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Janssen, Stephanie; Hermans, Leon

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Assessment of nature-based flood defences implementation potential – development and application of a game theory based method

Working paper by Stephanie Janssen and Leon Hermans
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Abstract

Nature-based flood defence (NBFD) by means of vegetated foreshores is an innovative flood protection strategy. In contrasts with traditional hard structures it combines nature and flood protection functions and employs natural dynamics. Introducing such an innovation into actual flood protection projects requires not just proper understanding of the physical aspects of the approach. Equally important is the understanding of governance implications as NBFD decision-making implies involvement of different actors and actor interactions and requires alternative governance arrangements to enable implementation. Moreover NBFD implementation is far from self-evident; in fact most of the time traditional solutions are preferred. In this report we look into the actor-interactions that are associated with NBFD and aim to improve understanding of NBFD implementation in flood defence projects. For that purpose we develop and apply a game theory based research approach. The objective is to: 1) systematically describe actor interactions in NBFD decision-making and the benefits of potential actor coalitions in NBFD projects; 2) identify exemplary NBFD games; and 3) understand solutions to the NBFD games and factors that may foster NBFD implementation. The approach is applied it three Dutch NBFD case studies: the Sand Engine, Markermeer dikes and the Afsluitdijk.

Key-words

Nature-based flood defence
Game theory
Implementation
Rational-choice theory
Netherlands

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1 Introduction

Nature-based flood defence (NBFD) by means of vegetated foreshores is an innovative design alternative for achieving protection against flooding. Instead of conventional flood protection approaches, such as dike reinforcement, dike heightening, dike enlarging or the use of construction techniques, flood protection levels are improved by employing the vegetated foreshore as part of the flood protection barrier. Vegetation on foreshores can absorb wave energy, counteract erosion and facilitate sedimentation processes (Moller et al. 2014; Gedan et al. 2011). Under ideal conditions (involving hydrodynamic conditions and availability of sediment) the foreshore may be able to adapt to rising sea level. Often vegetated foreshores function in combination with existing hard structures such as dikes. A vegetated foreshore is just one form of different possible NBFDs. Other NBFD solutions for instance are oyster reefs, mussel beds and sand nourishments to contribute to flood protection (Borsje et al. 2011) and managed realignment (French 2006). NBFD approaches have been attracting increasing global attention over the last decade. For example, ecosystems form a central element in achieving a number of the Sustainable Development Goals and are central in the Sendai Framework for disaster risk reduction. Also in the scientific field NBFD has progressed significantly regarding for example modelling tools, large-scale pilot studies and development of general NBFD concepts for different coastal systems.

With regard to full implementation NBFD is facing at least two main barriers: the uncertainties associated with the design and its multifunctional nature. Vegetated foreshores involve uncertainties that originate from natural (seasonal, climate and other) dynamics and are related to the long-term performance and impact of extreme conditions such as storms. The limited real-life experiences with vegetated foreshores for flood protection and other NBFD solutions exacerbate the real and perceived uncertainties. In addition, implementation of vegetated foreshores as flood protection measures is highly depending on local environmental and hydrodynamic circumstances and there is no such thing as a 'standard' NBFD design. For example in the Netherlands typical vegetation types on foreshores range from willows and reed in fresh water environments, to grass weed in brackish environment and cord grass in salt environments (Borsje et al. 2014). The second barrier regards the multifunctional of NBFD in combining nature and flood protection functions. Therefore, enabling implementation of NBFD implies involvement of different parties and changed actor coalitions (Korbee et al. 2014). Besides flood protection authorities and contractors, additional players make up the playing field among others players in the nature domain. In addition, users and managers of the area, local and regional governmental authorities, various (nature) interest groups and knowledge providers such as consultants and researchers enter the arena. Broadening the actor coalitions, for example by including private actors and consultants early on in the project, improves possibilities to NBFD implementation (Korbee and Van Tatenhove 2013). There is not a single actor that can unilaterally implement a NBFD solution and thus analysis of actors and their interactions is central for the understanding of NBFD implementation. One of the challenges that these actors phase is the need to make trade-offs between nature and flood protection functions. A classic example here is the trade-off between ecological heterogeneity (for biodiversity reasons) and ecological homogeneity (for flood protection purposes) (Van Loon-Steensma and Vellinga 2013).

The focus of this report is on actor-interactions associated with NBFD. The objective of this report is to improve understanding of actor-interactions towards enabling NBFD implementation. Such understanding will help to understand how uncertainties and trade-offs associated with NBFD decision-making can be dealt with. For that purpose we develop and apply a game-theory based approach, by which we can: 1) systematically describe actor interactions in NBFD decision-making and the benefits of potential actor coalitions in NBFD projects; 2) identify exemplary NBFD games at project and institutional level; and 3) understand solutions to NBFD games and factors that may foster NBFD implementation. Our interest starts from vegetated foreshores implementation, but the research covers different types of NBFD solutions, which are characterised by: 1) using natural dynamics (biotic or abiotic) that contribute to a flood protection function, 2) enhancement of the local ecosystem (quantitatively or qualitatively) and 3) the combination of nature and flood protection functions (Janssen 2015).

The paper is structured as follows. First we further deepen our understanding of NBFD solutions and decision-making. Second, we introduce the framework in which game theory is employed for the analysis of NBFD actor-interactions. Third, we introduce our research approach. Fourth, three case studies are described. The report ends with a discussion and outlook.

2 Nature-based flood defence

This section reflects on uncertainties associated with NBFD, the multi-functionality and on NBFD decision-making.

2.1 NBFD uncertainties

NBFDs are often associated with significant uncertainties as the designs are dynamic and not static as in conventional flood protection solutions. It is a new type of solution with many unknowns and prevailing knowledge gaps (Bouma et al. 2014) and the experience with real-life examples and thus the 'proof of concept' is limited, especially on a larger scale (Temmerman et al. 2013). Van den Hoek et al. (2012) suggested that uncertainties regarding the social implications of NBFD designs are even more disturbing than the uncertainties associated with the natural system.

In order to indicate the NBFD uncertainties the matrix by Brugnach et al. (2008), which is partly based on the work by Walker et al. (2003), is used. Brugnach et al. (2008) differ between three types of uncertainties - unpredictability, incomplete knowledge and multiple knowledge frames - and between three sub-subsystems to which the type of uncertainties belong, the natural, technical and social system. Incomplete knowledge implies insufficient or incomplete knowledge, while unpredictability's are uncertainties that we cannot and will not know. Incomplete knowledge may be solved over time, but unpredictability's will not and have to be dealt with in other ways than producing more knowledge. Stakeholders have to enlarge their box of tools and find new ways to enable effective implementation and management of unpredictability's. Multiple knowledge frames refer to different or even conflicting views on the system. For example, while one party may consider the functioning of a vegetated foreshore for flood defence purposes sufficiently understood, another party will not agree. Table 2.1 provides a rough indication of possible uncertainties related to vegetated foreshores for flood defence.

	Unpredictability	Incomplete knowledge	Ambiguity
Natural system	How fast will sea level rise? How will the plant structure and dispersion evolve? What type of storms will affect the foreshore and when?	How does the foreshore function under extreme conditions? Is enough sediment available to allow natural growth of the foreshore with sea level rise?	Is natural growth and decline of foreshores predictable or not?
Technical system	What is the shape of the foreshore at a certain moment of time? When will erosion and accretion occur?	How much wave dampening will occur by the vegetated foreshore?	Is the behaviour of foreshores sufficiently understood to conclude it is effective under extreme conditions?
Social system	Development of political preference for flood defence: hard predictable measures or nature-based solutions.	What type of assessment tools can be used to assess flood defence capacity of vegetated foreshores?	How to handle uncertainties related to the vegetated foreshore?

Table 2.1 Rough indication of uncertainties associated with vegetated foreshores for flood defence

2.2 NBFD: multifunctional solutions poses dilemmas

NBFD solutions combine nature and flood protection functions and are therefore multifunctional constructions. The use of vegetated foreshores in front of a dike implies that the flood defence does not contribute to flood protection alone, instead the ecosystem or nature benefits as well. Combining nature and flood protection functions is not self-evident, but often presents a social dilemma. In social dilemmas the preferred 'selfish' strategy of individual parties does not align with the best strategy for the coalition. As Ostrom (2005, p.79) describes: "there are many differently structured social dilemmas, but they all are characterized by a situations where everyone is tempted to take one action but all will be better off if all (or most of them) take another action." In NBFD terms, a NBFD solution does not maximise nature value nor maximizes flood protection values, rather it is an 'optimal' solution combining both. For such a solution trade-off between functions is necessary (Van Loon-Steensma and Vellinga 2013). For example a trade-off between vegetation heterogeneity (preferred by nature parties) and vegetation homogeneity (preferred by flood protection parties, for stability and predictability reasons) or a trade-off related to allowing natural dynamics or not. Regarding the latter trade-off, from an ecological perspective cyclic development of erosion and sedimentation of saltmarshes is preferred (Dijkema et al. 2013) whereas from a flood protection perspective stable and predictable saltmarshes are ideal.

