledge development may not end after the first study is completed. Instead it is an iterative process that may need various modifications before the knowledge is shared and supported by all actors in the coastal project. The case studies suggest that this may consume 30 to 40% extra time. In the Texel dike reinforcement project, a follow-up study – costing 32% of the previous study- was undertaken to address the concerns of the Texel based organisations. In the Delfzijl spatial development project one research institute spent 40% more time than originally budgeted due to the many meetings and additional research.

In addition to the mechanisms, theoretical conditions are developed for achieving socially robust knowledge. The conditions offer an additional conclusion on the functioning of interactive knowledge development in coastal projects. Namely, the capacities of boundary spanning individuals and the application of boundary objects are vital in achieving socially robust knowledge. Various organisational boundaries have to be spanned to obtain consensus on the developed knowledge, since a range of actors participate in interactive knowledge development. Boundary spanning tasks are conducted by project managers and facilitators who oversee the developed knowledge and frequently meet with the various actors, ranging from researchers to governmental administrators, influential stakeholders and regulators. In addition, easily understood knowledge serves as a vital boundary object to ensure that researchers and non-researchers understand each other. A boundary object is instrumental in creating a shared understanding about the proposed plans and their impacts. The case studies present different boundary objects, ranging from a jointly developed sketch plan in Texel to qualitative restoration alternatives in San Francisco Bay and an assessment framework in Delfzijl.

The above conclusions are based on exploratory research. The functioning of interactive knowledge development was analysed in three very different coastal projects. Together, these three cases represent a most different research design since the projects differ in their institutional setting (The Netherlands and the USA) as well as in key aspects of project management (scope, finance, time). The results and conclusions of this study may be of relevance to other coastal projects since the findings are based on a most different research design but with identical processes of data collection and analysis in the three case studies.

The findings of this study are likely to apply to coastal projects where knowledge is developed interactively for sustainable, multifunctional coastal solutions since in each case study knowledge was interactively developed for a coastal solution that combines human needs (i.e. flood protection and coastal recreation) with environmental concerns of nature restoration. As such, both the mechanisms of interactive knowledge development and the conditions for socially robust knowledge may be applicable to coastal zones, where a high human dependency on the coastal space puts pressure on engineering projects to combine various functions in sustainable solutions. This study shows that the mechanisms and conditions could function in the contexts of the Netherlands and the USA. Due to the exploratory character of this study, further research is needed to provide more clarity on the specific circumstances and institutional contexts in which the findings may apply.

6.2 Scientific contributions

This study advances the conceptual and empirical understanding of interactive knowledge development (Section 6.2.1 and Section 6.2.2). In addition, the study clarifies the possibilities and limitations of interactive knowledge development for coastal decision-making (Section 6.2.3). Lastly, the study extends the applicability of the policy arrangement approach (Section 6.2.4).

6.2.1 An improved analysis of interactive knowledge development in the project environment

The framework of project and knowledge arrangements is developed to structure an analysis into processes of interactive knowledge development since key knowledge production concepts as Mode 2 knowledge and post-normal science are theoretical and prescriptive. The following three contributions improve the analysis of processes of interactive knowledge development.

First, in the conceptual framework of project and knowledge arrangements the process of knowledge production is separated from the context of application. Existing frameworks do not make this separation. They either focus on the context of application such as in knowledge governance (Van Kerkhoff, 2013), or, they do not separate the process of knowledge production from the context of application (Edelenbos et al., 2011; Hegger et al., 2012; Röling and Jiggins, 1998). Yet the separation of knowledge production and context of application is relevant in the light of the societal debate to open up processes of knowledge production (this debate is discussed in Chapter 1, Section 1.1.3). Many knowledge production concepts like Mode 2 knowledge and engaged scholarship claim that practitioners from the context of application should be involved in knowledge production. The framework of project and knowledge arrangements can substantiate these claims by analysing how actors from the context of application impact the knowledge production and whether such knowledge production indeed results in more practically relevant knowledge.

Second, the causal mechanisms are a first attempt to uncover the underlying mechanisms of interactive knowledge development. that explain the functioning of interactive knowledge development in coastal projects. Others have termed the underlying mechanisms of interactive knowledge development to be indirect and hard to discern (Hegger et al., 2012). This study is a first attempt to uncover them for coastal projects. Causal mechanisms link causes with outcomes in a process of interactive knowledge development (after Beach and Pedersen, 2013; George and Bennet, 2005). The mechanisms cover three sorts of causes. Namely, processes in the project arrangement that impact the knowledge arrangement, processes in the knowledge arrangement that have outcomes within the knowledge arrangement and outcomes of the knowledge arrangement that impact the project arrangement. The mechanisms were derived within each case study by iterating between the analysis of the project and knowledge arrangement, the conceptual framework for potential connections between arrangement dimensions and the drafted causal mechanisms that gave a first case-specific explanation. The mechanisms therefore explain the functioning of interactive knowledge development as a dynamic interplay between the project and knowledge arrangement. The eleven generic mechanisms explain how causes in project decision-making and interactive knowledge development contribute to three consequences (broader support, improved feasibility and consuming substantial more time).

Many of the individual mechanisms are in line with insights from other studies that focused on processes of interactive knowledge development. The insight that actors have different perspectives is central to why processes of knowledge production should be opened up to a variety of actors to develop knowledge of practical relevance (Gibbons et al., 1994; Van Buuren and Edelenbos, 2004). Detailed accounts exist of evolving actor relations during a process of interactive knowledge development (Edelenbos et al., 2011; Hartmann and Dewulf, 2011) and other studies discuss how facilitators contribute to a smoother process in interactive knowledge development (Bammer, 2013; Cornell et al., 2013; Wiek et al., 2012b). Furthermore, the point has been made that knowledge should be made easily understandable to non-experts (Edelenbos et al., 2011; Kirchhoff et al., 2013) and that interactive knowledge development consumes additional time (McNie, 2007; Roux et al., 2006).

Therefore, the main scientific contribution of the generic mechanisms is not found in their individual descriptions. Instead, the main scientific contribution is the explanation on the functioning of interactive knowledge development provided by the entire set of generic mechanisms. As a set, the mechanisms draw connections between structuring factors in project decision-making, the process of knowledge production and its outcomes for decision-makers. The mechanisms thereby connect different bodies of literature, thus advancing the analysis of interactive knowledge development. These bodies of literature focus on the governance of knowledge (Manuel-Navarrete and Gallopín, 2012; Van Buuren, 2009; Van Kerkhoff, 2013), research processes of knowledge co-creation and joint knowledge production (e.g. Edelenbos et al., 2011; Hegger et al., 2012; Wiek et al., 2012b) and the uptake or usability of knowledge (Nowotny et al., 2001; Cash et al., 2003). Furthermore, since the generic mechanisms operate in three very different projects, the understanding provided by the set of mechanisms moves beyond descriptive analyses and case-specific findings for interactive knowledge development in the engineering project environment (e.g. Hartmann and Dewulf, 2011; Edelenbos et al., 2011; Van Buuren and Edelenbos, 2004).

Third, the theoretical conditions clarify how boundary spanning efforts are instrumental in achieving social robustness. The connection between boundary spanning and social robustness is not made in the original aspects of social robustness (i.e. Nowotny et al., 2001; Nowotny, 2003). In addition, the conditions provide a more specific interpretation of key terms as socially robust knowledge and context of application. Therefore, the conditions facilitate an improved analysis into socially robust knowledge in coastal projects.

6.2.2 A practical understanding of interactive knowledge development in coastal projects

A prime reason to analyse interactive knowledge development in coastal projects was to come to a more practical understanding of practices of interactive knowledge development. This practical understanding is needed since researchers and practitioners struggle to develop knowledge interactively, despite initiatives in science and society to open up processes of knowledge production. This study contributes in three ways to a more practical and realistic understanding of interactive knowledge development in coastal projects.

First, a pragmatic motive drives the actors in coastal projects to organise interactive knowledge development. In all three cases, project managers and policy makers involved others in knowledge production to avoid that these actors would later hinder the implementation of coastal solutions. This contrasts with theoretical arguments used in concepts like Mode 2 knowledge and engaged scholarship since these concepts claim that interactive knowledge development is needed to produce practically relevant knowledge. An implication of this pragmatic motive is that it may be quite difficult to organise processes of interactive knowledge development in coastal projects. That is, project managers might not take the extra effort to develop knowledge interactively when they expect no hindrances in implementation of the coastal solution.

