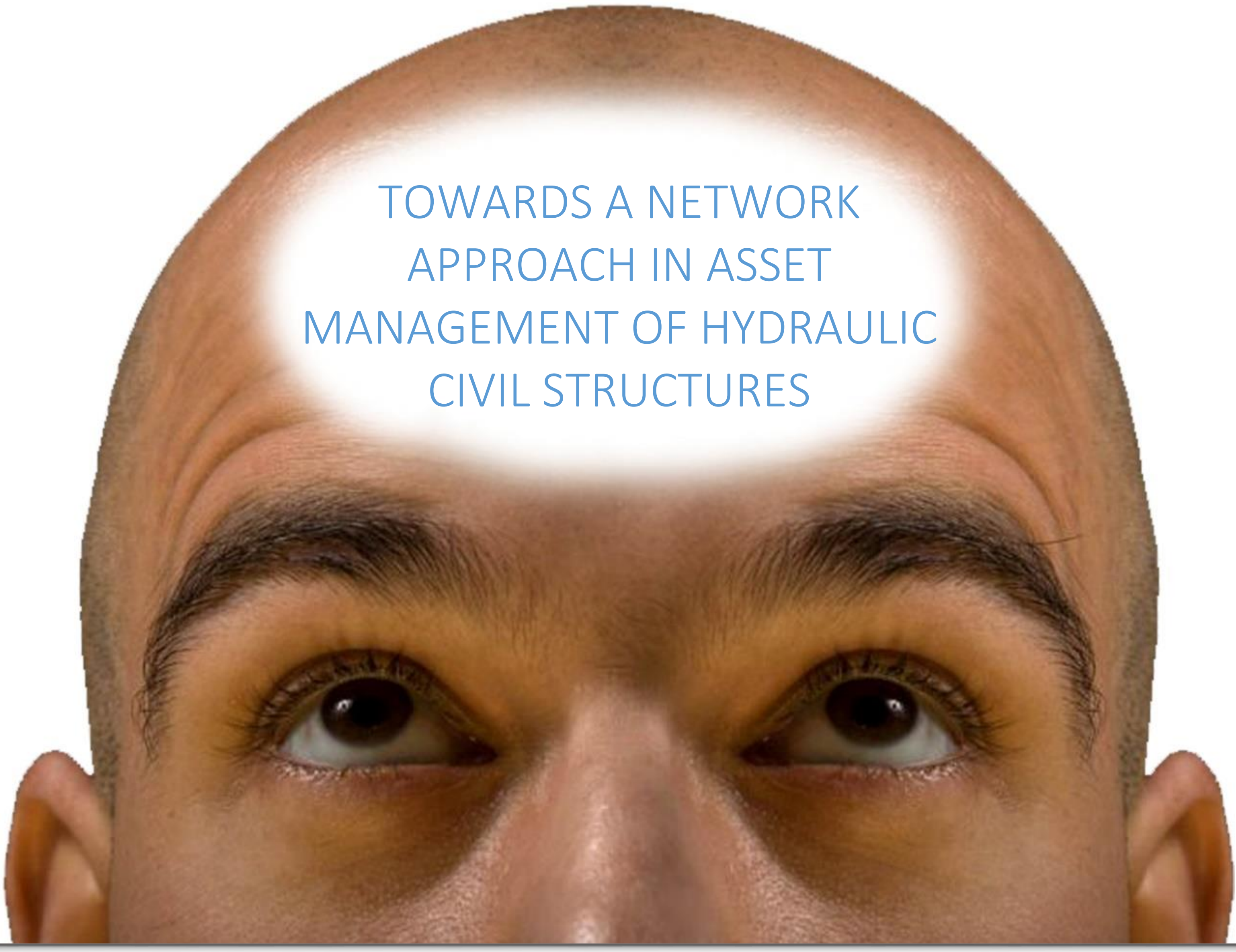
MAARTEN VISSERS

TOWARDS A NETWORK APPROACH IN ASSET MANAGEMENT OF HYDRAULIC CIVIL STRUCTURES



TU Delft

Deltares
Enabling Delta Life

Towards a network approach is Asset Management of Hydraulic Civil Structures

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Construction Management and Engineering
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“Everything we hear is an opinion, not a fact.
Everything we see is a perspective, not the truth.”

- Marcus Aurelius

Preface

Carrying out my graduation research felt like being on a heroic adventure. A journey in which I needed to discover my academic mission. What I desired was clear from the start: receiving a Master's Degree. However, the path to achieving this goal proved to be a journey without a clear direction. It was weird to get lost in a quest that I created myself. Like any great adventure, it came down to defeating a fierce monster, in order to achieve what I desired. This monster I needed to defeat, is the document you are reading now. However, since I am done with it, it is not as scary as it used to be. The monster showed great similarities with the mythical Hydra. Every time I cut down a problem, three additional problems came up. However, not like the heroes in most adventures, I am just a mortal being with no superpowers. This was not necessary, since I luckily had the help of a great group of colleagues and friends to finish this monster.

First of all, I would to thank Maaike and dad for all the support and patience, and especially Jeroen and mom for correcting my work. Secondly, I would like to thank Joris, Terry, Q, Xander, Rutger, Bram, Ben, Rinze, Dennis, Wouter Jan, Yvo, Roman, Pieter, Kieft, Elise, Roland, Carolien, Twan, Matthijs, Peta, Ewout, Hoyte, Fitch, Hugo, Bart, Rens and Wouter for helping me with my report or Management Game. Thirdly, I would like to thank all my colleagues at Deltares, the TO2 study and ROBAMCI, for all the learning experiences I gained from them. Fourthly, I would like to thank the interviewees from Rijkswaterstaat, Hoogheemraadschap Holland Noorderkwartier, Rijnland en Waternet. Last but not least, I would like to thank my graduation committee, for all the time and effort they put into guiding a stubborn bastard like myself.

Even though it was tough at times, I look back satisfied on this adventure. It was one of the most interesting learning experiences I have had so far. Maybe a book will be written about it someday.

Maarten Vissers

The Hague, February 2016

Executive summary

In the Netherlands there are thousands of hydraulic civil structures (HCS). HCS are crucial for the functioning of the multiple purposes of the water networks. The most common known HCS are: Locks, weirs, storm surge barriers, water pump stations, culverts, bridges and tunnels. The HCS in The Netherlands have for a large part been realized halfway through the 20th century. Most of these HCS are designed for a service life of 75-100 years. HCS can reach its technical of functional end of service life, due to wear and deterioration or when the functional demand on a HCS outgrows its functional capacity. Therefore, most of the HCS need to be rehabilitated or replaced at some point in the 21st century. HCS are managed by means of Asset Management. The Asset Management of the HCS in The Netherlands is regionally and functionally divided over multiple organisations. The organisations that perform Asset Management in the Netherlands are Rijkswaterstaat (RWS), waterboards, provinces and municipalities.

Thus, the rehabilitation or replacement of HCS exceeds the scope of a single organisation. Every decade, dozens of HCS reach their end of service life in the Netherlands. The total cost can reach up to billions of euros over de next decades. Generally, HCS are financed, owned, operated and maintained by public organisations. The high construction costs of HCS make the rehabilitation or replacement task an *economic issue* for these organisations. The Dutch water network is full of interdependencies and the HCS are key functional assets in the network. Consequently, the end of service life of the HCS creates an opportunity to redesign the layout and functionality networks. This makes the rehabilitation or replacement task also a *functional issue*. If the complete task will be executed as organisations currently do, all HCS will be one by one independently rehabilitated or replaced. This 'object approach' has the risk of overspending and a limited effectiveness.

The proposition of this research is that a 'network approach' in the Asset Management of HCS has an action perspective with better economic and functional scenario for the Netherlands, compared to the current object approach. The ROBAMCI study, executed by Deltares in cooperation with 16 institutional and commercial partners, estimates that Asset Management improvements in the water sector, have the opportunity to save up to 20% of the total cost (Den Heijer, 2015). Not only is it expected that a network approach has an impact on the action perspective of the Asset Management organisation, it is also expected that a network approach impacts the decision making process. Considering the complete network and its action perspective, this implies that the multiple Asset Management organisations involved in this network, have to be involved in the decision making process as well.