Combining functions in NBFD decision-making also involves crossing the boundaries of different institutions or 'policy domains'. Policy domains are characterised by particular stakeholders, rules, discourse, resources and represent particular knowledge and knowledge processes (Janssen 2015; Van Buuren 2009; Dewulf et al. 2013). In order to proceed towards NBFD implementation a form of merging of these domains, at least on a project base, is required (Janssen 2015).

2.3 NBFD decision-making

NBFD decision-making refers to the process of decision-making in projects that intend to employ a NBFD design solution. Such projects are typically routine flood defence projects, but may as well be multi-functional projects which combine for example nature, flood defence or other objectives. Pilot projects are another project type in which NBFD solutions can be employed. Pilot projects may be typically appealing for NBFD implementation as pilots are projects used to test innovations in real-world settings. Pilot projects can have varying purposes including knowledge development, influencing decision-making processes, learning-by-doing in policy practices or a combination of these (Vreugdenhil et al. 2010). Routine projects in contrast are not called into being to test innovations. Routine projects need to meet certain results (i.e. project or policy objectives), whereas pilots are allowed to fail. In practice this means that pilots are more low-risk and allow for flexibility and creativity (Vreugdenhil et al. 2010). In addition, it allows by-pass of (institutional) implementation barriers.

Project run through different decision-making phases. First a phase of exploration, planning and design occurs. In this phase the problem is defined and the different design alternatives are developed and decided upon. When a design has been selected the construction phase can start. After construction, the project requires monitoring, management and maintenance. NBFD solutions differ in that from traditional 'hard' solution as NBFD designs are not finished after construction but start or continue to develop (De Vriend et al. 2014). A vegetated foreshore is dynamic by nature and will change over time. Therefore decision-making (or management) should continue after construction into the management and maintenance phases. NBFD implementation affects all three different decision-making phases reflected in different project types. Table 2.2 represents an overview of the 12 resulting settings in which actor-interactions occur.

Decision-making phase: NBFD project type:	Exploration, planning and design	Construction	Monitoring, management and maintenance
Mono-functional flood defence project			
Multi-functional flood defence project			
Mono-functional pilot project			
Multi-functional pilot project			

Table 2.2 Overview of 12 different settings in NBFD implementation in which NBFD actor-interactions occur

3 Conceptual framework

In this section we introduce the framework for analyses of actor-interactions in NBFDs decision-making processes. A framework functions as guidance for research by identifying the main elements and mutual relations to consider for analysis. Theories are different in being more specific in explaining and making predictions regarding certain processes. In our framework the interactions among actors in NBFD decision-making settings are put central. The conceptual framework (Figure 1) is adapted from the model by Scharpf (1997, p.44) and complemented with elements identified by Ostrom (2005). In the framework actors and actor- interactions are influenced by the institutional setting. Such framework is purposeful to "explain past policy choices and to produce systematic knowledge that may be useful for developing politically feasibly policy recommendations or for designing institutions that will generally favour the formation and implementation of public-interest-oriented policy" (Scharpf 1997, p.43).

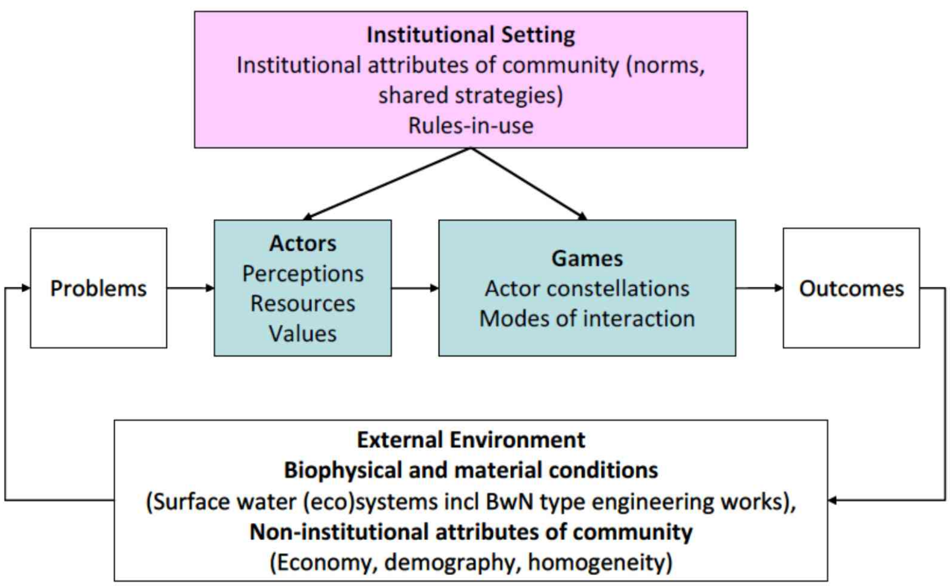

Figure 1 Conceptual framework for the analysis of actor-interactions in NBFD decision-making (adapted from Scharpf (1997) and (Ostrom 2005))

The focus in this research is on NBFD decision-making in flood defence project or pilots. However, in order to understand the project level awareness of the context is required. Ostrom (2005) differs between four levels of analysis: the operational level of rules, the collective choice situations, the constitutional situations and the meta-constitutional situations. Projects are what Ostrom refers to as the *operational level of rules* where "operational rules directly affect day-to-day decisions made by the participants" (p.58). Decisions on this level directly impact on the world, for example a decision to construct a NBFD solution. Games at project level are shaped and restricted by the 'institutional setting', determining the rules of the game. Ostrom (2005) refers to this institutional setting as the *collective-choice level of rules.* At this level the terms are set for decision-making in the operational situation, i.e. NBFD decision-making in projects. Changing the collective-choice rules impacts on NBFD decision-making, for example when objectives of a project are set or changed. The collective-choice rules are again determined by rules at the constitutional level and meta-constitutional level. At this level it is for example determined which parties can be involved in drafting collective-choice rules.

The conceptual framework (Figure 1) for the analysis of actor-interactions can be applied to the different levels identified by Ostrom. For this research the operational (project) level are collective-choice level are most relevant. At the operational level NBFD decision-making occurs, at the collective-choice level the rules or 'institutional setting' for NBFD decision-making is defined. In the following sub-sections we elaborate on the main components of the conceptual framework: the institutional setting, the actors and the games.

3.1 Institutional settings

The institutional setting refers to the set of formal and informal rules that are in use, including legislation, agreements, project objectives and evaluation criteria, contracts and also tacit rules such as cultural conventions and norms. Institutions function as "the prescriptions that humans use to organize all forms of repetitive and structured interaction" (Ostrom 2005, p.3). The institutional setting does not just affect interactions among actors, institutions also "constitute[s] composite actors, create and constrain options, and shape perceptions and preferences" (Scharpf 1997, p.42). Prior to understanding the games that actors play, there is to be an understanding of the institutional setting and the actors involved, including their resources, perceptions and values. "The games that are in fact being played in policy processes are to a large extent defined by institutions" (Scharpf 1997, p.40).

The institutional setting will not represent a static picture, but can be changed over time. The rules that are in use at the operational level are arranged at the higher, collective choice level. The rules at the collective choice level are again determined at the constitutional level. The pace of change may differ however. Changing the objectives of a simple small-scale project may be easier and faster to do than changing a countries constitution.

3.2 Actors

Actors are defined by their resources, preferences and perceptions. Resources relate to the means an actor has to enforce a particular strategy and can include legal, financial or other resources. An actor is 'critical' when resources are not replaceable and highly important in the specific problem situation. For example when an actor holds 'power of realisation' or 'blocking power' (Enserink et al. 2010). Preferences relate to the interest and values actors hold. These are reflected in the actors' objectives beyond the particular problem situation and for the specific problems situation. Perceptions result from the knowledge and ignorance of a specific player. Based on his understanding an actor interprets a situation. The perception refers to the gap that the actor perceives between the desired and existing situation, the causes for this gap and the possible and desirable solutions. Perceptions and preferences can be (but not necessarily are) changeable through learning or persuasion (Scharpf 1997). Learning processes may lead to developing a shared knowledge base among actors. Actors with similar background in terms of education, working environment and with intensive interaction may start to develop a shared understanding.

Actor are present at operational, collective-choice and (meta-)constitutional levels. The same actors may also be involved in multiple levels at the same time. For example two actors in a project can decide to include a third actor in the project team or to redefine the purpose of the project. When the latter occurs the institutional setting of that specific project is changed.

3.3 Games

Game theory is concerned with "the actions of decision-makers who are conscious that their actions affect each other" (Rasmusen 2007, p.11) and involves describing and solving games by means of a "logical analysis of situations of conflict and cooperation" (Straffin 1993, p.3). Games are described by means of players, the set of possible moves for each player, possible outcomes (resulting from the combination of actions by players), and the payoffs each players receives for a certain outcome. In describing games we follow Scharpf (1997) who discerns between the actor constellation and the modes of interaction in a game. The actor constellation represents a static picture of the game involving players, moves, outcomes and payoffs. The mode of interaction represents the way actors make decisions in the game. Scharpf (1997) identifies among four different modes of interaction which are the unilateral action (the 'non-cooperative game', see section 3.3.1), the negotiated agreement (a 'cooperative' game, see section 3.3.2), the majority vote and hierarchical decisions.