Second, this study shows how power and exclusion are intrinsic to interactive knowledge development. Flyvbjerg (1998) discusses how power defines what counts as knowledge and how knowledge results in power. Yet such a power perspective is mostly absent for interactive knowledge development as authors conceive interactive knowledge development as a collaborative endeavour between researchers and other actors (Armitage et al., 2011; Hegger et al., 2012; Pohl et al., 2010). This study provides another perspective, since the resource-dependencies of key actors structure the problem for which knowledge is developed, thereby excluding problem frames of other actors. In addition, a relative narrow group of actors is involved in knowledge production: governmental organisations who hold formal responsibilities relevant to the project, researchers and consultants hired by the project organisation and well-organised stakeholders who can attend multiple meetings over the course of the project. Further, actors are excluded during activities of knowledge production by the project organisation.

Third, this study gives a first estimate of the costs and benefits of interactive knowledge development. Interactive knowledge development enhances societal support and feasibility for the developed coastal solutions. Yet this study shows that this comes at the price of extra meetings and additional research to respond to concerns of participating actors. The cases show that this extra effort may consume 30-40% more time when compared to 'basic research' (i.e. researchers conducting research in relative isolation from the coastal project). Although this time-consuming aspect of participatory modes of knowledge production is highlighted by some (Hanssen et al., 2009; McNie, 2007; Roux et al., 2006), estimates are not given how much more time or budget is consumed. This cost estimate implies there is a considerable price to pay for interactive knowledge development. The price may be acceptable as feasibility and societal support might increase for the developed coastal solutions.

6.2.3 Knowledge production and uptake in coastal decision-making

Interactive knowledge development offers an approach to respond to coastal problems since it results in increased societal support and feasibility of the developed coastal solutions. This study advances the understanding on knowledge production and uptake for coastal decision-making in three ways.

This study indicates that interactive knowledge development is a promising approach to respond to complex problems. The approach is promising for coastal decision-makers since it results in increased societal support and feasibility of developed coastal solutions. These two outcomes are relevant for coastal decision-makers, since they are confronted with knowledge uncertainties and conflicting interests when responding to complex coastal problems. In addition, the study emphasises the limitations of interactive knowledge development. Only a limited group of actors is involved in interactive knowledge development, of which some are excluded during one or more activities. Further, the complex problems for which knowledge is developed are structured by resources of key actors, thereby excluding other problem frames. Finally, interactive knowledge development consumes substantial more time than basic research. Clarifying the possibilities and limitations of interactive knowledge development is a major contribution to the debate of interactive knowledge development for the coastal zone. Existing studies offer either reflections without empirical support (e.g. Bremer and Glavovic, 2013; Weinstein et al., 2007) or empirical insights from one institutional setting (Bruckmeier and Glavovic, 2013; Schmidt et al., 2012).

In addition, this study contributes to an improved theoretical understanding of interactive knowledge development for coastal decision-making in engineering projects. The generic mechanisms and the project and knowledge arrangements represent a middle-range theory which moves beyond case-specific explanations for interactive knowledge development in coastal projects. A middle-range theory applies to a specified subclass of a general phenomenon (George and Bennet, 2005). When built on causal mechanisms, a middle-range theory describes causal mechanisms that are generalisable outside the individual cases yet bound within specific contexts (Beach and Pedersen, 2013). The middle-range theory developed in this study explains the functioning of interactive knowledge development in coastal projects through the interplay between the project and knowledge arrangement. This interplay is explained by eleven mechanisms (see Table 6.1 for an overview). The mechanisms cover three sorts of processes that determine the interplay: the structural factors in the project that impact interactive knowledge development, the actor dynamics that explain how differing contributions are aligned during a process of interactive knowledge development and the consequences of interactive knowledge development for the coastal project. This middle-range theory might be applicable to coastal zones where a high human dependency on the coastal space puts pressure on engineering projects to combine various functions in sustainable solutions.

6.2.4 Extend the applicability of the policy arrangement approach

This study extends the applicability of the policy arrangement approach in two ways.

First, the analysis of arrangements that conceptually differ is novel and has not been done before. Whereas the project arrangement focuses on project decision-making, the knowledge arrangement analyses how knowledge was developed interactively for a proposed solution. Analysing conceptually different arrangements enabled a separation of the research topic (i.e. practices of interactive knowledge development) from the coastal project as context of application. The separation results in two sorts of analyses. One analysis focuses on the stability and dynamics within the arrangements, the other on the interplay between the two arrangements.

Second, the policy arrangement approach is applied to the engineering project environment. Although the purposes of knowledge production differ between an engineering project and a policy domain, namely constructing engineered solutions versus implementing policies, this study has shown that coastal projects can be analysed in terms of actors, rules, resources and discourses. This study adds to the growing body of research that adopts the policy arrangement as an analytical framework to analyse the institutionalisation of arrangements at a different level than the policy domain. The policy arrangement approach has been used to pursue a variety of research interests. These research interests range from marine infrastructural projects (Korbee and Van Tatenhove, 2013), to joint knowledge production in research projects (Hegger et al., 2012), to interacting knowledge arrangements of different policy fields in greening flood protection (Janssen et al., 2014) and the impact of marine governance on the authority of nation states (Van Leeuwen, 2010).

6.3 Methodological contributions

Interactive knowledge development is analysed qualitatively through a structured approach consisting of six steps (see Figure 1.4, Chapter 1). This structured approach makes two contributions to methodological debates in coding and theory building from causal mechanisms.

6.3.1 The incompleteness of existing coding approaches

Exploratory case study research that starts the analysis with a well-defined framework is confronted by the incompleteness of existing coding approaches of template coding and grounded theory. The template coding approach is incomplete since the coding template cannot create new codes to cover aspects that are in the template (Crabtree and Miller, 1999; Miles and Huberman, 1994). Thus it cannot handle the exploratory aspect of this study. Similarly, grounded theory does not offer an applicable coding approach since researchers start their analysis unbiased and neutral (Glaser and Strauss, explained in Boeije, 2010).

Due to this incompleteness, I have developed a template coding approach that relies on deductive and inductive reasoning through the three coding rounds of template coding, axial coding and selective coding. Although the analysis starts from the coding template new codes can be attached to text fragments in the axial coding round. This axial coding allows for inductive reasoning and new codes, such that the coding template does not dominate the qualitative analysis. This modified template coding approach is a clear methodological contribution since it offers a coding approach for case study researchers who have an exploratory objective, rely on a conceptual framework and analyse their data qualitatively.

6.3.2 Develop theory from case-specific mechanisms

The structured approach for analysing interactive knowledge development in coastal projects addresses the ‘division of labour’ between methodologists in qualitative data analysis and methodologists focusing on theoretical explanations through qualitative research (Gläser and Laudel, 2013). Gläser and Laudel observe a division of labour as methodologists who focus on qualitative data analysis are rather vague about the outcomes of such an analysis (e.g. Boeije, 2010). Similarly, methodologists who focus on theoretical explanations from case studies do not formulate requirements for data analysis (e.g. George and Bennet, 2005). The division results in a limited methodological understanding how qualitative data analysis can lead to theoretical explanations as only few researchers address this connection (e.g. Eisenhardt, 1998).

This study provides an example how qualitative analysis leads to a middle range theory of generic mechanisms. This connection between qualitative analysis and mechanisms is novel and marks a contribution to the methodological debate. The following claims illustrate the relevance of this contribution. According to Gläser and Laudel it is unclear “how to identify social mechanisms from descriptions of social phenomena provided in the texts we analyse” (Gläser and Laudel, 2014, paragraph 15). Similarly, Beach and Pedersen (2013) claim that there are no studies that inductively build a midrange theory of causal mechanisms from case studies. The middle range theory on interactive knowledge development in coastal projects was derived inductively since the generic mechanisms are grounded in the individual case studies and not predefined by a theory on knowledge production.

6.4. Limitations of the study

The main interest of this study is the functioning of interactive knowledge development in coastal projects. This section clarifies what cannot be determined from the findings presented in this study.

6.4.1 The framework of project arrangements and knowledge arrangements

The framework of project arrangements and knowledge arrangements analyses interactive knowledge development as an interplay of both arrangements. Actors are analysed at the organisational level since organisations have specific responsibilities and interests in relation to a coastal project. In addition, each organisation has resources in terms of budget and information. Individuals were conceived as represents of their organisation during data collection. Other individual aspects then boundary spanning capacities are therefore excluded from the analysis.