On the basis of the research proposition, the following research question is formulated: *How can a network approach be beneficial to the future rehabilitation or replacement of the hydraulic civil structures in the Netherlands?*

The first method this research uses is a literature and background study. This study is used to set-up a theoretical framework. Focal point of the theoretical framework are the causes and effects concerning the action perspective and the decision making process, in an object approach and a network approach. In addition to the theoretical framework, on the basis of literature and background study a possible strategy to establish a network approach is addressed and formulated. The second method that is used, is a case study. This study is executed to test the theoretical framework and to supplement the framework with empirical data, based on in-depth interviews with experts of the case. As a last method a management game has been designed and tested, in order to test the proposed strategy. The case situation forms the basis of the design of the management game. The case has been tested multiple times, to analyse whether it has the desired impact.

In the literature and background study the following theoretical framework is established:

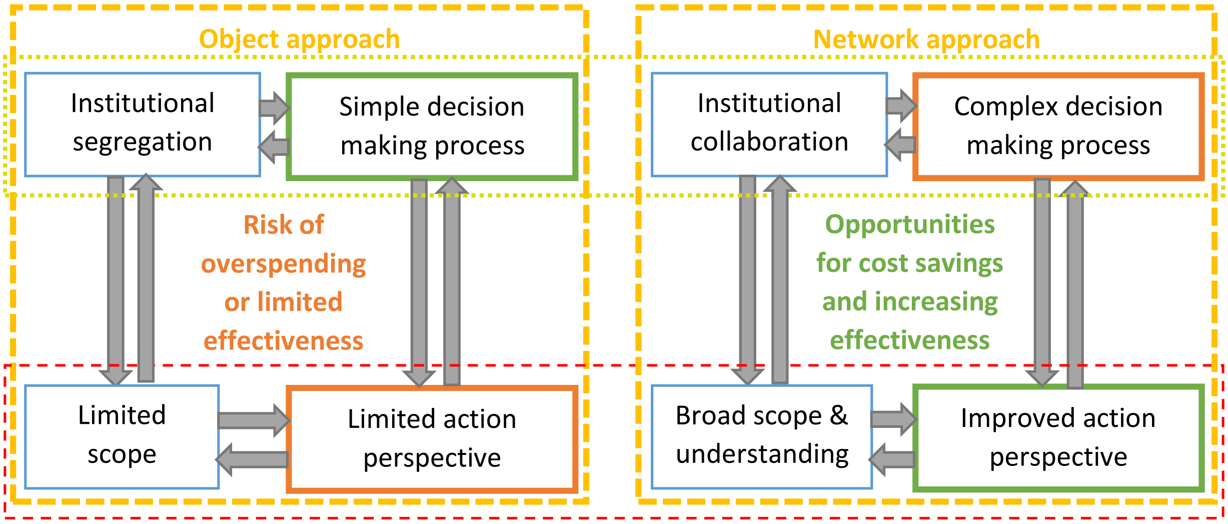


Figure A Theoretical Framework: Abbreviated version (own illustration)

The blocks at bottom left of both approaches in Figure A, discuss the scope of the organisations in these approaches. It is determined that the scope of organisation operating Asset Management on HCS with an object approach, is too limited for appreciation of the technical complexity of the water network and high uncertainty of the future developments. With interventions that have long term effects, an object approach is incapable of addressing the complete scope of problems and opportunities. The broad scope of a network approach helps understanding this technical complexity and future developments.

The blocks at bottom right of both approaches in Figure A, discuss the action perspective of the organisations in these approaches. The limited scope of an object approach, limits the action perspective. There is no network wide change possible in this limited action perspective. Additionally, the limited action perspective entails a risk of overspending or limited effectiveness. The risks are the effects of lock-in situations, problem shifting and overinvestment. Due to the broad scope and understanding in a network approach, an improved action perspective emerges. The new alternatives make network-wide changes possible and can minimizes the risk. Furthermore, these new alternatives provide opportunities for synergy advantages.

The blocks at top left of both approaches in Figure A, discuss the institutional structure in these approaches. In an object approach the governance of HCS is segregated on a geographical and functional level. The organisations operate as if their regions are isolated, because the water systems beyond their regional borders are beyond their authority. On functional level the organisations do not have broad perspective, because this is not within their interests. Collaboration between the different Asset Management organisations is key for a network approach. In order to ensure collaboration the institutional segregations need to be overcome. Geographically, the focus on isolated regions needs to make way for the an integral focus on the network. Functionally, the organisations need to address the mutual interdependencies, instead of their own interest.

The blocks at top right of both approaches in Figure A, discuss the decision making process in these approaches. The institutional segregation provides a structure for the decision making process by setting clear responsibilities, liabilities, budgets and mandates for the Asset Management organisations. It can be stated that there is a simple decision making process in the object approach. Wicked problems and asymmetric information division, unclear liability and high controversy risk, split incentive and sluggish actions, all emerging in a network approach, can have a paralyzing effect on the decision making process. All the consultation and alignment between the different organisations in this approach, create a sluggish decision making process.

On the bases of the literature and background study, it can be concluded that:

- A object approach has a simple decision making process towards local actions with risk on disadvantageous effects. This has the risk of overspending or limited effectiveness.
- A network approach has a complex decision making process towards network broad interventions with opportunities on synergy. The network approach has opportunities for cost savings and increased effectiveness.

Asset management of HCS is typically hierarchically performed in three organisational layers, as shown in the Figure B. In the strategic (top) layer the functionality and necessary performance level of a water network is determined. In the tactical (middle) layer, interventions are prioritised and budgets are determined for rehabilitation or replacement of HCS. In the operational (bottom) layer the performance and failure risk of the HCS is actively monitored, and based on this monitoring data, operation and maintenance regimes are determined.

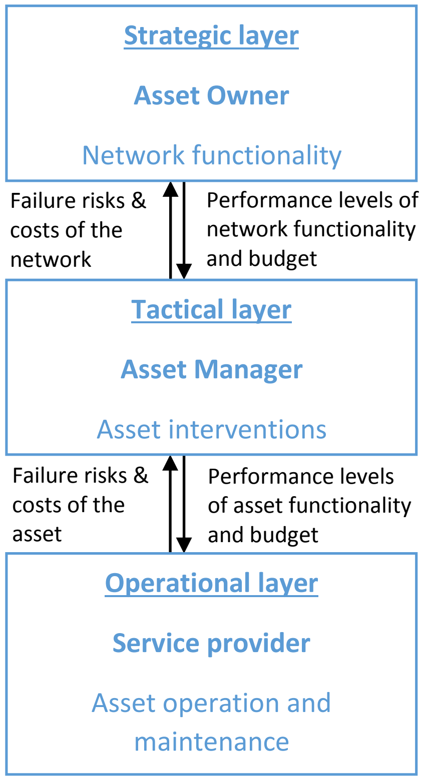


Figure B Organisational structure of Asset Management (Den Heijer, 2015)

The object approach in Asset Management is a system with a self-sustaining feedback loop, which is difficult to abandon. The best opportunity to achieve this, is by making organisations together recognize shared problems. Subsequently, the limitations of the current governmental structure and knowledge about future plans and outcomes can be aligned. Through alignment of the frame of perception on the problems, a network approach can emerge. Gradual problems like the rehabilitation and replacement of HCS, do not create the a collective problem perception by itself. Framing can be used in order to create a collective problem without the presence of a catastrophic event. Framing is a method for managing perceptions and creating awareness and possible support for a particular frame of perception. Through a frame, different ideas from different organisations can be matched. A shared problem frame is best established at the strategic layer of the organisational structure and implemented top-down. This layer has the authority and resources to establish a network approach and has the broadest network scope for identifying alignment opportunities.