In line with Rasmusen (2007) we consider game theory as a modelling tool, that can be used to provide insight in strategic situations. Game theory involves two main branches: the 'classic' branch of non-cooperative game theory and the cooperative form of game theory. Non-cooperative game theory is concerned with strategic situations among actors in which cooperation is assumed to be impossible. Alternatively, cooperative game theory considers binding agreements among actors. In the following sections we elaborate on these two forms of game theory.

3.3.1 Non-cooperative games

Non-cooperative game theory is concerned with understanding strategic situation between players and finding the viable solutions in these games. A central assumption is that players strive to maximise their individual utility and behave in a rational manner. In addition it is assumed that players do not/ cannot enter into binding agreements. The payoff matrix and the game tree are very effective means to model actor constellations in non-cooperative games (Figure 2). The payoff matrix resembles the players in a game (Colin and Rose in Figure 2), their possible moves (A, B or C in Figure 2), and the payoffs to each player in a particular game outcome (the (x,x) notification in Figure 2). A player's strategy is the rational by which the player selects his moves given certain circumstances in the game (e.g. when the other player choses A, I choose B and when the other players choses B I chose A). A decision tree holds the same situation as the payoff matrix, but adds to that the order of play as well as the possibility for information sets. By game trees 'sequential' games can be shown where one players moves before the other does, or knows the other players move before moving himself. In an information set it is possible to hide knowledge or action for a particular player. Moreover in decisions trees it is rather easy to include more than two players.

		Colin	
		A	B
Rose	A	(2, -2)	(-3, 3)
	B	(0, 0)	(2, -2)
	C	(-5, 5)	(10,-10)

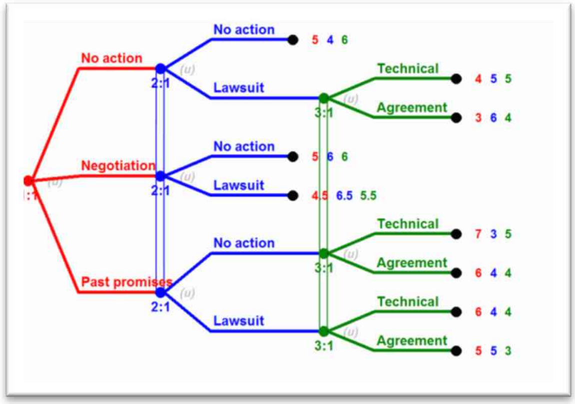

Figure 2 Visualisations of a game: the payoff matrix and the game tree (source Scott Cunningham EPAcourse)

Solution concepts in non-cooperative game theory help to identify viable solutions in a game (but will never predict solutions, see next paragraph). Two widely used concepts are 'dominance' and the 'Nash-equilibrium'. A player has a dominant strategy when, regardless of the action of other players, the strategy yields him the highest payoff (i.e. always choose A). When both players in a game have a dominant strategy, the game has a *dominant-strategy equilibrium outcome*. It may also be that one player has a dominant strategy and the other player doesn't, but when the dominated strategies (i.e. the non-dominant strategies) of the first player are eliminated the second player also has a dominant strategy. What results is an *iterated-dominance equilibrium*. The Nash equilibrium, named after its founding father John Nash (Nash 1951) is another famous solution concept. The outcome of a game is a Nash equilibrium when no player has an incentive to deviate from the outcome. In the payoff matrix the Nash equilibrium can be found using arrows showing how a player will respond to a particular outcome. Games may have multiple Nash equilibriums, such as the case in the prisoner's dilemma. A Nash equilibrium is 'strong' when it is at the same time an (iterated-) dominance equilibrium (i.e. the 'confess-confess' outcome in the prisoners dilemma), or 'weak' when it isn't (the 'deny-deny' outcome in the prisoners dilemma). The challenging dimension in the prisoner's dilemma is that the weak Nash equilibrium is at the same time the optimal outcome (i.e. the best outcome for both players) whereas the strong Nash equilibrium is non-optimal. Despite many attempts (including the two of solution concepts described above), solving games by means of non-cooperative game theory is seriously restricted. Non-cooperative games are difficult to solve in absence of equilibriums or the presence of multiple equilibriums.

The predictive power of non-cooperative game theory is restricted by the limited practical value of the rational-and-utility-maximising-player assumption. In practice players may not solely care about their individual payoffs or act rational. For this purpose Scharpf (1997) discerns five 'interaction orientations' indicating the relationship among actors. Actors may act individually, show solidarity, compete with other players, be altruistic or act hostile. Furthermore in practice there may be many reasons why a player will not act rational. Solving games thus becomes quite difficult when only using non-cooperative game theory. Schelling (2010, p.33) puts the value of non-cooperative game theory as follows: "the *question* is nicely formulated in the matrix, the *answer* is not". More information is needed to find a solution to a game including for example culture, precedents, reputation, identification, and conversation (Schelling 2010). These aspects are captured in our framework under 'institutions', 'actors' and 'modes of interaction'.

3.3.2 Cooperative game theory

In contrast to non-cooperative game theory cooperation and coalitions are put central in cooperative game theory. The two central questions are 'who should cooperate?' and 'how to divide the winnings among the parties in the coalition?' (Straffin 1993). The strategies of players or coalitions on how to arrive at a particular value are not concerned. In cooperative game theory it is assumed that players can communicate and make deals and that the winnings of a coalition can be divided among the players, i.e. these are 'transferable'.

Several solution concepts have been developed in cooperative game theory, indicating the value of cooperation or suggesting a distribution of the winning. The most famous are the core, the Shapley value and the nucleolus. The core (Figure 3) is the solution to a game that is in the interest of the group of players (i.e. group rational) as well the individually players (individually rational) at the same time. It is in the interest of all players to cooperate as they will earn at least the amount they would earn when acting alone. Not all games have a core.

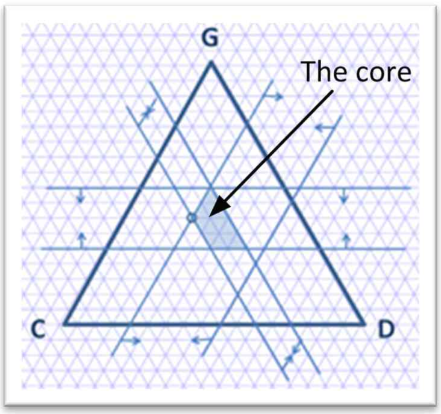

Figure 3 Diagram of a game with three players C, D and G and a non-empty core (source: Cunningham, 2015)

While the core represents a set of solutions, the nucleolus and the Shapley value reflect a single point. The nucleolus is the point where we make "the most unhappy coalition as little unhappy as possible" (Straffin 1993,p.202). If a game has a core, the nucleolus is in the middle of the core. The Shapley value depicts the 'fair' distribution of the payoffs among the players. In this solution the payoffs are distributed according to what a player brings to the coalition. The Shapley value is the solution that an outside arbiter might assign to a game, but may not necessarily be satisfactory to individual players or the outcome of a competitive game. The Shapley has been nicely illustrated in the 'divide-the-dollar' game. In this game three players divide one dollar. An independent arbiter would give each player 1/3 dollar, but in a competitive game it is more likely that two players cooperate and split the dollar leaving the third player broke. The three solution concepts presented here represent particular perspectives on solutions to a game. The core matches the idea of market forms of organisation, the nucleolus reflects the idea of egalitarianism and the Shapley value builds on a fairness criterion. There are however many other ways to evaluate a game and its outcomes, such as economic efficiency, equity, general morality and robustness (Ostrom 2005).

3.3.3 Practical use of game theory

We employ game theory in order to describe and understand actor-interaction in NBFD decision-making. The value of non-cooperative game theory in that respect is in elucidating NBFD dilemma's and strategic situations for which the payoff matrix and the game tree can be off great value (Hermans et al. 2014; Schelling 2010). In order to understand how NBFD implementations can be enabled, we must look beyond games and include characteristics of the situation, including institutions, actors and interaction modes. Real life projects can inform us on the player's strategies and the outcome of NBFD games. In addition, we can take advantage of the rich body of 'standard games' available in the non-cooperative field game theory literature. Such games have been subject to extensive analysis. Examples are the prisoner's dilemma, the pigs game and the battle of the sexes. These games are well described, tested and thought through and we may be able to employ these when NBFD games prove to resemble standard games. The value of cooperative game theory for this research is in providing explanations regarding why players cooperate, indicating the value of cooperation and in finding incentives for cooperation.

Modelling cooperative and non-cooperative games provides some challenges. First is the large amount of information needed to model a game. It may be quite challenging to collect information and also to quantify the payoffs for different players. Furthermore, it may be difficult to reconstruct the different actions that had been available for players, especially when performing an ex post analysis of NBFD decision-making. Second complication is the complex structure of real-life games and the large number of players that are involved. Game theory is best applied with a limited number of players (Hermans et al. 2014) and therefore simplification of real-life games are going to be needed to employ game theory.