The analysis of interactive knowledge development focuses on the interplay between one project arrangement and one knowledge arrangement. The findings on interactive knowledge development are derived from coastal projects in different institutional contexts. The impact of a different institutional context is not explored in this study since the cross-case analysis focused on generic mechanisms that explain the functioning of interactive knowledge development. As a result, cultural aspects that may enable or constrain processes of interactive knowledge development are not addressed. Similarly, it cannot be determined whether other developments have impacted interactive knowledge development. For instance, how relations between government, science and society have developed at the national level. Although these institutional impacts on interactive knowledge development are not explored, the mechanisms reveal within coastal projects a generic explanation for interactive knowledge development.

The project arrangement captures the context of application for which knowledge is developed. Knowledge is considered to be socially robust when all actors in the project arrangement accept the developed knowledge. However, I cannot determine how actors that are not involved in the project evaluate the developed knowledge and associated solution. For instance, whether restoration scientists in a different country agree with the developed solutions, or if developed solutions can count on support of globally operating NGOs. Consequently, the robustness of the developed knowledge is relative and relational, as it refers to acceptance of actors in the project arrangement. Therefore, socially robust knowledge does not fit in philosophical standpoints of Habermas that validity claims should be universal (Flyvbjerg, 2001). Instead, socially robust knowledge relates to the contextual standpoint of Foucault, to address 'problems that are as concrete and general as possible' (cited in Flyvbjerg, 2001; p. 101).

The conceptual framework makes a conceptual distinction between a project arrangement and knowledge arrangement. The difference between a project and knowledge arrangement is expected to be observable in terms of actors, rules, resources and discourses. When there is much overlap, it becomes more difficult to make the conceptual distinction. For instance the analysis of the San Francisco Bay nature restoration project reveals much overlap in the dimensions of actors, rules and resources (information). Nonetheless, a distinction can be made by focusing on the four activities of knowledge production for the particular solution. This results in a knowledge arrangement that is more specific than the entire project arrangement since knowledge production is one of the activities in project-decision making. In addition, actors, resources (information) and legislation may be specifically related to a knowledge arrangement since they are linked to the geographical location of a proposed solution. In the San Francisco Bay nature restoration project, the knowledge arrangement could be separated from the project arrangement since the knowledge arrangement had a more narrow discourse, two new actors (the consultant team and the City of Mountain View) and resources and legislation that were linked to the proposed solution.

6.4.2 Drawing conclusions from a multiple case study

The multiple case study advances the empirical understanding on interactive knowledge development. However, the multiple case study method also restricts the findings of this study in two ways.

First, cases were selected for their attempts to develop knowledge interactively. The qualitative analysis has produced mechanisms that explain how interactive knowledge development functions when knowledge is interactively developed for coastal solutions. I cannot determine whether the mechanisms apply to other types of interactive knowledge development. These types may cover monitoring, modeling, policy evaluation, or scenario analysis of an uncertain future. Similarly, it cannot be determined whether the mechanisms apply to other types of engineering projects that develop multifunctional solutions.

Second, case-specific mechanisms were eliminated in the cross-case analysis when they were not operating in each case. Despite eliminating the case-specific mechanisms, I cannot claim that the case-generic mechanisms are necessary or sufficient conditions to produce the outcomes of interactive knowledge development. Another case might show that if one mechanism is absent, interactive knowledge development would still take place. This would prove that the mechanisms are not necessary. Alternatively, another case might show that the case-generic mechanisms are present yet that the outcomes of interactive knowledge development do not occur. This would demonstrate that the mechanisms are not sufficient and other mechanisms explain interactive knowledge development. Although the mechanisms are neither sufficient nor necessary, they do cover a diversity of processes that contribute to interactive knowledge development and operate in three different cases and institutional contexts. Therefore, the mechanisms offer an insightful explanation for the functioning of interactive knowledge development in coastal projects.

6.4.3 Developing causal mechanisms in case studies.

The causal mechanisms that were derived in this study explain the functioning of interactive knowledge development in coastal projects. The insights offered by the causal mechanisms are limited in three ways.

First, this study cannot identify one major overarching causal mechanism that links the causes and outcomes of interactive knowledge development in a coastal project. Given the research interest of interactive knowledge development, causal mechanisms were identified that are directly linked to the process of interactive knowledge development. Throughout this study, the causal mechanisms are discussed as individual mechanisms in the framework of project and knowledge arrangements. Each mechanism represents a linkage between a cause and an outcome that is directly related to the process of interactive knowledge development (after Beach and Pedersen, 2013; George and Bennet, 2005). This resulted in three different types of causal mechanisms: (1) mechanisms that discuss causes in the project arrangement that result in outcomes for the knowledge arrangement, (2) mechanisms that discuss causes and outcomes within the knowledge arrangement, and (3) mechanisms that conceive interactive knowledge development as cause to which outcomes are connected for the project arrangement. These types of mechanisms can be linked to a typology of social mechanisms (Beach and Pedersen, 2013; Hedström and Ylikoski, 2010). The first type represent *situational mechanisms* that link social structures to individuals actions, thus from the project arrangement to the knowledge arrangement. The second type represents *action-formation mechanisms* that discuss actions on the micro level that is within the knowledge arrangement. The third type represents *transformational mechanisms* that specify the mechanisms by which individuals through their actions and interactions in interactive knowledge development generate intended and unintended social outcomes; thus taking the knowledge arrangement as a cause and discussing the outcomes of the knowledge arrangement for the project arrangement. Consequently, since the mechanisms represent different types of mechanisms, it is not possible to determine one overarching mechanism that explains the functioning of interactive knowledge development.

Second, the generic mechanisms lack a particular spatial and temporal context in which they operate since they provide explanations that apply to the three studied coastal projects. The spatial and temporal context of the case-specific mechanisms of Chapter 2 and 3 is replaced by generic mechanisms that operate across three cases. This resulted in one mechanism in which the cause and effect is not clearly articulated. That is the mechanisms of actor exclusion that states 'Actors are excluded during one or more interactive knowledge development activities'. The case studies in the Wadden Sea and the Ems estuary revealed that exclusion resulted in fierce criticism from excluded actors. Yet the San Francisco Bay case revealed a different type of exclusion, that of involving other actors after the main directions have been set. Therefore, the generic mechanism on exclusion is missing a clear consequence and merely states that exclusion is an element of interactive knowledge development.

Third, this study cannot identify the dominance of one causal mechanisms over the other since exploratory case studies can only identify causal mechanisms (George and Bennet, 2005; Gerring, 2007). Consequently, it cannot be stated which mechanism has a larger impact on the functioning of interactive knowledge development. Instead, the mechanisms reveal how a set of causes in the project and knowledge arrangement contribute to three consequences of interactive knowledge development in coastal projects. Therefore, the mechanisms are throughout this study grouped in the type of explanation they offer, instead of trying to assess their relative importance.

6.5 Outlook for research

This study has advanced the understanding on interactive knowledge development by revealing how it functions in the coastal project environment. Below I propose three research topics to come to a better understanding of the implications and potential applicability of interactive knowledge development.

The role of consensus and conflict in interactive knowledge development could be further studied. Although conflict and consensus might seem incompatible, this study has shown that both are part of interactive knowledge development eventually resulting in solutions that are supported by all actors in the project. This study suggests that a facilitator, easily understood knowledge and frequent informal contacts are vital in achieving consensus. Yet consensus might not be achieved since knowledge production can also lead to major disagreement and knowledge fights (e.g. Van Buuren and Edelenbos, 2004). The challenge is to manage the conflicts during interactive knowledge development as constructive conflicts (Cuppen, 2012). Further research might explore how this is achieved.

The understanding of costs and benefits of interactive knowledge development can be strengthened by future research. Although interactive knowledge development results in increased societal support and feasibility for coastal solutions, it also consumes more time than basic research due to additional meetings and follow-up research. Evaluative research may indicate whether investments in interactive knowledge development in the planning phase are repaid by a quicker implementation since solutions are feasible and supported in society. Or alternatively, whether interactive knowledge development results in a muddling through; where knowledge is developed that does not lead to decision-making since concerns of participating actors are endlessly addressed through additional studies. Further, other types of interactive knowledge development could be studied to explore the costs and benefits of interactive knowledge development in modelling, monitoring and management, policy evaluation and scenario analysis.