Merely having a strategy for top-down implementation, does not necessarily result in implementing a network approach. Also, in the operational layer the frame of perception of the organisations, should be in line with the organisational changes. An effective tool for overcoming institutional segregation, is a management game. A management game is an informal arena, in which organisations actively participate in a simulation of a complex network, comparable to their field of work. In this simulation learning objectives can be conveyed to the participants. The simulated reality in the game should be based on experiences of the operational layer of the governmental structure, because in that layer the impacts of the complex effects in the network are known best. In addition, composing the game in the reality of the operational layer, contributes to the acceptance of the problem frame. A management game is a proper method to create an alignment of the frame of perception between the different organisation layers in a bottom-up fashion. This way the network approach has the support of every organisational layer.

The following strategy is proposed by this research as a strategy to establish a network approach: *"Framing from the top, gaming from the bottom".* The objective of this strategy, is to align the frame of perception of all organisations, from both the horizontal and vertical direction of the institutional structure, in order to successfully implement a network approach. Establishing of the frame should take place horizontally in the strategic layer and should be implemented top-down in the vertical direction of the governance structure. The tool of this strategy is a management game. This game incorporates the frame as learning objective and uses operational layer experiences for the simulation. The intension is, that this game is established bottom-up and gets to be played by all organisational layers.

A case study is executed to explore the field of Asset Management of HCS in practice and to create a frame, that can be used as a learning objective in the game. The experiences of the case will form the basis for the simulation of the game. The structure of the four topics of the theoretical framework is used as structure for the execution of the case study analysis. This analysis consists of an elaborate documentation research and in-depth interviews with seven experts of the case field.

The case study is about the water network surrounding the pumping station complex at IJmuiden. It concerns the water discharge of the Noordzeekanaal/Amsterdam-Rijnkanaal. The water network is under functional pressure and supposedly the pumping station at IJmuiden has reached its end of functional service life. The study focusses on the current Asset Management practices and what the implications are of a network approach in the situation of this case. The network is technically complex and there are multiple organisations responsible for the Asset Management of HCS. Therefore the case proved to be suitable for this research.

On the basis of the case study, some new insights were obtained:

1. In the case it is not unequivocally determined when there is a functional end of service life.
2. The case situation does not have an object approach as strictly as the theoretical framework describes.
3. The rehabilitation or replacement of HCS is not perceived or addressed as a shared problem.
4. The additional actions that emerge in a network approach can be categorized.
5. Underinvestments occur in the case situation.
6. RWS and the waterboards count on each other to come up with a solution for the network problems.
7. Interdependencies in the network can differ per organisational layer.
8. The waterboards in the case situations have internally quite some issues, due to public involvement.
9. There seem to be more issues that influence the decision making process, than determined in the theoretical framework.

By means of designing and testing of the management game pilot, it is tested if this tool can achieve an alignment of the frames of perception of its participants. The management game was developed in four phases, with iterative feedback and try-out sessions with gaming experts, water resource management experts and students. The frame that the management game intends to convey to its participants as a learning objective, is the idea that the rehabilitation or replacement of HCS is a shared problem in the tactical layer. The gaming simulation is a simplified representation of the network of the case study. The management game pilot, named "Deltego", is played by four participants that take on the role of the water resource manager. The participants have conflicting interests, but through collaboration a better result for the group can be attained. Through the gaming experiences, the game intend to convey the its learning objective on its participants.

In total three game sessions of Deltego were executed for this research. One session with experts of Deltares and two sessions with students, that had profound knowledge on the topic. An analysis was made of the in-game actions that the players performed, and of the feedback forms the players handed in after the game. On the basis of these analyses, is can be concluded that, the game was able to convey its learning objectives on its participants. Consequently, it managed to create a shared frame of perception on the problems. However, on the basis of three gaming sessions without participants that do not make the decision of the game in real-life, it is too far-reaching to conclude that, through Deltego, a network approach will be established on all organisational layers.

On the basis of the results of all methods, the main question of the research can be answered: *How can a network approach be beneficial to the future rehabilitation or replacement of the hydraulic civil structures in the Netherlands?*

A network approach can be beneficial to the future rehabilitation or replacement of HCS in The Netherlands, whenever collaboration takes place between the responsible organisations. A network approach has opportunities for substantial cost savings or an increased effectiveness. Collaboration can be established by introducing a shared problem frame on the responsible organisations. However, the feasibility of this strategy cannot be determined on the basis of this research. Alignment of the frame of perception of the problems can be achieved by means of a management game. Even though the results of the game sessions were promising, is too far-fetched to conclude that the alignment will also take place in organisations and between organisations in real-life on the basis of this research.

To draw more far-reaching conclusions on the feasibility of the network approach, it is recommended to perform additional research on the following subjects:

- Application of the management game on a larger scale and in practice.
- Perform an in-depth research into the rehabilitation or replacement of specific types of HCS.
- Research the possibilities and limits of inter-organisational Asset Management.
- Research the feasibility of the proposed strategy.
- Deepen out role of trust in the theoretical framework provided by this research.

Table of content

List of definitions and abbreviations

The following list of definitions and abbreviations are specified for this research. Some of the terms have various definitions in different context or other terms might be applicable for these descriptions. Nonetheless the below definitions will be used in this research.

Term	Definition	Page
Action Perspective	A range of possible actions on which a decision can be made. An action is in that case the product of an action perspective.	4
Arena	An informal space of interaction between the different organisations, that stimulates collaboration, so organisations learn the standpoints of each other and are able to share a common frame.	34
Asset	HCS, as a tangible element of infrastructure.	3
Asset Management	Coordinated activities (operation and maintenance) of an organisation to realize life cycle value from assets in delivery of its objectives.	3
Coding	A method of naming fragments by giving them a summarising label. It is a method to make sense of the data from theoretical perspective through segmenting and reassembling.	39
Construction Combination	The clustering of different construction projects. A surplus in resources on one project can help a shortage in another.	20
Decision making process	A process that consists of phases in order to reach a decision. These phases are: the determining of a problem or an opportunity, determining the action perspective, determining the effects of alternative actions and finally making a decision. A decision is the product of a decision making process, however a decision making process does not necessarily result in a decision.	4
Delta Program	A national program that helps to prevent The Netherlands from flooding and makes sure that there is sufficient fresh water in the future.	4
Dialogues of the deaf	Communicating parties are unresponsive to the arguments of one another.	28
Discharge Water	A water used to discharge water. (Not to be mistaken with 'water discharge')	43
Dutch Layers Approach	A model that divides the spatial layout into three different layers, that have all their own time dynamics: The ground layer, the network layer and the occupation layer.	15
Earmarked budget	Budget that is reserved for a certain purpose.	26

Economies of scale	Whenever the total scale becomes greater, the unit price becomes cheaper.	20
Economies of scope	Due to the wider scope of a network perspective, the physical and functional cohesion of the network can be identified.	20
Effectiveness	The extend to what degree a solution complies to the (future) requirements.	6
Efficiency	No unnecessary resources are wasted in order to achieve the desired effect.	6
Exploitation combination	Different interventions for multiple functions can be clustered in a central intervention.	20
Failure risk	The probability of a failure taking place, relative to the impact of the failure.	3
Feasibility	The capability to accomplish something. In the context of this research, the feasibility of the proposed approach is determined by the ability to reach a decision.	4
Frame of Perception	The result of an interpretation and valuation process that consists of assumptions, interests, values and beliefs. The frame of perception provides a simplification of the problem or opportunity, and in this way leads to a limited scope of this problem or opportunity.	13
Framing	A method for managing perceptions and creating awareness/ support for a particular presented frame of perception.	32
Functional end of service life	A moment in time when the functional demand on a HCS outgrows its functional capacity. It is possible that a HCS reaches its functional end of service life, even though it is still in a good technical condition.	2
Game Theory	An economical theory that describes that, in order to achieve the best results for the group, collaboration is needed instead of competition	58
Greenports	These are high quality and sensitive agriculture fields, like flower bulbs.	121
HCS	Hydraulic civil structure(s) (in Dutch: Natte Kunstwerken): Key infrastructure constructions that are necessary for the realisation and operation of a function of the water network. HCS are usually located on important intersections.	2
I&E	Ministry of Infrastructure and Environment in The Netherlands.	23
Legitimacy	The effectiveness and acceptance by external stakeholders of policy outputs.	28