4 Research approach

The objective of our research is to improve understanding of actor interactions (games) in NBFD decision-making and NBFD implementation in the Netherlands. We employ three research questions:

1. What (exemplary) actor interactions (games) occur in NBFD decision-making?
2. What are solutions to NBFD games in theory and in practice?
3. How can NBFD implementation be enabled? For example by means of cooperation or changing the game.

4.1 Methodology and data collection

In order to answer the three research questions we a case study approach is employed. Case studies allow for studying real-life and complex phenomena (Yin 2009). In this research we look for NBFD games, which can only be found in real life. In addition we are interested in the solutions to these games. While game theory is valuable in structuring games predictive value is low and we need real-life example projects to understand how dilemmas are actually solved.

We will make ex post analyses of case studies. The advantage of an ex-post analysis is that the outcome of the case study is known prior to starting the research, ensuring a fair distribution of different types of cases studies. Another advantage is that case studies may have been subject to earlier evaluations or analyses which can be used for our purpose. We will actively look for this form of data in our research. Disadvantage of the ex-post approach is that the analyses can be misguided by the outcome of the case study. Stories of possible interviewees and interpretations of dilemmas may be influenced by the (positive or negative) outcome.

4.2 Analysis and case selection

The analysis of case studies is split into two parts. First individual case studies are analysed and learned from. Second a meta-analysis of all case studies is performed. In the meta-analysis we compare NBFD games and try to find similarities connected to the different institutional settings.

Figure 2 presents the research scheme that serves as guidance for the analysis of the individual case studies. This scheme indicates two types of games we look for: the games at collective-choice level and the games at operational level. The collective choice level games determine the institutional setting of the project. We have four categories of institutional settings: the single objective pilot or regular project and the multi-objective pilot or regular project. The NBFD games occur in projects with a specific institutional setting and may have two types of outcomes: NBFD implementation or no NBFD implementation. In the analysis of the individual NBFD case studies we examine four topics. First, we provide a general introduction and look into the context of the case involving the problem, outcome and external environment of the project. Second, we analyse the institutional setting constituting the rules, norms and share strategies in one of the four institutional setting categories.

Third we describe actors in the case study. Fourth, we describe and elaborate the games that occur at operational level and collective-choice level. In this attempt we strive for simplicity in order to capture the essential part of the NBFD decision-making. We describe the players, their moves and payoffs using pay-off matrices or game trees. Payoffs will be simplified and captured in an ordinal 1-4 scale. We explain the game and outcome in the case study and discus how the game could have yielded alternative (better enabling NBFD) outcomes.

We will select NBFD case studies in the Netherlands which represent four different institutional settings. So far our analysis covers three case studies: the Markermeer dikes phase 1 case study; the Afsluitdijk case study; and the Sand Engine case study. The analyses are found in the following sections. For the analyses we have made used of earlier work in which the three projects have been extensively described (Janssen et al. 2014a; Janssen et al. 2014b; Janssen 2015).

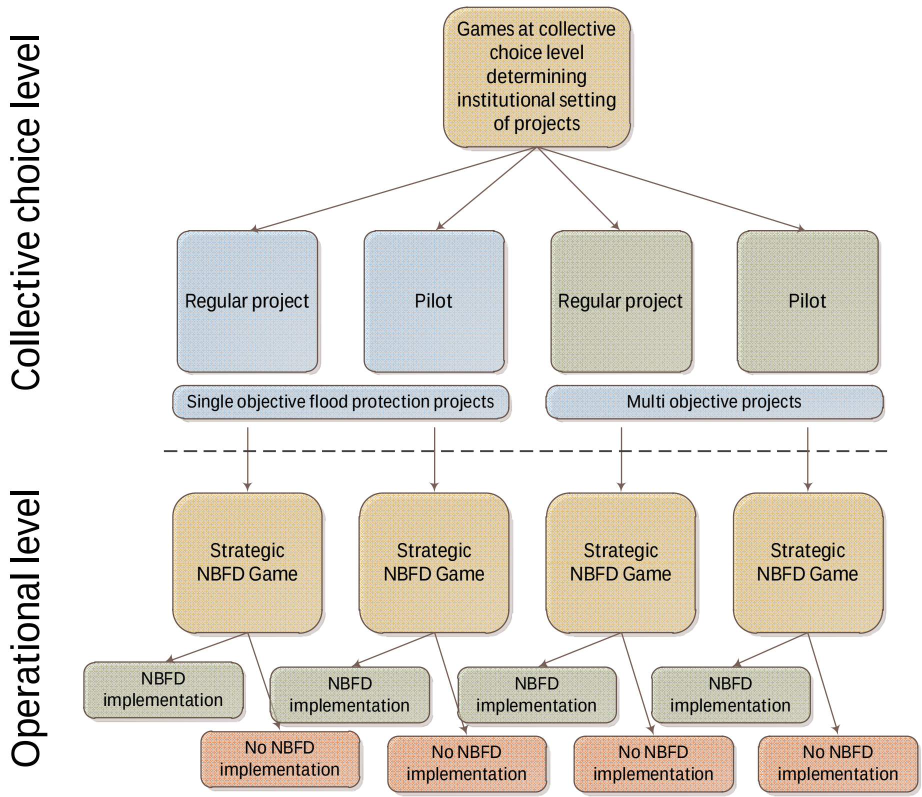

Figure 4 Research scheme for the analysis of NBFD case studies.

5 Case study analyses

5.1 The Markermeer dike case study – phase 1 exploration phase

Case study introduction

The Markermeer dikes cases study concerns a stretch of 33 kilometre dikes along Lake Markermeer which needs reinforcement. Reinforcement of these dikes is a complex matter. Houses are built directly against the dike and on the landside of the dike is an important regional road connecting surrounding communities. In addition, Lake Markermeer is a recognized nature reserve and suffers from ecological deterioration at the same time. Interference with the lake requires careful consideration of environmental impacts. The national government had appointed this project as a

NBFD trial, in which nature and flood protection functions should be combined. The rational was that the poor ecological status of the lake and the dike reinforcement task could become a win-win.

In the process of evaluating different dike designs traditional dike reinforcement measures turned out to be problematic in this project. Sheet piles or enlargement of the dike were both very expensive and seriously complex in terms of construction. An innovative solution was proposed: the shore dike. The shore dike is a body of soft sandy material to be located in front of the existing dike, within Lake Markermeer. The shore dike would replace the flood protection function of the current dike. The soft and sandy structure of the shore dike provides opportunities for nature functions as well.

The introduction of the shore dike formed the starting point for a design process in which flood protection and nature functionalities of the design were explored. The shore dike was selected as the preferred design for implementation along one-third of the dike stretch. This final design however, did not comprise any nature-based elements.

The policy outcome that we aim to explain by means of this analysis is the decision for a 'bare' shore dike, in spite of the desire and potential of this design to include natural elements.

Institutional setting: single-objective project

The dike reinforcement project of the dikes along Lake Markermeer is a single-objective, flood protection project. It is part of a large subsidy programme under the minister of Infrastructure and Environment (I&E) called HWBP-2. Subsidies are provided to projects that meet the evaluation criteria of cost-efficiency, robustness (project life of at least 50 years) and appropriateness (for flood protection only). The deadline for the Markermeer dikes project is 2021[1]. The responsibility for safe dikes is with the local dike managers. The dike manager of the Markermeer dikes is the waterboard Hoogheemraadschap Hollands Nooderkwartier (HHNK). The ministry of I&E indicated the dike reinforcement project as a NBFD trial. For that purpose Rijkswaterstaat (RWS, the executive agency of the Ministry of I&E) runs a parallel 'synergy' project in which NBFD solutions are explored.

The dike reinforcement project requires an Environmental Impact Assessment (EIA) in order to obtain permits. In an EIA report different dike designs are compared based on environmental consequences of the construction and design. In the Markermeer dikes project the following environmental topics make up the assessment framework: landscape quality, ecology, culture, living, recreation, accessibility, soil, water, hydraulic characteristics and costs[2]. Because Lake Markermeer is a protected nature reserve negative effects on the lake should be minimized or alternatively compensated.

Actors

The main actors in this case study are HHNK, HWBP-2 and RWS. HHNK is responsible for the flood protection project, HWBP-2 provides subsidies and sets the criteria for the project, and RWS executes the synergy project. Table 5.1 lists the perceptions, resources and interests of the actors in this project.

[1] HWBP-2 granted five year postponement to the dike reinforcement project for additional research

[2] The flood protection designs are not assessed on the criteria flood protection as the base requirement is that the designs meet the flood protection standard.