Lastly, projects in other domains could be studied to strengthen the understanding on interactive knowledge development in relation to sustainable development. The topic of turning knowledge into action for sustainable development is usually analysed from the perspective of researchers, by analysing how research programs and science projects attempt to develop knowledge interactively (e.g. Hegger et al., 2012; Wiek et al., 2012b). I have approached this topic from the practitioners side, by focusing on knowledge production initiated by practitioners in the context of coastal projects. This study shows the value of this perspective, since interactive knowledge development results in coastal solutions that combine human needs with environmental concerns. Further research may explore whether similar outcomes are achieved by projects in the domains of water management, nature restoration, agriculture and forestry. These projects operate in a setting that is similar to coastal projects since they are confronted with complex environmental problems, strike a balance between human needs and environmental concerns and operate in a network where actors hold potentially conflicting interests in relation to project solutions.

6.6 Recommendations for practitioners

A key insight of this study is that *if* organisations aim to develop knowledge interactively it will require a different process than basic research. Consequently, organisations should not approach interactive knowledge development as 'business as usual'. Therefore, I discuss recommendations to facilitate interactive knowledge development (also known as knowledge co-creation, joint fact finding, joint knowledge production). The term practitioners is broad as it ranges from those involved in interactive knowledge development in coastal projects (Section 6.6.1) to research institutes and engineering firms (Section 6.6.2) to the Dutch government, knowledge co-creation experts and directors of research programs (Section 6.6.3).

6.6.1 Organise interactive knowledge development to respond to complex coastal problems

This study has clarified for coastal decision-making the possibilities (e.g. enhanced societal support and feasibility) and limitations (e.g. exclusion of actors and problem frames) of interactive knowledge development. In order to strike a balance between these possibilities and limitations, I recommend that practitioners consider the following aspects when aiming to organise a process of interactive knowledge development in a coastal project:

- Share responsibilities for project outcomes since that encourages a setting in which a variety of actors can share their knowledge and develop new knowledge in interaction.
- Involve those organisations that can facilitate or hinder the implementation of the coastal solution since interactive knowledge development enables them to share their concerns and criticism.
- Hire a facilitator who acts as mediating actor and aligns perspectives of participating organisations, or, who makes the differences between participating organisations explicit.
- Develop easily understood knowledge to ensure that non-experts comprehend the developed knowledge. In addition, it enables them to contribute their knowledge. Knowledge can be made easily comprehensible through visualisations and qualitative analyses of the (impact of) proposed solutions on the coastal system.
- Respond to voiced concerns and criticism by participating and excluded actors since that strengthens the feasibility and support of the developed solution. This could be done through additional meetings and follow-up research.

As a result of the above recommendations, interactive knowledge development might take more time than when coastal solutions are developed through basic research (i.e. researchers conducting research in relative isolation from the coastal project).

6.6.2 Offer interactive knowledge development as a distinct product

Main knowledge producers –like research institutes and engineering and consultancy firms- could offer interactive knowledge development as a distinct product to their clients. That reflects the insight of this study that there are clear benefits of interactive knowledge development, yet that this requires a different process with extra efforts when compared to basic research. In order to develop knowledge interactively, research institutes and consultancy firms may follow the recommendations mentioned in 6.1. In addition, they would need to adapt their cost estimates when offering interactive knowledge development since this study showed it may consume 30-40% more time than basic research. In the Netherlands, there is a demand for this distinct product since a variety of Dutch governmental institutions promote approaches that are similar to interactive knowledge development. For instance, the Delta programme promotes joint fact finding and Rijkswaterstaat emphasises the importance of co-creation. Other organisations like the Rathenau Institute and the national Environment Assessment Agency (PBL) advocate the co-creation of knowledge.

6.6.3 Anchor interactive knowledge development institutionally in the Netherlands

Since interactive knowledge development represents a different mode of knowledge production than basic research, existing institutions are not always well-equipped to create a setting where knowledge is interactively developed. By anchoring interactive knowledge development in institutions, it may become easier for practitioners to develop knowledge interactively. I therefore discuss three opportunities to anchor practices of interactive knowledge development institutionally.

First, the professional capacity for interactive knowledge development could be increased. This study shows that the contributions of researchers, policy makers and other societal actors are aligned during interactive knowledge development. The case studies of San Francisco Bay and Delfzijl emphasise how consensus building organisations are vital in aligning these different perspectives and contributions. Their skills and experience make it easier for various organisations to participate in a process of interactive knowledge development. Consequently, I recommend a professionalisation of knowledge co-creation experts. This professionalisation could help to spread best practices and learn from tough practices, thereby increasing the institutional capacity for interactive knowledge development. Professionalisation may increase through courses, symposia and the development of a professional code. The better trained the knowledge co-creation professionals are, the more likely knowledge co-creation can deliver its promise of developing knowledge that is practically relevant.

Second, research programs that aim for knowledge co-creation could take actions to involve practitioners and researchers in knowledge co-creation. A risk of knowledge co-creation is that knowledge becomes irrelevant or heavily criticised when actors exit a process of knowledge co-creation. The following two recommendations could decrease this risk. First, establish a firm connection between researchers and practitioners (i.e. those working in the context of application) prior to submitting research proposals. Practitioners will not participate in knowledge co-creation when they do not experience a need for new knowledge to solve their problems. A firm connection would signal a joint interest in knowledge co-production. Co-funding could contribute to co-creation since practitioners are more committed, resulting in an active participation in the research process. Second, set aside part of the research budget to ensure that all actors remain involved in knowledge co-creation from the beginning till the end. This study has shown that a variety of measures might be needed to achieve this. These measures are either needed to explore criticism and concerns of participating actors, or to ensure that non-experts can participate. Such measures could range from additional meetings and follow-up research to a facilitator and easily understood knowledge.

Third, regional funding systems could be initiated that promote multifunctional coastal solutions which are broadly supported in the coastal region yet difficult to fund from national funding sources. These funding systems could result in novel solutions that combine functions of for instance flood control, nature restoration, cultural heritage and public access. These funding systems create a setting for interactive knowledge development, especially when proposed solutions need the support of governmental organisations, NGO's and other local and private organisations. Such funding systems are in the Netherlands limited to the Wadden fund and the Dream Fund of the People's Postcode Lottery. Similar kinds of funding systems could result in coastal solutions that are more sustainable since combinations can be made between human needs and environmental concerns, serving the interests of multiple organisations. Revenues for these funds may come from the national government, gifts from donors (for instance wealthy individuals who grew up in the region) and returns from regionally located resources (for example harbours and renewable energy).

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Appendices

Appendix I. Example of an interviewguide

The interviewguide presented below is used in the Texel dike reinforcement project. The questions are operationalised to cover the various indicators of the knowledge arrangement (in this case study a sandy seaward solution). The interviewguide differs from the one used in interviews that focuses on the project arrangement (in this case study the Texel dike reinforcement project). The key difference is that this interviewguide focuses on knowledge development for a sandy seaward solution and the other on decision making and other activities in the Texel dike reinforcement project. Consequently, the interview guide of the project arrangement does not include questions on interactive knowledge development and outcome.

Starting questions

Rationale technical study	Why is the sandy seaward solution incorporated in the project? What are according to you important characteristics of the technical study? Is there an ambition regarding the involvement of diverse organisations in knowledge development? (if yes) How would you describe this? (if no) Is there an ambition about involving different sources of knowledge in this track?
Actor involvement	What were important events for your organisation regarding the sandy seaward solution since January 2011? Does your organisation take initiative in specific subjects related to the sandy seaward solution? (if yes) on which subjects?

Actors

Actor involvement	Which organisations are involved in the sandy seaward solution as of January 2011? What role does each organisation has?
Actors relations	Are there any relations between various organisations related to the sandy seaward solution? (if yes) What are the relations? How would you characterise these relations?
Coalitions	Are organisations working together on the sandy seaward solution? (if yes) Which organisations work together? And on which topics are they working together? And where does this cooperation come from?
Actors affected	Who is affected by the outcomes of the sandy seaward solution?

Resources

Time	What is the expected duration of the sandy seaward solution? (beginning-end) How much time does your organisation spend on the technical study? Do you spend "spare time" into the sandy seaward solution? (if yes) How many hours per week/month?
Money	Did your organisation spend money to the sandy seaward solution? (if yes) On what? And how much did your organisation spend?
Information	Is information available within your organisation relevant for the sandy seaward solution? (if yes) And what kind of information is that? Does your organisation lack information at this moment, which is relevant for the sandy seaward solution? (if yes) What kind of information is that?