Line of sight	The whole organisation, from top till bottom, complies to the same goal. This is usually ensured by proper communication between the different layers.	22
Lock-in situation	Developments are stuck to only one situation (or path), in order to meet the future requirements. It is exceptionally expensive or impossible to deviate from this situation. Lock-in situations are also known as path dependence.	17
Main Water System	All main open waters that are maintained and operated by RWS. This includes all types of functions.	4
Management Game	A form of an arena in which organisations actively participate in a simulation of a complex network.	34
Meaning	Learning objectives of management game	34
NAP	Nieuw Amsterdams Peil: Unit that is used for measuring the water level. All water level in The Netherlands are measured relative to the fixed ground water level of Amsterdam.	44
Network Approach	Asset Management of HCS in consideration of the network and its stakeholders. These are defined by the functional context of the HCS. A network approach is also referred to as a corridor approach.	6
Object Approach	The object oriented approach of Asset Management of HCS that is currently performed by the Asset Management organisations. This approach does not consider the HCS in their network context, nor the other Asset Management organisations in the network. The object approach ultimately results in rehabilitation or independently replacing all HCS.	6
Overinvestment	The intervention is overly dimensioned and for this reason too many resources are invested on this intervention	18
Performance	The extent to which and asset meets the required function. This is mostly measured by the means of a performance level.	3
Performance Level	Indicators that are used to measure the performance of assets.	3
Poldering	A Dutch expression for working together and reaching compromises	115
Primary Waterways	Important waterways that are state owned transport routes.	4
Probes	Responsive follow up questions designed to elicit more information in an interview. Can be non-verbal.	39
Problem Shifting	The risk of transferring the problems to other parts of the network with an intervention. The positive impact on performance from interventions is experienced locally or user	18

	specific, whilst elsewhere or by different users the negative impact is experienced.	
Report Wars	Organisations strategically share information in order to win an argument.	28
RWS	Rijkswaterstaat: The executive organisation of the Dutch ministry of Infrastructure and Environment. It is responsible for the maintenance and operation of all state owned roads and waterways.	3
Socio-Economic Change	Changes in the spatial occupation layer. This layer consists of public space, buildings, metabolism and population. The estimated change period of this layer is 5-50 years.	15
Split Incentive	One organisation profits more from a shared solution than the other and this other organisation has no real incentive in participating. However, this shared solution is depended on the power and resources of this other actor in order to succeed.	29
Strategic Behaviour	Behaviour that is not determined by opinions, but is aimed at consolidating a power position.	28
Sunk Cost	Initial investment cost that has been spend and can't be made undone.	17
Synergy	In a network approach it entails; that the combined action perspective of multiple actors have a greater effect than the sum of their individual action perspective. This makes alternatives of the combined action perspective potentially more effective and efficient.	20
Tame Problems	Problems that can be solved through 'normal science'. The problems can be complicated, but with the appropriate amount of authority, expertise, equipment and money, organisations have the possibility to address these problems	25
Technical complexity	The functional and physical interdependencies in the water network	13
Technical end of service life	A moment in time that is reached when a HCS fails to meet its performance level due to wear and deterioration. Or, when the operation and maintenance costs in order to make the HCS meet its performance level are getting too high, making it no longer feasible.	2
Time Value of Money	Postponing an investment which has value because of the interest rate of the total investment cost can benefit the investor. This accounts for own budget, since in that case the interest rate is earned over the budget, and accounts for loans, since the interest rate is saved. The higher the investment costs are, the higher is the advantage of postponing it.	5

Triadic Game Design	The design of a management game must focus on three important aspects: Reality, Meaning and Play. Reality is the extent to which the game is related to domain and practices for which it is being developed. The meaning is the learning objective that the game needs to convey to its participants. Play is how the game is experienced by the participants.	57
Water basin	An artificial water with no natural water supply and the in- and outlet of water can be controlled.	43
Water discharge	The disposal of surplus water. (Not to be mistaken with 'discharge water').	41
Water Network	A collection of waters bodies with a functional cohesion, specified to a function. The area of the region is depended on the definition of the function.	3
Water Resource Management	The total set of activities to control and distribute the volumes of ground and surface water, since abundance and shortage of water are both undesirable. It entails ensuring of safety against flooding and ensuring the availability and supply of fresh water as a resource.	2
Water System	A water system is a collection of all waters in an area that is defined as management area of one organisation, that responsible for the water resource management. It is a regional division of the country, which is similar to the provincial and municipal division of the country.	3
Waterboards	Democratic organisations that perform the water resource management of the regional water systems.	3
Wicked Effects	Consequences of interventions on interdependent network components. This contributes to the relentless characteristics of wicked problems.	14
Wicked Problems	Problems in a technical complex network that impact many network components. Wicked problems are unstructured, cross-cutting and relentless.	14

1 Introduction

Imagine how unpleasant it would be, if your basement is filled up with sewage water after a night of heavy rain. Or if you have to take a detour since the old bridge is closed off for cars. Or if you cannot park your new yacht next to your house, because it does not fit through the locks. If it were not for the highly developed infrastructure network in The Netherlands, these could have been daily troubles for its inhabitants.

Fortunately, the Dutch have managed to live with water throughout their history. They did not only succeed to minimise the danger of floods, they even found ways to make proficient use of the large areas of water in their country. Peat could be used as fuel and drained soil is perfectly fertile for agriculture. The network of artificial and natural waterways played a large role in the economic development of the country. The Netherlands has become internationally famous for its knowledge of living in a river delta. From the monumental windmills to the development of large storm surge barriers, the country is shaped by infrastructure that enables an optimal use of the water. It took centuries of innovation in order to provide land, suitable for a good and safe living environment, and to sustain economic growth.

1.1. Asset management of hydraulic civil structures

The water network in The Netherlands has multiple functions. It is used to keep the land dry, enhance transport over water, maintain sufficient fresh water of good quality and preserve ecologic diversity (Deltacommissaris, 2014; Edelenbos, Bressers, & Scholten, 2013b). All infrastructure of the Dutch water network is built to perform one or more of these functions. Management of these functions is performed through hydraulic civil structures (**HCS**). HCS are key infrastructure constructions that are necessary for the realisation and control over functions and are usually located on important intersections. The most common known HCS are: Locks, weirs, storm surge barriers, water pumping stations, culverts, bridges and tunnels (Technische Adviescommisse voor de Waterkeringen, 1997). Dikes and waterway structures are considered hydraulic structures, but are not HCS.

For a country that is located in a river delta like The Netherlands, **water resource management** and trade over water are of great importance (Heemskerk, 2012). Water resource management is the total set of activities to control and distribute the volumes of ground and surface water, since surplus and shortage of water are both undesirable. It entails ensuring safety against flooding and guaranteeing the availability and supply of fresh water (Lautze, 2014). Water resource management is of great importance for The Netherlands, since it has a high social and economic impact. About 60% of the inhabitants live below sea level and 70% of the gross national product is earned in this part of the country (Bernardini et al., 2014; Ligtvoet & Knoop, 2014). Water trade is important for The Netherlands, because it still is and has been one of the main economic drivers of the country. About 45% of all transport in the country is waterborne (Bernardini et al., 2014; Kuypers, Lejour, Lemmers, & Ramaekers, 2012).

The HCS in The Netherlands have for a large part been realized halfway through the 20th century. The HCS can reach an end of their **technical service life** or **functional service life** (Den Heijer, 2015). As most of these HCS are designed for a service life of 75-100 years, these structures need to be rehabilitated and replaced at some point in the 21st century. The end of technical service life is reached when a HCS fails to meet its **performance level** due to wear and deterioration. Or, when the operation and maintenance costs, in order to let the HCS meet the performance level, are getting too high, making it no longer economically feasible.

The end of functional service life is reached if the functional demand on a HCS outgrows its functional capacity. It is possible that a HCS needs to be replaced, even though it is still in a good technical condition. A good example is whenever, due to their increasing size, freight ships become too large to pass through a lock. It can be decided that the lock needs to be replaced by a larger lock, in order to keep up with the functional demand of the freight ships. For this reason a new sea lock is currently planned at IJmuiden (Rijkswaterstaat, 2015a).