Table 5.1 Actors in the Markermeer dikes case study

Actor	Responsibility	Perception	Resources	Interests
HHNK	Execute flood protection project Markermeer dikes	The shore dike is an innovative solution. Flood protection is most important and should be guaranteed Flood protection designs should meet the HWBP-2 criteria for subsidy and be feasible within the HWBP-2 time schedule.	Project organisation Task and responsibility to reinforce dikes	Acquire budget HWBP-2 budget Design and construct a dike that meets the required flood protection level.
HWBP-2	Grant subsidies for dike reinforcement	HWBP-2 grants subsidies for dike designs which are sober, robust and efficient. In order to assess flood protection a test framework is required.	Subsidies for construction (not maintenance) of dikes for flood protection purposes.	Meet programme objectives, i.e. realisation of 87 flood protection projects.
RWS	Execute synergy project: present a design which involves synergy among nature and flood protection	Dike designs with synergy for flood protection and nature are possible on some locations along the 33 km stretch. The shore dike provides a very good opportunity.	Assignment to investigate and develop design involving synergy Money for research not for other things	Show design options with synergy between nature and flood protection
DGW	National water policy	Integrated projects combining flood protection, water quality and ecology offers opportunities.	Policy making power No budget No enforcement power in the flood protection project	Improve ecological condition Lake Markermeer

NBFD games and outcomes

In the Markermeer dikes case study we identified two NBFD games. At operational level we found the *design game* which was played towards establishing the final design of the shore dike. At collective choice level we found the *project objective game* in which the project objectives were discussed and determined.

The design game

Description of the game. The shore dike was brought up as a conceptual idea in 2009. This concept had to be designed in more detail and required additional research to proof effectiveness of the concept and structure the design. In the design game HHNK and RWS were involved. Both parties developed ideas and research to develop the shore dike using different design rationales. In the design process we identify two moves available for HHNK. The first move is to design the shore dike according to prevailing flood protection principles called the 'Basic Flood Protection' (BFP) shore dike. Flood protection principles involve stability and predictability of the design. The second move is to employ nature-based principles in the design, which would imply allowing for more dynamics in the design and involving vegetation. For the second player, RWS, we also identify two moves. The first move for RWS is to indicate the ecological potential of the shore dike. The second move is to design the shore dike using NBFD principles. This combination of moves reveals four possible outcomes. The payoff matrix of this game is found in Figure 5.

For RWS the outcomes are evaluated on the possibility to combine nature and flood protection (employ a NBFD rational in the design) or include ecological value with the design. Outcome D (RWS designs a shore dike according to NBFD principles and HHNK selects this type of design) is therefore most attractive for RWS. Outcome D would involve implementation of NBFD ideas. Outcome B is second most attractive for RWS as still NBFD principles are employed and chances increase that the ecological potential is used. When HHNK employs a BFP approach NBFD knowledge is of no value but there may still be an option to create ecological potential for example when designing the shore dike in more detail in the continuation of the project. HHNK evaluates the outcomes in terms of having the subsidy granted, i.e. in term of effectiveness of flood protection. As such HHNK is not inclined to employ a NBFD rational in the design. In the design process the added value of a NBFD remained unclear and involving nature or nature-based approached do not yield additional benefits for HHNK.

Explaining the game and outcome. In the game the strategy of RWS is known to HHNK. Conversely, RWS does not know what HHNK will select as the preferred design. During the design process HHNK kept the two options open, but in the end employed a design involving flood protection principles. In this game the two player value opposite outcomes. RWS values a NBFD approach, while HHNK values a BFP approach. Unfortunately for RWS it is HHNK whose move is decisive. NBFD implementation is highly unlikely in this game which is in line with the outcome of the game (outcome A). RWS spend effort on indicating the ecological potential during the game and did not come up with NBFD design for the shore dike. Three factors explain this strategy. First between the RWS synergy project and the HHNK flood protection project a strict division of tasks was employed: flood protection was handled by HHNK and Ecology by RWS. Second financial, knowledge or time resources in the RWS synergy project may have been insufficient. We assume this, because in the last RWS report (Noordhuis and Wichman 2012) it was one of the objectives to include the value of ecology for flood protection, but this was not addressed. Last, one NBFD design option was explored (Smale et al. 2012), but research indicated no feasible route towards a NBFD shore dike.

How to change the game? A number of factors may alter this game and make NBFD more plausible.

- Change valuation by HHNK by giving other evaluation criteria. (see also project objective game in the next section)
- Show added value of NBFD by RWS in order to change the perception of HHNK (not the evaluation criteria)

		HHNK: Basic Flood Protection (BFP) shore dike: Design a shore dike based on flood protection principles	HHNK: Ecological shore dike: Design a shore dike which employs NBFD principles
RWS	Indicate ecological potential of the shore dike design	A 2;4	B 3;1
RWS	Develop a shore dike design employing NBFD principles	C 1;4	D 4;1

Figure 5 Payoff matrix of the shore dike design game in the Markermeer dikes case study using an ordinal 1-4 scale. Outcome A was the outcome in the case study: HHNK designed the shore dike using flood protection principles and RWS showed the ecological value of the shore dike.

The project objective game

Description of the game. The project objective game is a game played at the institutional level, early 2009 and before the shore dike was introduced into the project. DGW and HHNK discussed the possibility of giving the flood protection project a double objective: besides flood projection also an ecological objective. Changing the project objective from single flood protection objective to a double objective would change the institutional setting of the project into a multifunctional project (and thus alter the valuation in the previous game). The game being played is a sequential game involving DGW and HHNK. DGW is the first to take action and has two possible moves: propose a double objective for the flood protection project or alternatively choose to initiate a separate ecology project. In response to a proposal for a double objective HHNK may accept or reject the offer. In response to a separate nature project HHNK may ignore or cooperate with this project. The game has four possible outcomes which are presented in the game tree in Figure 6.

In evaluating the outcomes the main concern for HHNK is meeting the flood protection requirements (criteria for the grant as well as time schedule) imposed by HWBP-2. A secondary factor is the relationship with DGW, which should remain good. HHNK values a double objective low because they fear delays in the flood protection project and there is no clear added value (outcome A). HHNK would reject a proposal for a double objective and stick with a single objective project (outcome B). When DGW initiates a separate project the best option for HHNK is to cooperate: it is low-risk and beneficial for the relationship, moreover possible results might be employed in the flood protection project when useful (outcome C). For DGW a double objective would be the best outcome (outcome A), cooperation for this party is second best (outcome C).

Explaining the game and the outcome. In the game DGW takes the initiative and HHNK responds. The choice by DGW is however not definite. When HHNK is not willing to give the project a double objective DGW can still decide to initiate a separate ecology project. This is what happened in the case study. DGW proposed the double objective, which was rejected by HHNK and thereupon DGW started the ecology project and cooperated with HHNK (outcome C). From a game theoretic perspective outcome C is an equilibrium as can be understood from the corresponding payoff matrix with arrows (Figure 7).

How to change the game? A number of factors may change the game and alter the outcome.

- Also in this game the valuation by HHNK is the result of the HWBP-2 criteria. If these would be different the valuation would change. For example valuing flood protection as much as ecology, or be more flexible in terms of planning.
- DGW compared to HHNK cannot enforce change in this game and has limited power or resources. The game may have changed when DGW could make a financial contribution to the project.

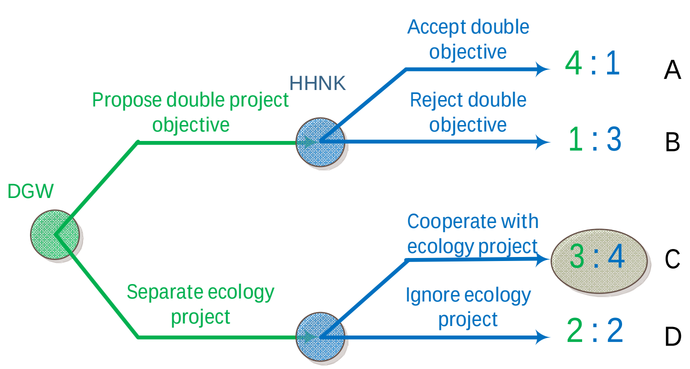

Figure 6 Game three shore dike project objective game in the Markermeer dikes case study

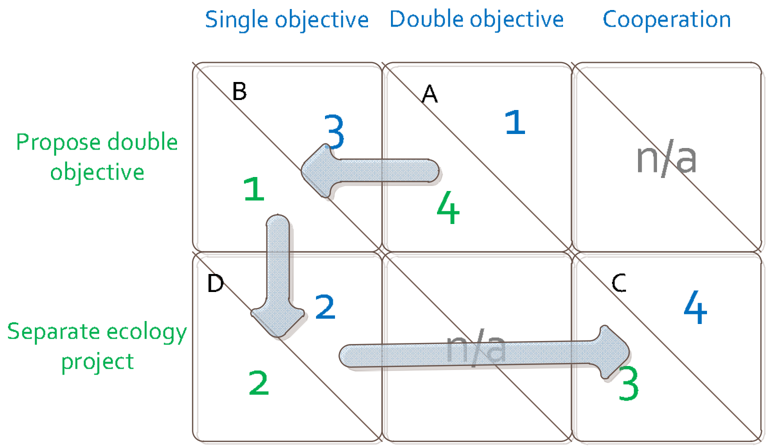

Figure 7 Payoff matrix of the project objective game in the Markermeer dikes case study with arrows indicating outcome C as the equilibrium outcome

5.2 The Afsluitdijk case study

Case study introduction

The Afsluitdijk is a 32 km long dam in the north of the Netherlands which closed off the Zuidersea, now Lake Ijsselmeer, in 1932. After more than 80 years of performance this dam needed a serious makeover to ensure future protection against flooding. In 2007 a project was initiated with an ambition to not just renovate the dam from a flood protection perspective but to do ‘more’ and make it an integral project. ‘More’ involved nature as well as sustainable energy, mobility, economy and landscape values.