Rules

Legislation and policy rules	Which legislation and policy apply to the sandy seaward solution?
Interaction rules	How often do meetings take place with respect to the sandy seaward solution? Where do they take place? Who is involved in which meetings? What are typical topics in these meetings? Do you contact involved people outside meetings? (if yes) How often? How would you characterise these contacts? Is the interaction with other organisations / people formalised in procedures?
Allocation of responsibilities	Does your organisation has responsibilities related to the sandy seaward solution? (if yes) And what kind of responsibilities is that? Where does this responsibility come from?
Access rules	Where could the involvement of an organisation for the sandy seaward solution come from? Where could the lack of involvement of organisation X in the sandy seaward solution come from?

Interactive knowledge development

Problem formulation	What is the purpose of knowledge development in the technical study? What is the topic for which knowledge is developed? How has the topic and research questions been defined? Is knowledge development for the sandy seaward solution relevant? (if yes) For whom?
Methods and techniques	Was there an inventory/discussion about possible methods and techniques to address this problem?

	(if yes) By whom? And which decisions were made in this respect?
Causal models	Did the report of the technical study resulted in differing viewpoints of organisations involved? (if yes) What are they? And where do they come from? Has anything been done with these differing viewpoints?
Interpretation of results	Who interpreted the results of the technical study? Was there a discussion about the key conclusions? (if yes) among who?
Choice of solution	Has a choice been made for a specific solution in the technical study? (if yes) Which one? (if not) What determines this? Are various solutions considered? (if yes) Which ones? Where could this come from, that several solutions are being considered?
Evaluation	To which extent do you agree with the followed process in the technical study? (degree of interaction, methods, research questions, communication, collaboration)

Outcome

Tangible products	Which tangible products have been delivered by knowledge development for the sandy seaward solution? Did you contribute to one of these products? In what way? To what extend do you agree with the main outcome as written down in the tangible products?
Use of outcome	Are outcomes of this technical study used in organisations? (if yes) By whom? In which way?
Communication	Are key findings of the technical study communicated? (if yes) By whom? How are key findings communicated? To whom?

Discourses

Coastal defence	What does coastal defence mean to you? What is important for you in coastal defence?
Solutions for coastal defence	What is your opinion about the current solutions for coastal defence that are addressed within this project? On which kind of solutions should this project focus?

Appendix II. Coding template for project and knowledge arrangement

Table I. Coding template that is derived from the conceptual framework of project and knowledge arrangements.

Project arrangement		Knowledge arrangement	
Dimensions	*Indicators*	*Dimensions*	*Indicators*
Actors	Actors involvement	Actors	Actors involvement
	Actors relations		Actors relations
	Actors affected		Actors affected
	Actor coalitions		Actor coalitions
Rules of the game	Acces rules	Rules of the game	Access rules
	Allocation of responsibilities		Allocation of responsibilities
	Legislation and policy rules		Legislation and policy rules
	Interaction rules		Interaction rules
Resources	Time	Resources	Time
	Money		Money
	Information		Information
Discourses	Project rationale	Discourses	Rationale sub-project
	Maritime development Delfzijl		Coastal defence
	Solutions for maritime development		Project solutions
		Multiple frames	Problem formulation
			Methods and techniques to be used
			Interpretation of results
			Choice of solution
		Outcomes	Tangible output
			Agreement
			Use by actors
			Communication of findings

Appendix III. Data collection in the Texel dike reinforcement project

Table II. Overview of semi-structured interviews for data collection of the project arrangement and knowledge arrangement in the Texel dike reinforcement project.

Date	Actor	Interview scope
13-12-2011	Witteveen+Bos	Project arrangement
14-12-2011	Towards a Rich Wadden Sea	Knowledge arrangement
15-12-2011	Hoogheemraadschap Hollands Noorderkwartier	Project arrangement
15-12-2011	Hoogheemraadschap Hollands Noorderkwartier	Project arrangement
22-12-2011	Municipality of Texel	Project arrangement
12-01-2012	Municipality of Texel	Knowledge arrangement
16-01-2012	Province of Noord-Holland	Project arrangement
24-01-2012	Hoogheemraadschap Hollands Noorderkwartier	Knowledge arrangement
20-01-2012	Witteveen+Bos	Knowledge arrangement
20-02-2012	NIOZ deputy director (Koninklijk Nederlands Instituut voor Onderzoek der Zee)	Knowledge arrangement

Appendix IV. Data collection in the South Bay Salt Pond Restoration project

Table III. Recorded interviews

Organisation	Date	Scope of interview
US Fish and Wildlife Service	20-09-2012	Project arrangement
State Coastal Conservancy	24-09-2012	Project arrangement
US Geological Service	24-09-2012	Project arrangement
US Army Corps of Engineers	25-09-2012	Project arrangement
Santa Clara Valley Water District	26-09-2012	Project arrangement
Alameda County Flood Control and Water Conservation District	27-09-2012	Project arrangement
Californian Department of Fish and Wildlife	28-09-2012	Project arrangement
State Coastal Conservancy	10-10-2012	Project arrangement
Center for Collaborative Policy	10-10-2012	Project Arrangement
Former Executive Project manager	11-10-2012	Knowledge arrangement – science programme
URS Corporation	22-10-2012	Knowledge arrangement – Alviso phase 2
Former lead scientist	26-10-2012	Knowledge arrangement - science programme
State coastal Conservancy	30-10-2012	Knowledge arrangement - Alviso phase 2
Fulfrost and Associates	02-11-2012	Knowledge arrangement - science programme
US Fish and Wildlife Service	05-11-2012	Knowledge arrangement - Alviso phase 2
City of Mountain View	09-11-2012	Knowledge arrangement - Alviso phase 2
Center for Collaborative Policy	13-11-2012	Knowledge arrangement – Alviso phase 2
UC Davis	14-11-2012	Knowledge arrangement – science programme
US Geological Service	14-11-2012	Both knowledge arrangements

Table IV. Observed meetings.

Meeting	**Date**
Project Management Team (PMT) meeting	11-09-2012
Science programme - PMT meeting	18-09-2012
Regulatory group – PMT meeting	27-09-2012
PMT meeting	09-10-2012
PMT meeting	13-11-2012
Stakeholder forum	15-11-2012

Table V. Overview of prime documents used in this case analysis.

Project Arrangement	Knowledge Arrangement (Alviso phase 2)
Baylands Ecosystem Habitat Goals (1999)	Phase 2: Preliminary Options for Future Actions (2010)
Framework Agreement for Acquisition (2002)	Request for Services Consultant Team, phase 2 (2011)
Stakeholder and Organizational Assessment Findings and Recommendations (2003)	Opportunities and Constraints for Alviso Pond Complex (2012)
Memoranda of Understanding 2003, 2004, 2009	Comment Matrix Alviso OC memo (2012)
Newsletters November 2003-January 2013	Notes, agendas, presentations of meetings with stakeholder forum (2010-2012) and principal investigators (2011-2012)
Notes, agendas, presentations of meetings with stakeholder forum (2003-2012), local work groups (2007-2011), principal investigators (2011-2012), National Science Panel (2003-2006)	Phase 2 Project Development Results of Alternative Screening for EIS/EIR (2013)
Baylands & Creeks of South San Francisco Bay (2005)	
Final EIS/EIR (2007)	
Annual reports 2009-2011	
Agendas of PMT meetings 2010-2012	
SBSP Overall Project Costs (2012)	

Table VI. Field trips.

Area	Date
Ravenswood complex and Mountain View ponds	06-09-2012
Alviso complex	10-09-2012
Eden Landing complex	28-09-2012
Alviso complex	31-10-2012
Mountain View ponds	15-11-2012

Appendix V. Data collection in the Delfzijl spatial development project

Table VII. Recorded interviews.