Since the 1950's, a lot has changed in the construction industry. There is a large contrast in the approach and mentality in construction of HCS, compared to the present-day. In the past there were no computers. For the design of HCS, fixed design criteria were used. There was a focus on over dimensioning the concrete structure, in order to guarantee long-term safety. Climate change was at that time still an unknown phenomenon. There are nowadays more stakeholders and they are better organised. There is an increase in the complexity of projects, but a decrease of construction budgets. Inhabitants, clients and users are being empowered by new forms of media, making them less accepting of construction nuisance (Van Marrewijk, 2013). Due to these changes, plans to construct or enlarge infrastructure are nowadays often greeted with scepticism. Major interventions are not logically the preferred cause of action. There must be extensive evidence to substantiate the need for large investments. Any (short term) intervention needs to fit into the long term strategies.

Most organisations that operate HCS have a department responsible for the maintenance of the HCS. However, these departments are usually separate from the departments that determine the long term goals and strategies. As a result, there is a poor connection between the short term interventions and long term strategies in these organisations. This has led to the emerging of a method that embraces the vision that operation and maintenance of infrastructure should be approached strategically. This method is known as **Asset Management**. According to Schoenmaker, Asset Management is *"coordinated activities of an organisation to realize life cycle value from assets in delivery of its objectives"* (2013). In the case of this study, **assets** are the HCS, as tangible elements of infrastructure. Asset management is a method that places **performance** of these assets in their functional context and determines a **failure risk**. It analyses what actions are able to increase the asset's performance level, and it provides a framework to consider the preferred cause of action. This makes it possible to maximize the value of current assets over time.

There are thousands of HCS located all over The Netherlands, which makes the total asset management of these structures a major challenge. The operation and maintenance of the HCS is regionally and functionally divided over multiple organisations. Which organisation is responsible, is determined on the basis of the topographical location and functions of the HCS. In order to regionally define areas of water, the terms '**water system**' and '**water network**' are used interchangeably, but have a variety of meanings. To avoid confusion, this research will make use of the following definitions:

- A water system is a collection of all waters in an area that is defined as the management area of one organisation that is responsible for the water resource management in this area. It is a regional division of the country, which is similar to the provincial and municipal division of the country. Water systems do not overlap, therefore every waterbody is part of one water system. In The Netherlands, Rijkswaterstaat (**RWS**) and the **waterboards** are responsible for the water resource management, and for the water systems. The water systems are composed of all kinds of waterbodies, regardless of their function.
- A water network is a collection of waterbodies with a functional cohesion, specified to a function. Its area is depended on the considered function. For instance, the water network for shipping transport differs from the water network for water discharge. Since water incorporates multiple functions, different water networks can overlap. Multiple water networks are located in a water system, but for the same reason a water network can also be located in multiple water systems. A water network often does not have a clear border, since

the functional cohesion can differ depending on the scope and the interpretation of the network by the observer.

The water networks and water systems in which the HCS is located determine what organisation is responsible for the Asset Management of HCS. A rough division of this responsibility is made on the basis on the water systems. The Netherlands has two types of water systems: the main water systems and the regional water systems. The main water systems, which are the **Primary Waterways** and the **Main Water System**, are managed on a national level by RWS. The operation and maintenance of the main water systems include about 650 HCS (Rijkswaterstaat, 2014; Tosserams, 2013). This includes HCS with all types of functions. Waterboards manage regional water systems and have control over thousands of (mostly) smaller HCS (Huibregtse, 2015; Waterschapservices, 2015), mainly used for water resource management. In addition, provinces and municipalities are responsible for HCS, but the amount of these HCS is limited and the responsibilities differ per water network. In 2.2.1 this will be further elaborated upon.

The described organisations all have a range of possible actions for the Asset Management of the HCS. This range of actions are in this research defined as the **action perspective**. An action is always the product of this action perspective. In order to come to an action, it needs to be decided upon. The **feasibility** of an action is determined by the ability to reach a decision. Every decision is the result of a **decision making process**. A decision making process consists of multiple phases in order to get to a decision. These phases are: the determination of a problem or an opportunity, determining the action perspective, determining the effects of alternative actions and finally making a decision (Van Vlimmeren, De Reuver, & Van Vlimmeren, 2014). This way the decision can be seen as the product of a decision making process (in this instance, not taking action is considered an action as well). The decision making process and the action perspective are thus inextricably intertwined. If the action perspective changes, it impacts the decision making process and vice versa.

1.2. Problem definition

The rehabilitation or replacement of HCS is regarded on the Dutch policy agenda, as one of the focal points of the **Delta Program** (Deltacommissaris, 2014). The Delta Program is a national program that needs to protect The Netherlands from the impacts of climate change. The political concern for the rehabilitation or replacement of HCS is high, due to the potentially high costs of interventions on HCS and the important social and economic role of water resource management and trade over water. For this reason there are currently multiple initiatives and researches addressing Asset Management of HCS. These initiatives are elaborated upon in Appendix A: Research on Asset Management of HCS. This study is executed for the research institute of Deltares, as a part of the *'ROBAMCI'* and *'TO2: HCS of the Future'* studies. The different studies address a broad range of issues in the Asset Management of HCS. The extensiveness of the different approaches represent the struggle that the organisations have with the HCS that are reaching their end of service life. The remarkable thing is, that in all the initiatives there is an awareness that the task exceeds the scope of a single organisation. As Edelenbos et al. mention, water related problems are not caused by the lack of technology, but by the failure in governance. These problems need to be addressed through a multi-stakeholder approach (2013b). Currently there is no scientific research on Asset Management of HCS (or any form of infrastructure) in a multi-stakeholder environment. This research contributes to the ROBAMCI and TO2 studies by addressing this knowledge gap.

There are two reasons why all initiatives approach the rehabilitation or replacement of HCS as one task, that exceed the scope of a single organisation. On the one hand this is due to the threat of the total cost of the rehabilitation or replacement of all HCS. On the other hand this is due to the opportunity, of achieving a network wide adaptation to fulfil future demands that emerge through the end of service life of the HCS.

The threat of high total costs finds it origin in the fact that rehabilitation or replacement of a HCS is not just an everyday project. It is a capital intensive and time consuming operation. Construction under water is technically challenging, and construction activities in an environment that is at the same time in use, has practical limitations. For this reason, the cost of a rehabilitation or replacement of a HCS easily adds up to tens of millions of euros. Construction costs of HCS are by far the biggest contributor to the whole life cycle costs (Van Baars et al., 2009). This costs exceed the annual budget of the asset managers, so extra money should be reserved for these kind of investments (Centraal Planbureau, 2014; Nederlandse Waterschapsbank N.V., 2015). Annually 3-5 billion of euros is spend on hydraulic infrastructure in The Netherlands (Den Heijer, 2015). Every decade about 50 HCS in the Main Water System alone, are estimated to reach their end of their technical service life. The HCS of the regional water systems and HCS that reach the end of their technical service life, have not even been included in this estimation (Deltacommissaris, 2012; Rijkswaterstaat, 2014).

Generally in The Netherlands, HCS are financed, owned, operated and maintained by public organisations. The high construction costs of HCS make the rehabilitation or replacement task an *economic issue* for these organisations. Public budget is financed by tax money. Since the costs are indirectly influencing tax payers, the issue concerns all people paying taxes in The Netherlands. Public organisations are obliged to keep their expenses under control, in order to satisfy the public. To ensure this, most institutions apply Asset Management on their infrastructure. According to the **time value of money**, postponing an investment has value. This value is the interest rate of the total investment cost. The higher the investment costs are, the higher is the advantage of postponing it (Vrijling & Verlaan, 2013). Due to the high costs of interventions, Asset Management of the HCS is mainly focused on exploring ways to postpone or bypass major interventions. Alignment of replacement or rehabilitation of different HCS within a network can possibly help postponing or bypassing interventions. The ROBAMCI study estimates that improved Asset Management, aligned within a network, can save up to 10-20% of the costs spend on hydraulic infrastructure (Den Heijer, 2015).