The first step in the project was to develop designs for the improvement of the Afsluitdijk. Private firm consortia were challenged to develop innovative designs for the Afsluitdijk. Four diverse integral visions were the result. In parallel, the Ministry of I&M itself composed two flood protection designs. The second step was to assess and evaluate the visions and flood protection designs. In order to do so, the integral visions were split into ‘cores’ and ‘components’. Cores refer to the part of the vision that fulfil the flood protection function while components represent ‘other’ functions such as nature or sustainable energy. Both cores and components were assessed on technical, financial and maintenance feasibility. The last step was to select a preferred design for the Afsluitdijk improvement. In this phase of the project the ministry prepared a final design for flood protection. Responsibility for components was explicitly transferred to other parties, and formulated conditions for including components in the project. Because the development of the components was running behind the flood protection schedule, and financial resources for components were not secured at that point, the Afsluitdijk project continued as a single objective flood protection project.

A separate nature project evolved, the Fish Migration River. This project is the result of one of the ‘components’ in the Afsluitdijk project. It did not become part of the Afsluitdijk project, but was realised in parallel and finally in cooperation with it.

Institutional setting: from multi-objective project to single objective project

At the start of the project in 2007 the ambition of the project was to improve the flood protection function of the Afsluitdijk using an integral approach. The Afsluitdijk did not meet the required flood protection standard which is to withstand a storm with an occurrence of 1/10.000 years. Combining with other function may result in additional economic and societal benefits. The project was a joint initiative of the Ministry of I&M and the two provinces in the region, Friesland and North-Holland.

During the course of the project the focus changed. The Ministry of I&M explicitly stated to be responsible for flood protection by the end of 2010 and that other stakeholders were to realise related functions. The ministry formulated conditions for components to become (again) part of the Afsluitdijk project: these had to be 'substantial' in terms of organisation, content and budget. The provinces left the project team to work on a regional agenda for initiatives related to the Afsluitdijk.

Actors

Actor	Responsibility	Perception	Resources	Interests
Ministry of I&M	The ministry is responsible for providing safety against flooding and keep the Afsluitdijk at the agreed flood protection level.	The need to improve the flood protection level provides opportunities for other functions. Yet, these opportunities are for others to grasp.	Resources available for improvement of the Afsluitdijk dam. Early in the project it appeared as if resources for other functions were available as well. During the project it became clear that financial resources were for flood protection only.	Improve flood protection level, at the same time provide opportunities for other functions such as nature, wind energy, recreation etc.
Province	Spatial development	The Afsluitdijk is best approached as broad project.	Capacity to organise financial resources, initiate plans.	Integrated plan for the Afsluitdijk
Nature NGO's / interest groups	Represent nature interest. Develop nature ideas and designs (later in the project)	The Afsluitdijk forms a destructive barrier for ecology. Improvement of the dam should be combined with restoring nature functions.	Limited resources available. No decision-making power, no financial resources. Ability to organise and assemble different organisations and to generate support for their ideas.	Improve ecological value of the area. Among others by partly restoring the connection between the Waddensea and Lake IJsselmeer.
Private firms consortia	Participate in the Afsluitdijk project by developing innovative designs.	Developing the 'winning' design might result in additional work in the project and international exposure of the firm.	Capacity to develop and work out ideas for the Afsluitdijk project.	Create work for the firm. Participate in integral design 'competition' in order to win and get hired to work on the Afsluitdijk realisation.

Games and solutions

In the Markermeer dikes case study we identified two NBFD games. At operational level we found the design game. At collective choice level we found the project objective game in which the project objectives were discussed and determined.

The design game

Description of the game. A design game at operational level was played between the Afsluitdijk project team and the consortia designing integral visions. In 2008 eight consortia (composed of contractors, consultants and architects) were invited to develop 'an integral outlook for the Afsluitdijk'. The game is about how to design this outlook and how these outlooks are in the end evaluated.

The consortia basically had two possible moves. One move was to strive for 'winning' the 'design competition'[3]. In order to become the winner, the consortium tried to come up with the most innovative, spectacular outlook for the Afsluitdijk. The alternative move was to focus on feasibility and develop the most feasible outlook for improvement of the Afsluitdijk. The Afsluitdijk project team evaluated the outlooks and had two possible moves in doing so. They could evaluate the outlooks using a truly integral focus and consider the Afsluitdijk as an important location for innovation with potential worldwide exposure of a national icon. The second move is to go 'small' and consider the Afsluitdijk merely as a flood protection barrier and evaluate the outlooks in terms

[3] This design process was not an actual competition; however it was experienced as such by consortia.

of flood protection contribution and feasibility of the ideas. The game yields four possible outcomes and is represented the payoff matrix in Figure 8.

In this game the consortia aim for success in terms of acquiring a project assignment by the Afsluitdijk project team or (more indirect) from others clients who may become inspired by their work. Feasibility received less attention also due to the time constrains. Limited time was available to develop the outlooks. The best outcome for the consortia is then the outcome which aligns with the move eventually chosen by the Afsluitdijk project team (outcome A or D). When the move of the consortia does not align with the move chosen by the project team this is a disappointment for the consortia. It limits their chances for success (outcome B or C). An innovative design would then be slightly more attractive as it may yield some international exposure with other potential clients. The Afsluitdijk project team initially advocated an integral project, but when they had to decide on evaluating the outlooks designed by the consortia it turned out that feasibility was important for them and flood protection was the main function. For the Afsluitdijk project team it would be best when the consortia would develop feasible flood protection outlooks.

Explaining the game. The consortia do not know the strategy by the Afsluitdijk project team beforehand. From the project setting (experienced as a competition) they considered developing an innovative outlook the best option for achieving success. While the consortia developed truly innovative outlooks, the Afsluitdijk project team decided to evaluate these using feasibility and flood protection criteria (outcome B). The outcome of the game is for both parties suboptimal. Both outcome A and outcome D would have been a better result. Central to this outcome is the communication on evaluation by the Afsluitdijk project team. Why did the team organise a 'competition setting' and promote an integral project, while in the end evaluating on feasibility and flood protection. One reason may be that the team did not know beforehand how to deal or evaluate the outlooks. Although they had the ambition for being integral and innovative at the start, making it an actual societal accepted project proved much more difficult. Within the team there had been serious debate as to how evaluation should be done. Another reason was that an official cost benefit analyses was required and that objective comparison of the outlooks was needed. It was felt that this could only be done splitting the designs.

How to change the game? A number of factors may alter this game and make NBFD more plausible and also the project outcome more optimal.

- Evaluation criteria used by the Afsluitdijk project team should be clear from the start. This way the consortia can better align with the project team. In the project, the project team could not oversee the consequences of the design process for the evaluation process. This example may serve as a learning experience for other projects.
- Evaluation criteria used by the Afsluitdijk project team could be changed.

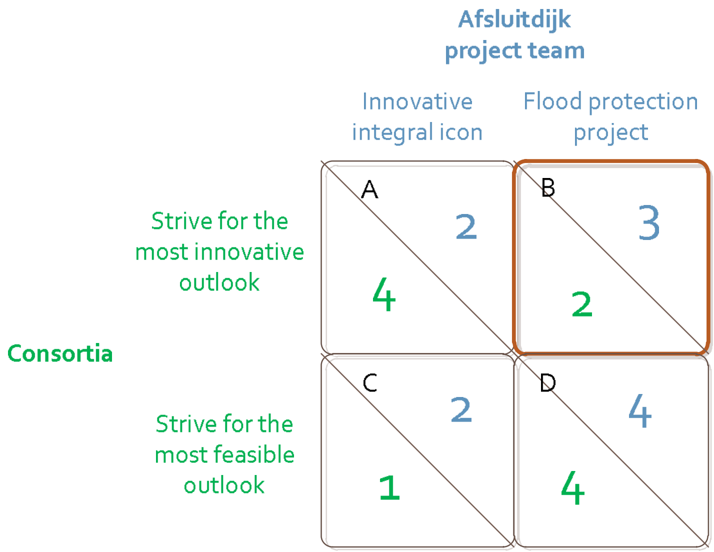

Figure 8 Payoff matrix of the Afsluitdijk design game. Outcome B is the outcome in the Afsluitdijk case study

The project objective game

Description of the game. This game is played at the collective choice level between the provinces and the Ministry of I&M and concerns the focus of the project. In the case study the game lasted over the entire course of the project. Both parties are in the Afsluitdijk project and form a collective project team. The game is a sequential game in which the provinces respond to the move taken by the Ministry. The Ministry has two possible moves: support an integrated project or strive for flood protection alone. The provinces also have two possible moves: stay in the Afsluitdijk project team or initiate a separate project. The game has four possible outcomes which are represented in the game tree in Figure 9.