Meeting	Date	Scope of interview
Waterboard Hunze & Aa's	03-06-2013	Project arrangement
Municipality Delfzijl	03-06-2013	Project arrangement
Groninger Landschap	04-06-2013	Project arrangement
Waterboard Noorderzijlvest	05-06-2013	Project arrangement
De Laar	06-06-2013	Project arrangement
Groningen Seaports	17-06-2013	Project arrangement
Rijkswaterstaat Noord-Nederland	20-06-2013	Project arrangement
Municipality Delfzijl	01-07-2013	Knowledge arrangement
Hanze Applied University	02-07-2013	Project arrangement
De Laar	03-07-2013	Knowledge arrangement
IMARES	09-07-2013	Knowledge arrangement
Waterboard Hunze & Aa's	11-07-2013	Knowledge arrangement
Province Groningen	11-07-2013	Project arrangement
Programma Rijke Waddenzee	17-09-2013	Knowledge arrangement
RoyalhaskoningDHV	19-09-2013	Knowledge arrangement

Table VIII. Observed meetings.

Meeting	Date
Preparation of steering committee at Municipality of Delfzijl	22-05-2013
Project management team meeting	05-07-2013
Project management team meeting	02-10-2013
Steering committee meeting	17-10-2013

Table IX. Overview of prime documents used in this case analysis.

Project Arrangement	Knowledge Arrangement
Notes, agendas and presentations of meetings of project management team (2010-2013), steering committee (2009-2012) and stakeholder forum (2009 and 2012)	De beschermende dijk: onderzoek kustverdediging Delfzijl (2009)
Maritieme concepten in beeld (2009)	Een verkenning naar het herstel Van het natuurlijk gebied 'Brunner Mond' (2010)
Definitiefase Multifunctionele dijk (2010)	Kwelderwal voor Delfzijl: indicaties voor ontwerp, kosten en ecologische potenties (2010)
Verkenning Schermdijk Delfzijl (2010)	Mogelijke golfreductie Schermdijk voor Delfzijl (2010)
Drie deelprojecten Marconi (2010)	Onderzoeksvoorstel Ecomorfodynamiek Delfzijl (2012)
	Ecodynamische variantenanalyse: Kustontwikkeling Delfzijl (2013)
Maritieme zone Delfzijl: een ruimtelijke visie (2012)	Veiligheidsbeoordeling voorliggende kering Delfzijl: effecten Van de Schermdijk (2013)
Integraal Investeringsprogramma Delfzijl (2012)	Klimaatbestendigheid Chemiedijk: Referentie-ontwerp aanpassingen (2013)
Intentieverklaring Marconi: ruimtelijke visie maritieme zone Delfzijl (2012)	Referentie-ontwerp prim. waterkering in kader Van Building with Nature project (2013)
Actieplan Centrum Delfzijl (2013)	

Table X. Field trips.

Area	Date
City centre and Schermdijk	16-05-2013
Industry at Groningen Seaports	22-05-2013

Appendix VI. Case-specific evidence for generic mechanisms

Table XI. Case-specific evidence supporting the existence of generic mechanisms.

Generic Mechanism	Wadden Sea: dike-reinforcement project	San Francisco Bay: nature restoration project	Ems estuary: spatial development project
Mechanisms that affect interactive knowledge development.			
Project partners are pressed to involve other actors in knowledge production.	Earlier proposed solutions were heavily criticised, water board pressed to involve the municipality and province due to their formal responsibilities.	Pressed by the need for public support since public support fosters project funding.	Earlier proposed solutions had been criticised, raising awareness that collaboration would be needed for implementation.
Project resources structure the interactive knowledge development resulting in a narrowed scope for interactive knowledge development.	Time pressure in the project arrangement resulted in time pressure in the knowledge arrangement. There was little time to comment on a draft version of the study.	An environmental impact analysis and limited time and money pushed the type of solution towards tidal marsh restoration.	Project partners had limited budget and therefore tried to exclude an industrial dumping site from the study since cleaning it up would be expensive.
Project-level actor relationships affect the actor that is the main knowledge producer.	The consultants were a trusted partner of the water board, and were therefore enabled to conduct the technical study in this knowledge arrangement.	Project partners had intimate knowledge on salt pond restoration. The project partners set the directions for knowledge production, and the consultants filled in the details.	Since the project partners had a limited budget, the research consortium formed an attractive partner since they could co-fund 50% of the study.
Sharing responsibilities at project level supports interaction rules for interactive knowledge development.	The water board took full responsibility for the project and was therefore reluctant to involve other actors in interpreting the results and formulating conclusions in the technical study.	Project partners followed a consensus-based approach, resulting in small, consensus-based, steps in knowledge production.	The steering committee and project management team followed a consensus-based approach, resulting in small steps in knowledge production.

Mechanisms that explain, or provide more detail on, interactive knowledge development.			
Actors have different perspectives, which result in differing contributions during a process of interactive knowledge development.	The water board was reluctant to investigate a sandy seaward solution favoured by the municipality and Texel-based organisations. Ecologists who were involved in developing the outline plan focused on the ecological benefits of sandy seaward solutions.	The Project Management Team (PMT) focused on tidal marsh restoration, whereas researchers indicated that bird islands could be combined with marsh restoration in deep ponds. The PMT wanted to include the Mountain View ponds, whereas bird protection organisations rejected this idea.	Steering committee wanted to exclude a dumping site from the study and the proposed solution; the nature coalition wanted to explore the impact on the Ems estuary; the researchers were not interested in studying an expanded city beach.
Easily understood knowledge supports contributions by non-experts.	The nature recovery program and the municipality had limited technical knowledge and found it difficult to comment on the technical study.	Restoration alternatives were easily understood by the non-experts and they could comment on the qualitative results (maps and descriptions). Critical comments could be incorporated as various restoration alternatives were developed.	Easy to understand knowledge (weblog and assessment framework) facilitated understanding among participating actors.
Facilitation smoothes the process of interactive knowledge development.	The nature recovery program made the technical study possible by funding 90% of the study. They also facilitated a discussion between project partners when they disagreed about the outcomes of the study.	The facilitating organisation enabled dialogue between decision-makers, researchers, stakeholders and regulators. During meetings they ensured that every voice was heard, that the scope of discussions was clear and that vague expressions were clarified.	Process facilitator ensured that directors understood and supported the main outcomes of the study; he also explored criticisms of the outcomes of the study by the nature coalition.
Actors are excluded during one or more	The municipality and the nature recovery program were hardly	The PMT set the directions and then the others became involved	A research institute was excluded from the research consortium

activities in the interactive knowledge development.	involved in the interpretation of results. This resulted in critical feedback on the estimated costs and the design of the seaward solution.	(consultants, researchers, regulators, stakeholders).	due budgeting reasons of the consortium; the nature coalition was excluded while the research proposal was negotiated.
Mechanisms that specify consequences of interactive knowledge development.			
Support for solutions broadens through interactive knowledge development.	Jointly developing an outline plan resulted in broad support; after the technical study ended, discussions among a range of actors resulted in broad agreement for a follow-up study.	Concerns were detected during various meetings where criticisms were explored and potential drawbacks discussed. These discussions between the PMT and stakeholders, researchers and regulators led to a shared understanding and support for the developed solutions.	Project partners were involved in the various phases of the Ecoshape study; engaging with the nature coalition resulted in their support for the preferred solution.
Feasibility of solutions improves through interactive knowledge development.	Due to interactions, especially with the municipality and their unpaid scientific advisor, the costs, location, shape of flood defences and the oyster reefs changed.	Interacting with regulators resulted in valuable insights into the permitting procedure; interacting with researchers resulted in changes to the restoration solutions (number of breaches, size and shape of nesting islands).	Researchers pressed for the dumping site to be included in the study since legislation demands environmental compensation for the proposed solution.
Interactive knowledge development consumes more time than expected.	Criticisms from various actors resulted in an unplanned follow-up study.	It took three years to develop restoration alternatives, partly due to the number of meetings with regulators, stakeholders and researchers.	Many meetings were needed to develop a research proposal and additional research due to criticisms from the nature coalition. One research organisation spent 40% more time than budgeted on meetings and additional research.