The opportunity for a network wide adaptation to future demands, finds its origin in the fact that the Dutch water network is full of interdependencies and that the HCS are key functional assets in the network. Consequently, the end of service life of the HCS creates an opportunity to redesign the layout and functionality of networks (Bernardini et al., 2014; Van Ast, Bouma, & Bal, 2013; Van Vuren, Konings, Jansen, Van der Vlist, & Smet, 2015). This makes the rehabilitation or replacement task also a *functional issue*. For this reason the replacement or rehabilitation of HCS is included in the Delta Program (Deltacommissaris, 2014). Including it in a national program shows that the nation as a whole can benefit from addressing this issue. However, currently the rehabilitation or replacement of HCS is not integrated in the program plans, it is only mentioned and elaborated upon in the Appendix of the program.

Bos and Zwaneveld of the "Centraal Planbureau" show in their research that, in addition to the unilateral decision between rehabilitation, replacement or postponing an intervention on a HCS, there are also synergy possibilities in the network (2014). According to their research, these synergy possibilities have economic benefits. Additionally, it is mentioned that there are negative effects possible, whenever the network is not considered in decision making. Van der Vlist and Van der Velde, both top advisors of RWS, mention that long term goals of the network adaptation can be achieved through a so called *'corridor approach'* (which is the same idea as a network approach) of the Asset Management of HCS (2015). According to them a corridor approach has functional benefits. The same is emphasized in the Guideline of Adaptation Delta Management by Van Rhee. She states a network approach has potential to increase the **efficiency** and **effectiveness** of the current approach. Efficiency entails that no unnecessary resources are wasted in order to achieve the desired effect, so these are economic benefits. Effectiveness is to what extend a solution complies to the (future) requirements, so these are functional benefits (2012). Thus, The Netherlands can have potential economic and functional benefits from a network approach in the Asset Management of HCS.

Van der Vlist, Van der Velde and Van Rhee acknowledge the importance of a network approach, but merely address the issue as a technical problem of individual HCS. There is a lot of research on technically improving the Asset management of HCS within one organisation. This mainly focusses on ways to extend the technical service life of these objects. On the one hand through improvement of maintenance regimes. On the other hand by improving detection and prediction methods of technical deteriorations (Wessels, 2014). The other focal point of analyses, is the functional performance of the objects. Methods are developed to optimize the operation of the objects (O'Mahoney, 2015). There is also research on alignment of the different Asset Management practices of different organisations, in order to come to a general practice framework (Den Heijer, 2015). Nonetheless, all these researches focus on individual HCS. Little attention is given to the functional context of the network and interdependencies with other HCS. This mainly occurs, because it is not part of the scope of the organisation that performs the Asset Management (Van der Brugge, De Bel, & Klerk, 2015).

The end of service life of the HCS in The Netherlands are broadly described and viewed as one huge task, but are not addressed as one task. If the complete task will be executed as organisations currently do, all HCS will be independently rehabilitated or replaced one by one (De Bouwcampus, 2015). Replacement of HCS should be addressed as the means to a goal, and not as the goal itself (Rijkswaterstaat, 2015b). It can be stated that the responsible organisations currently have an object oriented approach in the Asset Management of their HCS. This '**object approach**' does not consider the HCS in their network context, nor the other Asset Management organisations in the network. This way the approach seems to be more like a treatment of symptoms, but not a treatment of the issue itself. An object approach has as a result that ultimately all HCS would be rehabilitated or replaced independently. This is a unwanted scenario for The Netherlands, since this is the less advantageous economic and functional scenario.

1.3. Proposition, research objective and research questions

There are opportunities for a broader action perspective, when there is an approach that considers the network of the HCS and the stakeholders in this network. The proposition of this research is that such a '**network approach**' in the Asset Management of HCS has an action perspective with an opportunity for better efficiency (improved performance and/or cost reductions), compared to the current object approach. The question is to which extend the additional action perspective of this network approach is an improvement compared to the current practise of the object approach?

It is expected that a network approach has an impact both on the action perspective of the Asset Management organisation and the decision making process. In a network approach multiple organisations perform Asset Management on HCS. Considering the network and its action perspective, implies that the organisations involved in the network also have to be involved in the decision making process. Since different organisations have different values and interests, these might have a limiting effect on the development of an action perspective.

The proposition is that a network approach in the Asset Management of HCS has an action perspective with better improved performance and/or cost reductions compared to the current object approach. On the basis of the research proposition, the following research objective is formulated:

THE OBJECTIVE OF THIS THESIS IS TO RESEARCH AND ILLUSTRATE THE ADVANTAGE AND POSSIBLE APPLICATION OF A NETWORK APPROACH, AS A METHOD FOR IMPROVING THE EFFICIENCY AND FUNCTIONAL PERFORMANCE OF THE NETWORK, WITHIN THE FUTURE REHABILITATION OR REPLACEMENT OF HYDRAULIC CIVIL STRUCTURES IN THE NETHERLANDS.

This research objective leads to the following main research question:

HOW CAN A NETWORK APPROACH BE BENEFICIAL TO THE FUTURE REHABILITATION OR REPLACEMENT OF THE HYDRAULIC CIVIL STRUCTURES IN THE NETHERLANDS?

The main research question is decomposed in several sub-questions. The answers to these sub-questions together will lead to the answer of the main research question.

a) **WHAT ARE THE IMPLICATIONS OF AN OBJECT APPROACH FOR THE ACTION PERSPECTIVE AND DECISION MAKING PROCESS FOR THE ASSET MANAGEMENT OF HCS?**
b) **WHAT ARE THE IMPLICATIONS OF A NETWORK APPROACH FOR THE ACTION PERSPECTIVE AND DECISION MAKING PROCESS FOR THE ASSET MANAGEMENT OF HCS?**
c) **WHAT CAN BE A SUCCESSFUL STRATEGY TO ESTABLISH A NETWORK APPROACH IN THE ASSET MANAGEMENT OF HCS?**
d) **CAN A NETWORK APPROACH BE ESTABLISHED THROUGH THE APPLICATION OF A MANAGEMENT GAME?**

The research is composed of two parts:

- Theory building: researching the implications of the proposed network approach by drafting a theoretical framework
- Application: developing an application for the network approach

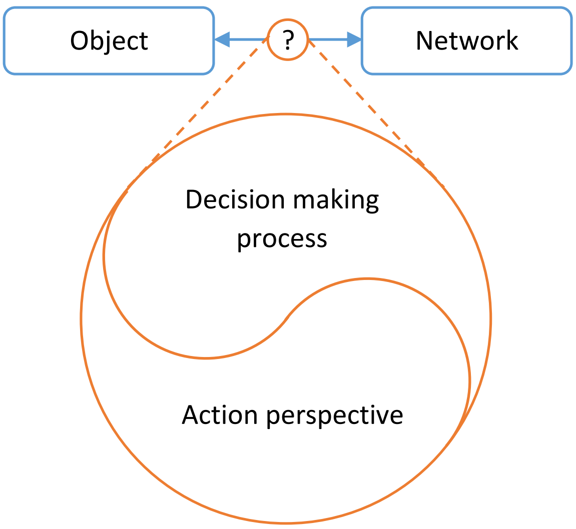


Figure 1 Graphical representation of the first part of the research (own illustration)

The *first part* of the research consists of comparing the object and network approach, which is visualized in Figure 1. As shown in the figure, the implications of the different approaches on the action perspective and decision making process are the focal point of the comparison. This first part researches whether the network approach can be beneficial. The benefits of the approach are clarified by researching the impact on the action perspective and the impact of the decision making process (questions a and b). On the basis of these findings, a potential strategy for establishing a network approach will be researched (question c).

The *second part* of the research consists of the development of an application for the proposed network approach of the research. The application is meant as a pilot study to illustrate and test how to initiate and achieve a network approach. On the basis of the results of part one of the research, it is determined that a management game is a suitable pilot application, for a network approach in this research. It is researched whether a network approach can be established through the development of management game as an application (question d).