This valuation of the outcomes by the Ministry changed during the project. At the start of the project (phase 1 in the game tree) the integral ambition was most important, while toward the end (phase 2 in the game tree) the ministry valued flood protection as most important. Therefore in phase 1 outcome A (an integrated project with provinces involved) is the best option. In phase 2 however, priority is given to flood protection. While involvement of the provinces in phase 2 is still appreciated, flood protection is most important.

Explaining the game. The outcome in phase 1 is attractive for both players. In phase 2 the ministry makes it a flood protection project. For the provinces this was a reason to leave the project team. They considered that their objectives could be better achieved outside the project team. Also there was a strong sense of disappointment. The decisive role of valuation becomes apparent in this case study. It led to a totally different solution to the game. In this game it is the Ministry who plays a decisive role. The provinces respond to their actions.

How to change the game? A number of factors may alter this game and make NBFD more plausible.

- Provinces could have indicated the added value of an integrated project or provide added value (for example by financial resources)
- …

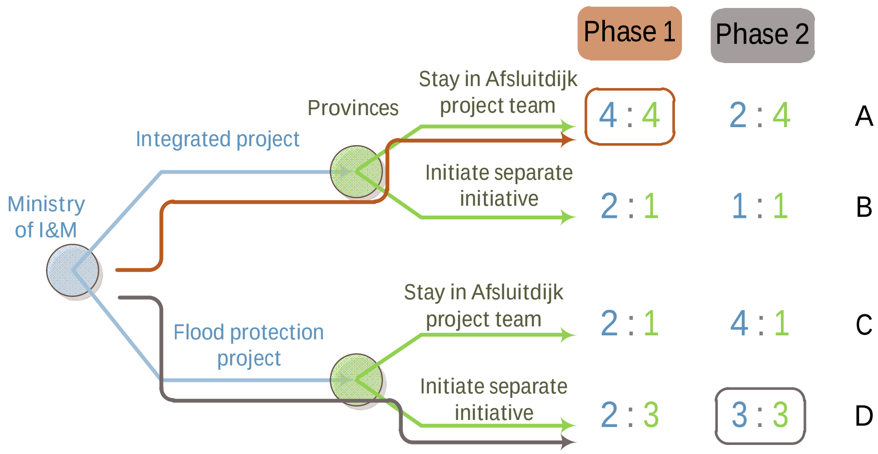

Figure 9 Game tree of the project objective game in the Afsluitdijk case study

The Sand Engine case study

Case study introduction

The Dutch coastline is subject to continuous erosion processes and for that reason about 12Mm3 sand is nourished along the coast every year. In order to make the nourishment strategy more efficient and sustainable the Ministry of I&M explored innovative approaches. One new approach was the ‘sand engine’. The rationale behind this approach is that instead of multiple nourishments on different locations (current policy) a large amount of sand is placed on one location from where the sand can disperse to adjacent coasts. This would lead to less disturbance of the ecology and stimulate natural processes such as dune growth.

The Sand Engine pilot was fully realized in 2011. It was a 21,5 Mm3 sand nourishment attached to the coast of South-Holland for a length of 2 kilometres and an above water area of about 75ha. Out of four different designs the ‘hook-north’ was finally selected and constructed. The nourishment is expected to erode over a period of about 20 years. The sand engine contributes to four objectives: flood protection, recreation, nature and innovation. It is set-up as a pilot and therefore involves significant knowledge development and learning.

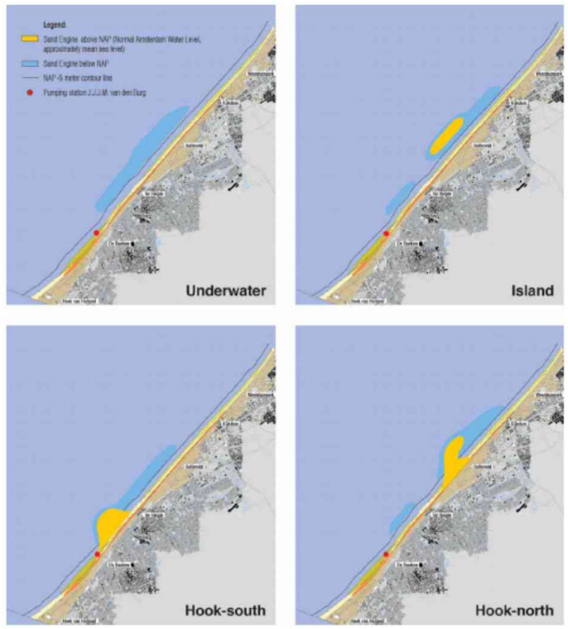

Figure 10 Out of four different designs options, the 'hook-north' was finally selected and constructed.

Institutional setting and actors

The sand engine case study is a multifunctional pilot project.

The project objectives are among others laid down in the ambition agreement and express the intention to combine flood protection, nature, recreation and innovation. These are however described in a general way and are not prioritized. For example, the meaning of 'nature' was not specified in terms of the type, size or location aspired and also 'flood protection' objectives were not specified. The implicit assumption was that any dune growth would contribute to safety and also to nature. Prevailing legislation and policy objectives for both flood protection and nature did not further specify the design, but functioned as boundary conditions: coastline (BKL) erosion and negative impact on the Natura2000 site were to be prevented.

Nine parties signed the ambition agreement (2008) in which they agreed to work on the realisation of the sand engine (the Ministry of I&M, the province of South-Holland, three municipalities, a waterboard and an NGO), but the main actors are the Ministry of I&M, Rijkswaterstaat (RWS) and the province. The ministry of I&M was a great supporter of the sand engine and financed most of it. The Province also made a financial contribution and was the leading party during the planning phase (2008-2010). RWS was the leading party during the construction phase. While RWS is the main party responsible for regular coastline maintenance, their part in this pilot project was significantly smaller.

Actor	Responsibility	Perception	Resources	Interests
Ministry of I&M	The ministry is responsible for coastline policy	The sand engine is a good opportunity to experiment with an innovative nourishment approach	The Ministry paid for 83,3% of the sand engine. The Sand Engine was financed by budget for innovation instead of coastline maintenance budget.	Interested in innovative solutions for coastline policy
Rijkswaterstaat (RWS)	Responsible agency in the Ministry of I&M for executing	The sand engine should be designed cost-effective, efficient and	Financial resources for executing sand nourishment policy, however not for the sand	Knowledge development for long-term coastline maintenance.

	coastline policy	predictable.	engine experiment. Ample experience and knowledge on coastal nourishments. Responsible for coastline maintenance.	(cost-) efficient and effective nourishment programme to maintain the coastline. Leading construction phase of the sand engine.
Province	Spatial development in the province. Leading party during planning phase of the project.	The sand engine makes the province more attractive. It contributes to green recreational space and will bring exposure.	The province financed 16,7% of the sand engine. The province was in the lead during the planning phase.	A visible sand engine accessible for recreants and with exposure for the province. Creating space in the crowded province.

Games and solutions

The design game

A design game was played between Rijkswaterstaat and the province during the planning phase and evolved around the selection of the preferred design out of the four design options. What a sand engine was and what it would look like was not clear at the start of the project in 2008. In the design process four possible sand engines were developed: the hook-north, hook-south, the island and a nourishment under water. Hook-south and the island were both unfeasible: the construction of hook-south would involve removing a recently restored pumping station, the island would be dangerous to recreants. As a result RWS had two options left: the nourishment under water, and the hook-north. The first was most attractive. This option was cheaper, most cost-efficient and the behaviour of this nourishment could best be predicted. The hook-north was considered inefficient and with some significant uncertainties. For the province however a nourishment under water was of no value. The province aimed for new land and a visible solution. The province only wanted to participate in a visible sand engine, if this was not possible they prefer withdrawing from the project. The payoff matrix is shown below. If the province would withdraw, RWS may continue without the province.

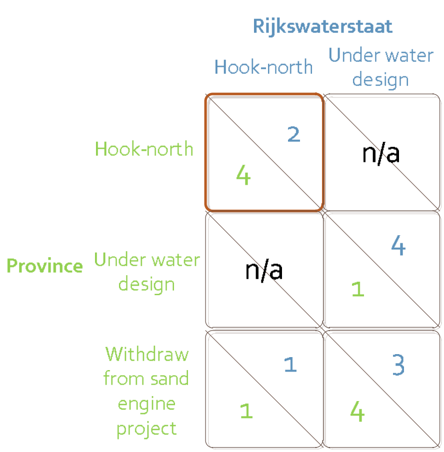

Figure 11 Design game between Rijkswaterstaat and Province in the Sand Engine case study

Solution to the game

Two factors determined the outcome of the game. Importantly RWS was overruled by the Ministry of I&M. The state secretary decided to spend money on the project and to cooperate with the province. Had the ministry not taken this step, RWS may have taken another route than agreeing with hook-north. Another factor is that the uncertainties in the design were taken care of. RWS was worried about the possible erosion of the coastline which would require additional maintenance effort. Therefore side-nourishments alongside the sand engine were located to prevent possible erosion.