Samenvatting (Dutch summary)

Het ontwikkelen van oplossingen voor een duurzame toekomst van kustgebieden is een complexe opgave. Vraagstukken die bijvoorbeeld spelen zijn: Hoe moet de Afsluitdijk worden versterkt? Hoe kunnen waddenzeehavens uitbreiden zonder dat de natuur er de dupe van wordt? Hoe kan de leefbaarheid vergroot worden terwijl een kustgebied kampt met bevolkingsafname? Hoe kan gas en zout worden gewonnen zonder onomkeerbare schade toe te brengen aan natuur en landschap? Kennis is cruciaal om te komen tot werkbare oplossingen voor dergelijke vraagstukken. De onderliggende problemen zijn namelijk complex omdat in een kustsysteem fysische, ecologische en sociale aspecten op elkaar ingrijpen; zoals de stroming van zand en water (zoet en zout), de populatiedynamiek van vogels en vissoorten en de invloed van maatschappelijke activiteiten, zoals toerisme en visserij op het kustsysteem. Tevens zijn er grote onzekerheden over de toekomst als gevolg van bijvoorbeeld klimaatverandering en bodemdaling. Tot slot hebben betrokken partijen uiteenlopende belangen die leiden tot andere voorkeursoplossingen voor de specifieke kustregio, variërend van natuurbescherming tot waterveiligheid en economische groei.

Alleen wetenschappelijke kennis is vaak niet toereikend om te komen tot duurzame oplossingen voor kustgebieden. Onderzoek, uitgevoerd in een relatief afgeschermde omgeving, los van beleidsmakers en andere maatschappelijke partijen, resulteert in kennis en oplossingen die niet aansluiten bij de behoeften van beleidsmakers, en kunnen worden bekritiseerd door maatschappelijke partijen omdat hun belangen en inzichten onvoldoende zijn meegenomen.

Dit proefschrift richt zich op interactieve kennisontwikkeling, als alternatief voor het doen van wetenschappelijk onderzoek in isolatie. Interactieve kennisontwikkeling verwijst naar een proces van kennisontwikkeling waarin onderzoekers, beleidsmakers en andere maatschappelijke partijen in interactie met elkaar kennis ontwikkelen. Tot nu toe is er weinig onderzoek gedaan naar de werking van interactieve kennisontwikkeling, waardoor er onvoldoende inzicht en kennis is of interactieve kennisontwikkeling wel resulteert in andere oplossingen die wel aansluiten bij de wensen en belangen van beleidsmakers en maatschappelijke partijen. Bovendien blijft het ook onduidelijk hoe dergelijke processen georganiseerd kunnen worden. Het doel van deze studie is daarom te onderzoeken hoe processen van interactieve kennisontwikkeling functioneren in kustprojecten. Een kustregio biedt een interessante omgeving om dit nader te bestuderen, aangezien de belangen divers zijn en de problemen complex. Dit proefschrift richt zich op kustprojecten aangezien die direct werken aan te bouwen oplossingen voor bijvoorbeeld waterveiligheid, havenuitbreiding, natuurherstel of leefbaarheid.

Deze studie analyseert processen van interactieve kennisontwikkeling in drie kustprojecten: een dijkversterkingsproject op Texel, een natuurherstelproject in de baai van San Francisco en een gebiedsontwikkelingsproject in Delfzijl. Deze projecten werken aan multifunctionele oplossingen die waterveiligheid combineren met natuurherstel en recreatie. Binnen deze projecten is kennis interactief ontwikkeld tussen overheden (bijv. waterschappen en gemeenten), onderzoekers (bijv.

ingenieursbureaus en onderzoeksinstituten) en andere maatschappelijke partijen (bijv. natuur- en recreatieorganisaties) Een conceptueel kader van project- en kennisarrangementen[58] heeft de analyse van interactieve kennisontwikkeling in deze projecten gestructureerd. Data zijn verzameld door betrokkenen te interviewen, projectbijeenkomsten te observeren, projectdocumenten te verzamelen en de kustgebieden te bezoeken.

In dit proefschrift worden causale mechanismen[59] gepresenteerd die verklaren hoe interactieve kennisontwikkeling functioneert in kustprojecten. De mechanismen worden ontwikkeld in de context van een specifiek kustproject, namelijk het dijkversterkingsproject op Texel (hoofdstuk 2) en het natuurherstelproject in de baai van San Francisco (hoofdstuk 3). Daarna volgt uit de cross-case vergelijking (hoofdstuk 5) een set van 11 causale mechanismen die van toepassing is in alle drie de projecten. Omdat deze causale mechanismen van toepassing zijn voor drie zeer verschillende kustprojecten, geven ze een belangrijke verklaring voor hoe processen van interactieve kennisontwikkeling functioneren in kustprojecten.

De volgende vier conclusies worden getrokken voor het functioneren van interactieve kennisontwikkeling in kustprojecten.

(1) De mechanismen maken duidelijk dat interactieve kennisontwikkeling nauw verweven is met de besluitvorming in het kustproject. Hulpbronnen van projectpartners bepalen de focus voor kennisontwikkeling en de relaties tussen organisaties in het kustproject bepalen de interactieregels waarbinnen kennis interactief ontwikkeld wordt.

(2) De mechanismen maken inzichtelijk welke specifieke maatregelen bijdragen aan een proces van interactieve kennisontwikkeling. Projectpartners dienen een noodzaak te hebben om diverse partijen te betrekken in kennisontwikkeling en de verantwoordelijkheid voor projectuitkomsten met elkaar te delen. Bovendien dragen professionele facilitering en eenvoudig te begrijpen kennis bij aan een gedeeld begrip tussen onderzoekers, beleidsmakers en maatschappelijke partijen.

(3) De mechanismen maken duidelijk dat interactieve kennisontwikkeling kan leiden tot een haalbare en breed gesteunde oplossing voor een complex kustprobleem. Verschillende partijen leveren bijdragen die de technische, juridische en financiële haalbaarheid van kustoplossingen vergroten. Door diverse partijen (diegenen die oplossingen kunnen blokkeren dan wel implementeren) te betrekken in interactieve kennisontwikkeling worden belangen en inzichten van partijen meegenomen waardoor er bredere steun ontstaat voor de oplossing.

(4) De mechanismen maken inzichtelijk dat de verbeteringen in haalbaarheid en maatschappelijke steun substantieel meer tijd en geld vragen dan 'standaard' onderzoek. Deze extra investeringen zijn nodig om de zorgen te adresseren van partijen die betrokken zijn bij de kennisontwikkeling.

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[58] Het projectarrangement focust op de context waarin kennis wordt ontwikkeld, namelijk de actoren, regels, hulpbronnen en discoursen in het kustproject. Het kennisarrangement conceptualiseert het proces van interactieve kennisontwikkeling door vier activiteiten: probleemformulering, selectie van methoden, interpretatie van resultaten, keuze van een oplossing.

[59] Een causaal mechanisme beschrijft hoe een specifieke oorzaak gekoppeld is aan een uitkomst.

Een gevolg is dat een proces van interactieve kennisontwikkeling niet is afgelopen na de eerste studie, maar dat meerdere aanpassingen en vervolgonderzoek nodig kunnen zijn voordat de ontwikkelde kennis gedeeld en gesteund wordt door alle betrokken partijen.

Tot slot biedt deze studie een reeks praktijkaanbevelingen hoe een proces van interactieve kennisontwikkeling vormgegeven kan worden. Projectpartners in kustprojecten dienen diverse partijen te betrekken in kennisontwikkeling en te zorgen dat kennis ook eenvoudig te begrijpen is. Ook zal de tegenspraak van betrokken en buitengesloten partijen daadwerkelijk geadresseerd moeten worden. Daarnaast kunnen ingenieursbureaus en kennisinstituten interactieve kennisontwikkeling als apart product aanbieden en daarmee overheidsorganisaties bedienen die vormen van kennis co-creatie willen ontwikkelen (bijv. Rijkswaterstaat, het Planbureau voor de Leefomgeving en het Deltaprogramma). Tevens kan interactieve kennisontwikkeling beter geborgd worden in instituties door de discipline van kennis co-creatie verder te professionaliseren, door onderzoeksprogramma's geld te laten reserveren voor interactieve kennisontwikkeling en door financieringsconstructies op te zetten die multifunctionele oplossingen in specifieke kustgebieden ondersteunen.

Deze studie heeft de mogelijkheden en beperkingen van interactieve kennisontwikkeling inzichtelijk gemaakt in de context van kustprojecten. Het onderzoek toont aan hoe een proces van interactieve kennisontwikkeling functioneert en welke ingrepen bijdragen aan een dergelijk proces. Daardoor kan in de toekomst beter worden beoordeeld of interactieve kennisontwikkeling een bruikbare benadering is om oplossingen voor kustproblemen te ontwikkelen en te implementeren. En, hoe dat vervolgens georganiseerd kan worden zodat interactieve kennisontwikkeling leidt tot haalbare en breed gesteunde oplossingen.