On the basis of the sub-questions it can be concluded to which extend and how the proposed network approach can be beneficial to the rehabilitation or replacement of HCS, which is the answer to the main research question.

1.4. Research scope

This research only addresses HCS, not hydraulic structures like dikes. Not all HCS are addressed in the research. There are tens of thousands of small HCS spread throughout The Netherlands (Rijkswaterstaat, 2014). Most Asset Management organisations have a standard annual maintenance budget for the rehabilitation or replacement of the smaller HCS, since for these organisations a yearly fixed amount of the small HCS is depreciated (Brugman & Kerssens, 2015; Waterschap Vallei Eem, 2012). This research addresses only the HCS for which the rehabilitation or replacement exceeds the annual budget. These are the bigger HCS of these organisations. Assuming that most of these HCS have a key functional use, removal of HCS as an alternative action is not part of the research scope.

The functions of waterbodies that are considered in this research for the definition of the water network of the HCS, are limited to the technical functions. The reason for this is the fact that technical functions are quantifiable physical conditions that are measurable. Additionally, technical functions determine the interdependencies between the HCS. Social and cultural functions of water are not part of the research scope, since these are difficult to quantify and their relationship with Asset Management of HCS is not always straight forward.

Another scope limitation is that this research only focusses on HCS owned and financed by public organisations in The Netherlands. The HCS that are owned and financed by private organisations are not part of the research scope.

1.5. Research methodology

As already discussed, the research execution is build-up of two parts. The first part of the research is the exploration of a network approach in the Asset Management of HCS. The function of the first part is '*Theory Building', s*ince this approach is within this context it has no precedents. The second part of the research is the design and testing of an application based on the theory that is delivered by the first part of the research. The function of the second part is *'application'*. The research structure is illustrated in the form of a flow diagram of Figure 2.

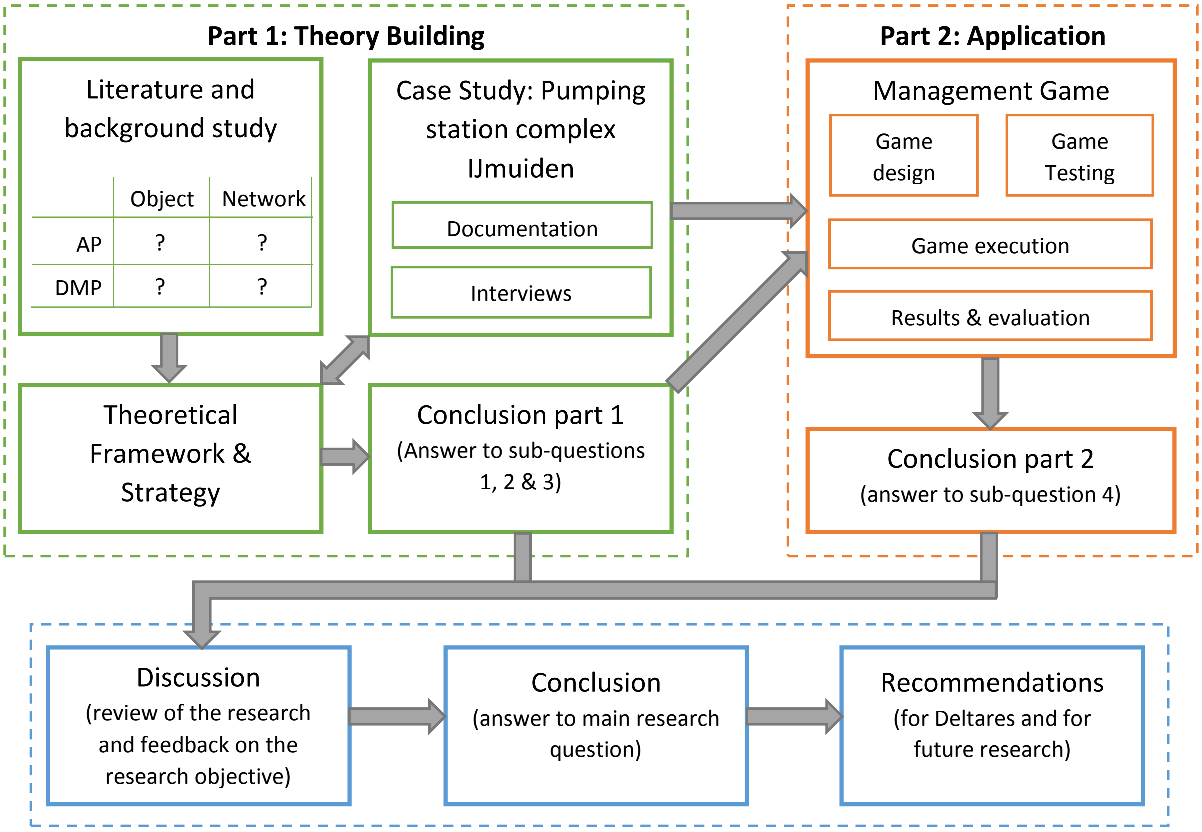


Figure 2 Research structure (own illustration)

A theory building research is characterized by an open-minded exploratory research approach. This approach is described by Boeije as a *"discovery of concepts"* (2010). It is the initial research of an proposition and seeks understanding of an observation (Harvard, 2015). Typical for an explorative research approach, is the inductive line of reasoning. Inductive reasoning means that the research moves from specific observations to broader generalizations and theories (Saunders-Smits, 2013). In case of this research, a theoretical framework is formulated. In order to come to a theoretical framework, two research methods are applied. The theoretical framework is drafted by means of a *literature and background study*. According to Yin this method is suitable for a research with an explorative character, which does not require control over behavioural events and focusses on contemporary events (2009). The explorative character of this part of the research is emphasised by the first three sub-questions of the research, since these questions start with the word "what". The literature and background study contributes to the answers to these questions. The literature and background study can be found in Chapter 2. The focus of this study will be further elaborated upon in the introduction of this chapter.

The second method applied for the theory building is a *case study*. According to Yin a case study is ideal for the understanding of complex social phenomena (2009). This fits the exploratory characteristics of the theory building. The objective of the case study is twofold. A case study has the ability to more deeply analyse a phenomenon, so it is on the one hand an addition to the literature and background study. The case study provides an concrete example that can be used for interpretation and testing of the theoretical framework. Through the reflection of the case study, the theoretical framework can provide definite answers to the first two sub-questions of the research. On the other hand the case study will be used as an inspiration for the design of the *management game* pilot. The case study consists of a documentation research and a series of in-depth interviews. Due to the latter, the case study provides the theory building and game design with empirical data. The case study can be found in Chapter 3. The set-up of the case study will be discussed in this chapter. Due to the extensity of the case and the time limitation of the research, this research only uses a single case study. The critique of a single case study, is that is it a poor basis for generalisation (Yin, 2009). However, since this research is based on a proposition, a single case study can judge if the proposition *can* be of added value and *can* be feasible.

The analysis of this research does not end with building a theory alone. The second part of the research, an pilot application will be the designed and tested, for the proposed strategy of implementing a network approach. The type of application and design is determined on the basis on the literature and background study. Furthermore, it is researched whether a *management game* is a suitable application for initiating a network approach. The objective of the management game is to research if the application can initiate and achieve a network approach. This will be the answer to the fourth sub-question of the research. The management game theory, manual, design and results can be found in Chapter 4.

It is expected on the basis of both parts of the research execution, it is possible to provide feedback on the research objective and review the research as a whole. This will be executed by the means of a managerial implications chapter, which is Chapter 5. After the managerial implications, the main conclusions will we drawn, by the answering the main research question. Lastly, recommendations will be made on the basis of the discussion and the conclusion. The conclusions and recommendations can be found in Chapter 6.