Discussion NBFD games and outlook

So far we have looked into three games that were played in three case studies: two mono-functional routine projects and one multi-functional pilot project.

- In all case studies we found design games being played. In the Markermeer and Afsluitdijk case studies the issue of multifunctional versus mono-functional was central in the design game. In both case studies the game was decided by the flood protection party (HHNK and the Ministry of I&M respectively) having the power (money) to do so and for whom multifunctionality had limited or at least less value than a mono-functional design. How possible outcomes are valued is crucial for the outcome of the game and this can also change, as was demonstrated in the Afsluitdijk case study.
- The design game in the sand engine project is somewhat different. Here the discussion was not necessarily about mono- versus multifunctional designing. What we saw in this game is that Rijkswaterstaat values other aspects of the sand engine design than the province. In order to solve this game a third party was needed. The Ministry overruled Rijkswaterstaat and determined the outcome.
- The games at institutional level are equally or even more important than the games at project level as these games determine the valuation of outcomes in the project games. In both the Markermeer and the Afsluitdijk project we reconstructed these games[4]. In both games the flood protection party decided the game.
- In order to perform a meta level analysis of NBFD games analysis of additional case studies is required. Especially case studies that are played under similar institutional settings. Instead of looking for any game in the case studies it may be interesting to particularly look into the design game and the project objective game, as these games were already found in the above case studies.
- The use of game theory so far has resulted in a structured overview of actor interactions and it has highlighted the difference between games at project level and games at institutional level. Constructing the games however, does not yet provide the solutions to the game. For example the Sand Engine design game has two likely outcomes and without interference of the Ministry the outcome of the game might very well have been different. Another thing is that games may change during the course of the project (i.e. the valuation of possible outcomes and thereby likely solutions), especially when games at institutional level are being played.
- At this point we have not yet employed the ideas of cooperative game theory. One of the following steps in our research is to use cooperative game theory to indicate the added value of cooperation among players.

[4] The game at institutional level must have been played in the Sand Engine case study as well. However, we do not have data to reconstruct this game. This game was played prior to the ambition agreement in 2007.

References

Borsje BW, Bouma TJ, de Vries MB, Timmermans JS, Vuik V, Hermans LM, Jonkman SN (2014) BE SAFE: Bio-Engineering for Safety using vegetated foreshores. http://www.citg.tudelft.nl/uploads/media/Poster_BE_SAFE.pdf.

Borsje BW, van Wesenbeeck BK, Dekker F, Paalvast P, Bouma TJ, van Katwijk MM, de Vries MB (2011) How ecological engineering can serve in coastal protection. Ecological Engineering 37 (2):113-122. doi:10.1016/j.ecoleng.2010.11.027

Bouma TJ, van Belzen J, Balke T, Zhu Z, Airoldi L, Blight AJ, Davies AJ, Galvan C, Hawkins SJ, Hoggart SPG, Lara JL, Losada IJ, Maza M, Ondiviela B, Skov MW, Strain EM, Thompson RC, Yang S, Zanuttigh B, Zhang L, Herman PMJ (2014) Identifying knowledge gaps hampering application of intertidal habitats in coastal protection: Opportunities & steps to take. Coastal Engineering 87:147-157. doi:10.1016/j.coastaleng.2013.11.014

Brugnach M, Dewulf A, Pahl-Wostl C, Taillieu T (2008) Towards a relational concept of uncertainty: about knowing too little, knowing too differently, and accepting not to know. Ecology and Society 13 (2):30

De Vriend HJ, van Koningsveld M, Aarninkhof S (2014) 'Building with nature': the new Dutch approach to coastal and river works. Proceedings of the Institution of Civil Engineers 167 (CE1):18-24

Dewulf A, Brugnach M, Termeer C, Ingram H (2013) Bridging Knowledge Frames and Networks in Climate and Water Governance. In: Edelenbos J, Bressers NEW, Scholten PHT (eds) Water Governance as Connective Capacity. Ashgate, Farnham, Surrey, pp pp. 229-247

Dijkema KS, Van Duin WE, Dijkman EM, Nicolai A, Jongerius H, Keegstra H, Jongsma JJ (2013) Friese en Groninger kwelderwerken: Monitoring en beheer 1960-2010. vol WOT rapporten. Wettelijke Onderzoekstaken Natuur & Milieu, Wageningen

Enserink B, Hermans LM, Kwakkel JH, Thissen W, Koppenjan JFM, Bots P (2010) Policy analysis of multi-actor systems. Boom/Lemma, The Hague, the Netherlands

French PW (2006) Managed realignment – The developing story of a comparatively new approach to soft engineering. Estuarine, Coastal and Shelf Science 67 (3):409-423. doi:http://dx.doi.org/10.1016/j.ecss.2005.11.035

Gedan KB, Kirwan ML, Wolanski E, Barbier EB, Silliman BR (2011) The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. Climatic Change 106 (1):7-29. doi:10.1007/s10584-010-0003-7

Hermans L, Cunningham S, Slinger J (2014) The usefulness of game theory as a method for policy evaluation. Evaluation 20 (1):10-25

Janssen SKH (2015) Greening Flood Protection in the Netherlands. A knowledge arrangement approach. Wöhrmann Print Service, Zutphen, The Netherlands

Janssen SKH, Mol APJ, Van Tatenhove JPM, Otter HS (2014a) The role of knowledge in greening flood protection. Lessons from the Dutch case study future Afsluitdijk. Ocean & Coastal Management 95 (0):219-232. doi:10.1016/j.ocecoaman.2014.04.015

Janssen SKH, van Tatenhove JPM, Otter HS, Mol APJ (2014b) Greening Flood Protection—An Interactive Knowledge Arrangement Perspective. Journal of Environmental Policy & Planning:1-23. doi:10.1080/1523908X.2014.947921

Korbee D, Mol APJ, Van Tatenhove JPM (2014) Building with Nature in Marine Infrastructure: Toward an Innovative Project Arrangement in the Melbourne Channel Deepening Project. Coastal Management 42 (1):1-16

Korbee D, Van Tatenhove JPM (2013) Environmental Governance for Marine Infrastructure: Enabling and Constraining Conditions for Ecodynamic Development and Design in Marine Infrastructural Projects. Journal of Environmental Policy and Planning 15 (4):533-550. doi:10.1080/1523908X.2013.807211

Moller I, Kudella M, Rupprecht F, Spencer T, Paul M, van Wesenbeeck BK, Wolters G, Jensen K, Bouma TJ, Miranda-Lange M, Schimmels S (2014) Wave attenuation over coastal salt marshes under storm surge conditions. Nature Geosci 7 (10):727-731. doi:10.1038/ngeo2251 http://www.nature.com/ngeo/journal/v7/n10/abs/ngeo2251.html#supplementary-information

Nash JF (1951) Non-cooperative Games. Annals of Mathematics 54:286-295

Noordhuis R, Wichman BGHM (2012) Ecologische uitwerking van het oeverdijkconcept. Op basis van ecologische uitgangspunten en grove inschatting waterkeringsveiligheid. .

Ostrom E (2005) Understanding Institutional Diversity. Princeton University Press, Princeton NJ

Rasmusen E (2007) Games and information: an introduction to game theory. 4th edition. Blackwell Publishing Ltd, Malden, MA

Scharpf FW (1997) Games Real Actors Play: Actor-Centered Institutionalism in Policy Research. Westview Press, Boulder, CO

Schelling TC (2010) Game theory: A practitioner's approach. Economics and Philosophy 26 (1):27-46

Smale AJ, De Vroeg H, Capel A (2012) Meerwaarde luwtestructuur voor de oeverdijk. Deltares,

Straffin PD (1993) Game theory and strategy. The Mathematical Association of America, Washinton, DC

Temmerman S, Meire P, Bouma TJ, Herman PMJ, Ysebaert T, De Vriend HJ (2013) Ecosystem-based coastal defence in the face of global change. Nature 504 (7478):79-83. doi:10.1038/nature12859

Van Buuren MW (2009) Knowledge for governance, governance of knowledge: Inclusive knowledge management in collaborative governance processes. International Public Management Journal 12 (2):208-235. doi:10.1080/10967490902868523

Van den Hoek RE, Brugnach M, Hoekstra AY (2012) Shifting to ecological engineering in flood management: Introducing new uncertainties in the development of a Building with Nature pilot project. Environmental Science and Policy 22:85-99. doi:10.1016/j.envsci.2012.05.003

Van Loon-Steensma JM, Vellinga P (2013) Trade-offs between biodiversity and flood protection services of coastal salt marshes. Current Opinion in Environmental Sustainability 5 (3-4):320-326

Vreugdenhil H, Slinger J, Thissen W, Rault PK (2010) Pilot projects in water management. Ecology and Society 15 (3)

Walker WE, Harremoës P, Rotmans J, van der Sluijs JP, van Asselt MBA, Janssen P, Krayer von Krauss MP (2003) Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. Integrated Assessment 4 (1):5-17. doi:10.1076/iaij.4.1.5.16466

Yin RK (2009) Case study research: Design and methods (4th Ed.), vol 5. Applied social research methods series. SAGE, Thousand Oaks, CA