About the author

Christian Johannes Lambertus Seijger was born on 11 August 1986 in Smallingerland. He spent his childhood in Gorredijk in the province of Fryslân. The province is known for its water-rich environment, which Chris enjoyed year round; either by ice-skating, swimming, fishing or ditch jumping. Chris finished his pre-university education (Gymnasium) at OSG Sevenwolden in Heerenveen in 2004. He followed in his father's footsteps by moving to Wageningen to study Soil, Water and Atmosphere at Wageningen University.

In Wageningen Chris developed a particular interest in water issues and solutions that require integration across policy domains (e.g. flood control, agriculture and nature) and between professions (e.g. researchers, policy makers and other societal actors). As a result, Chris specialised in Integrated Water Management during his master programme and obtained a minor in Irrigation and Water Management. His thesis explored the different perspectives on the silt issue in Lake Markermeer in the Netherlands. His internship at the International Water Management Institute in Lao PDR focused on water resources planning at a national level. In 2010, Chris graduated as Master of Science in Hydrology and Water Quality at Wageningen University.

In November 2010, Chris started his PhD research on interactive knowledge development in coastal projects at University of Twente. He moved to Utrecht since his research project was a collaborative research project between the University of Twente (Department of Construction Management & Engineering), Deltares (Unit of Scenarios and Policy Analysis) and Wageningen University (Environmental Policy Group). In 2012, Chris became a visiting scholar at Stanford University to analyse interactive knowledge development in the South Bay Salt Pond Restoration project. He published findings of his PhD research in peer-reviewed journals. In addition, he communicated his research to practice by a newspaper article, a YouTube movie and action perspectives for the Wadden Sea (the latter is a joint effort of science-policy interface researchers in the Dutch Wadden Sea). The quality of his research was recognized in international conferences where he received awards for 'Outstanding PhD student' and 'Best Poster Presentation'. Chris submitted his PhD thesis within four years to the graduation committee.

Nowadays, Chris continues to work on water issues and integrated solutions in two research institutes. At Deltares, he performs advice and research studies in national and international projects in the fields of water governance and interactive planning processes. At UNESCO-IHE, Chris is a postdoctoral researcher in the project 'Strengthening strategic delta planning processes in Bangladesh, the Netherlands, Vietnam and beyond'. His research focuses on the project's conceptual framework and a cross-case comparison of strategic delta planning in Bangladesh, Vietnam and the Netherlands.

List of publications

Peer-review published

Seijger, C., G. Dewulf, H.S. Otter and J. Van Tatenhove (2013). Understanding interactive knowledge development in coastal projects. Environmental Science & Policy 29: 103-114.

Seijger, C., J. Van Tatenhove, G. Dewulf and H.S. Otter (2014). Responding to coastal problems: Interactive knowledge development in a US nature restoration project. Ocean & Coastal Management 89: 29-38.

Under review

Seijger, C., H.S. Otter, J. Van Tatenhove and G. Dewulf. Socially robust knowledge in coastal projects. Submitted to Environmental Science & Policy.

Seijger, C., J. Van Tatenhove, G. Dewulf and H.S. Otter. Sustainable coastal development: Turning knowledge into action. Rejected after peer-review, an improved version will be submitted in the nearby future.

Papers presented at conference:

Seijger, C., J. Van Tatenhove, H.S. Otter and G. Dewulf (2014). Organising interactive knowledge development in coastal projects. In: Abstracts scientific programme Deltas in Depth. Deltas in times of climate change II. Rotterdam, The Netherlands, September 24-26 2014.

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Other output

Van der Molen, F., J. Floor, W. Van Enst, C. Seijger et al. (2014). Van frustratie naar integratie: Handelingsperspectieven voor de aansluiting tussen kennis en beleid rondom de Waddenzee.

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I switch for the final words of this thesis from English to Dutch to say a proper and honest thanks to those who supported me in completing the PhD research. Hoewel mijn naam als enige op de voorkant van dit proefschrift staat was het onderliggende promotieonderzoek zeker geen eenzame exercitie. In tegendeel, ik heb mogen samenwerken met inspirerende en gedreven personen die dit promotieonderzoek voor mij tot een erg waardevolle en leerzame periode hebben gemaakt. Allereerst wil ik de respondenten in mijn onderzoek bedanken voor hun medewerking. Alle gesprekken en interviews met jullie boden mij een kijkje in de complexe realiteit van kustprojecten en kennisontwikkeling. Dit proefschrift is mijn poging om bij te dragen aan een beter begrip van interactieve kennisontwikkeling in kustgebieden.

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Utrecht, oktober 2014

PROPOSITIONS

accompanying the dissertation

Interactive knowledge development in coastal projects

Chris Seijger, 17th of December 2014

1. The process of knowledge production holds many clues to improve the uptake of research in policy practices because research results are limited used in policy practices. (Chapter 2, this thesis)

2. The process of interactive knowledge development requires much more involvement from a diversity of actors than 'basic' research. This is described by the three conditions for socially robust knowledge: knowledge is tested by boundary spanners, diverse actors are involved and there is a close connection between knowledge production and the evolving project. (Chapter 4, this thesis)

3. Generic causal mechanisms for interactive knowledge development explain how interactive knowledge development functions in coastal projects and clarify how it can be organised in practice. (Chapter 5, this thesis)

4. The positive outcomes of interactive knowledge development –enhanced feasibility and societal support for a developed coastal solution - come at a price of consuming substantial more time. (Chapter 6, this thesis)

5. Too many social scientists forget that clear procedures in data collection and analysis are the only way to rigorous scientific research.

6. Researchers investigating an interdisciplinary topic need to be thick-skinned and continuously remember that they are on the right track when most of the commentators are just a little upset.

7. Conducting a PhD research is a social undertaking that is full of encounters with inspiring people, to who you can return when the journey becomes lonesome.

8. In the water sector, the mutual prejudices of professionals with either a social or technical background hamper collaboration between those that work across these boundaries for more sustainable solutions.

9. When Auguste Rodin (1840-1917) would have lived in our society he would have sculped 'Le Connaisseur' as a sculpture group to reflect the societal debate on opening up processes of knowledge production.

STELLINGEN

behorende bij het proefschrift

Interactive knowledge development in coastal projects

Chris Seijger, 17 december 2014

1. Omdat onderzoeksresultaten beperkt gebruikt worden in besluitvorming biedt een proces van kennisontwikkeling diverse mogelijkheden om de bruikbaarheid van onderzoek voor besluitvorming te vergroten. (Hoofdstuk 2, dit proefschrift)

2. Het proces van interactieve kennisontwikkeling vereist veel meer betrokkenheid van een diversiteit van partijen dan 'standaard' onderzoek. De drie voorwaarden voor sociaal robuuste kennis beschrijven dit: kennis wordt getest door bruggenbouwers, diverse actoren zijn betrokken en er is een goede verbinding tussen de processen van kennisontwikkeling en besluitvorming in het project. (Hoofdstuk 4, dit proefschrift)

3. De generieke causale mechanismen van interactieve kennisontwikkeling verklaren hoe interactieve kennisontwikkeling functioneert in kustprojecten en hoe het in de praktijk kan worden georganiseerd. (Hoofdstuk 5, dit proefschrift)

4. De positieve uitkomsten van interactieve kennisontwikkeling – vergrootte haalbaarheid en maatschappelijke steun voor een kustoplossing – worden bereikt door een extra tijdsinvestering. (Hoofdstuk 6, dit proefschrift)

5. Te veel sociale wetenschappers vergeten dat degelijk onderzoek heldere procedures vereist voor dataverzameling en –analyse.

6. Onderzoekers die een interdisciplinair onderwerp bestuderen moeten een olifantenhuid hebben en realiseren dat ze op de goede weg zitten zolang de meeste reageerders een beetje ontevreden zijn.

7. Een promotieonderzoek is een sociale zoektocht vol ontmoetingen met mensen die je inspireren, en tot wie je kunt terug keren wanneer de tocht eenzaam dreigt te worden.

8. In de watersector beperken de wederzijdse vooroordelen van professionals met een sociale of technische achtergrond de samenwerking tussen diegenen die wel over deze grenzen heen gaan om te komen tot meer duurzame oplossingen.

9. Als Auguste Rodin (1840-1917) in onze tijd zou leven zou hij 'Le Connaisseur' als beeldengroep hebben gemaakt om aan te sluiten bij de maatschappelijke discussies over interactieve vormen van kennisontwikkeling.