2 Literature, background and explanation

This chapter is the first step of the *Theory Building* part in this study. In order to come to this theoretical framework a literature study and background study are executed in this chapter. Focal point of the theoretical framework are the causes and effects concerning the action perspective and the decision making process, in an object approach and a network approach. This framework will contribute to answers of sub-questions 'a' and 'b'. Additionally, the literature study and background study focusses on possible strategies to establish a network approach. This will lead to the answer of sub-question 'c'. The literature search focusses on the one hand on the current situation of the Asset Management of HCS in The Netherlands and studies, on the other hand, a network approach in water resource management. The focus on water resource management is relevant, since there are developments and researches on network approaches, in this field of study. Since water resource management is executed through the operation of (certain) HCS, there is great common ground with Asset Management. Especially, since the operation is seen as part of Asset Management and, specifically in Asset Management of HCS, operation is usually executed by the same organisation. The theories found in the literature will be substantiated with examples that are found in the background research.

Figure 3 displays the general outline of the theoretical framework. The figure will be decomposed as the guideline for this chapter. The complete theoretical framework is in section 2.3. This chapter is build up in four sections. The first section discusses the action perspective in relation to an object approach and a network approach (2.1). The section is illustrated by the red dashed outline in the figure. The second section discusses the decision making process in relation to an object approach and a network approach (2.2). The section is illustrated by the yellow dotted outline in the figure. The third section is a conclusive section that sums up the findings of the literature and background study, considering sub-questions 'a' and 'b'. It proposes the complete theoretical framework (2.3). The final section explores what strategies are applied in order to successfully execute a network approach (2.4). The section is about the interaction between the orange dashed outlines in the figure. This section will lead to the answer of the third sub-question.

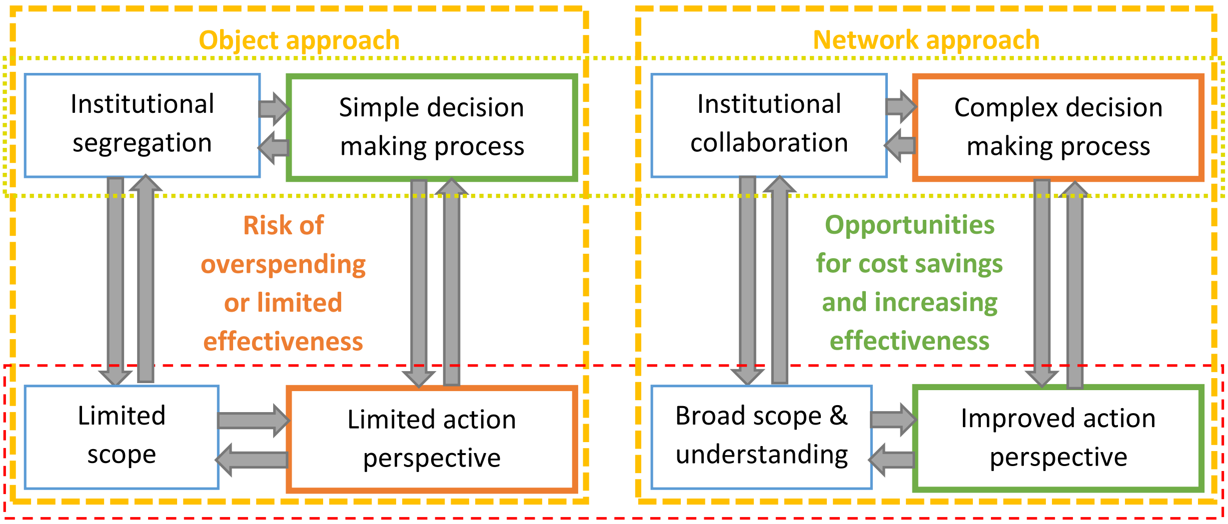


Figure 3 Theoretical Framework: Abbreviated (own illustration)

> *Note: In this chapter the terms 'object approach' or 'network approach' refer to the approach of Asset Management of HCS (these are the yellow blocks in the figures of the theoretical framework).*

2.1. Action perspective

This section discusses the action perspective in relation to an object approach and a network approach. This analysis explains which aspects of the current object approach can cause a less advantageous economic and functional scenario. In order to illustrate this, it is important to first understand which fundamental causes determine the action perspective. Subsequently, it is discussed how this changes in a network approach, when the entire network is considered and more actors get involved.

2.1.1. Effects of the object approach on the scope

As described in the definition of the decision making process (page 4), prior to the phase of determining the action perspective, is the phase of determining the problem or the opportunity. What is determined as the problem or opportunity depends on the **frame of perception** of the observer (Edelenbos, Bressers, et al., 2013b). The frame of perception is the result of an interpretation and valuation process that consists of assumptions, interests, values and beliefs (Kolkman, Veen, & Geurts, 2007). The frame of perception provides a simplification of the problem or opportunity and in this way leads to a limited scope of this problem or opportunity (Dewulf, Brugnach, Termeer, & Ingram, 2013; Kaufman, Elliott, Shmueli, Burgess, & Burgess, 2013).

The object approach relies on the frame of perception of a single actor and therefore has a limited scope. It is an approach with a specific spatial scope, focussed on the problems and opportunities occurring with a HCS. Therefore, it is relevant to explore whether problems or opportunities change in a larger spatial context. Furthermore, it is relevant to place the impact of spatial interventions in the context of time. Because, for major interventions it is important that they perform for their entire planned life time.

The literature and background study reveals that the object approach effects the determination of the problems or opportunities in two ways. This is illustrated in Figure 4. The object focus limits the scope on the problems and opportunities by not considering:

- the high technical complexity of the water network and wicked problems (Edelenbos, Bressers, et al., 2013b; Kunz, Moran, & Kastelle, 2013)
- the tension between the long term characteristics of infrastructure and uncertainties of future developments (Urich & Rauch, 2014).

Limited scope on

- Technical complexity
- Future developments

Figure 4 Theoretical framework: Effects of an object approach on the scope (own illustration)

In the water network there are many dynamic functional and physical interdependencies. In order to define these dynamic interdependencies, the term *"complexity"* is derived from literature dealing with large infrastructure projects. Bosch-Rekveldt defines the functional and physical aspects of projects, like goals and size, as *"technical complexity"* (2011). Hertogh & Westerveld define *"many components with a high degree of interrelatedness"* as *"Detail complexity"* (2010). This research addresses the functional and physical interdependencies in the water network as **technical complexity**.

From a physical perspective water networks are complex, because the whole water network is in physical cohesion due to water flow, water level and water quality, of both surface and ground water. Effects of an intervention on a HCS is physically carried on thought-out the rest of the network (Kunz et al., 2013). From a functional perspective, the water network is complex, because it has great diversity in functions. In contrast to the main road and rail networks, that primarily have a transportation function, the water network has multiple functions like transport, water discharge, drinking water, irrigation, water safety and biodiversity. To enable the network performance of these different functions, the navigability of the waterways, water quantity and water quality need to be regulated. The different functions are interrelated and affect each other. For instance, at high water levels, in order to prevent floods, it is better to use locks to discharge water in addition to the pumping stations. However, the water transport is blocked if the locks are used for discharge (Rijkswaterstaat, 2015c; Scheepvaartkrant, 2015). This way the performance for one function can limit the performance for another function.

Though the physical cohesion, HCS contribute to the total performance of the functions in the water network. HCS can be connected in a series and in a parallel setting. Both types of connections are illustrated in Figure 5. With the diversity of HCS there are countless variations of networks possible. Depending on the type of HCS, type of connection and the function, HCS differently impact the network performance. For example, in a series of locks. In such a situation, the performance of the ship size that fits in network is depended on the capacity of the smallest lock. This lock will be normative for the ship size that can pass through the network (Mackor, 2011). However, when focussing on the transit time, the total performance is depended on the duration of the operation of all the locks (Gijsberts, 2011). Depending on what criteria it is measured, a single HCS can be normative for the network performance or all HCS combined. In parallel connected HCS, the same functional relations are noticeable. For example in a parallel connected network of weirs. The lowest weir will be normative for the minimum water level. However, for the discharge of water, the discharge capacity of all weirs combined determines the total performance (Zuiderzeeland, 2015). All these different types of functional and physical relations contribute to the technical complexity of the network.

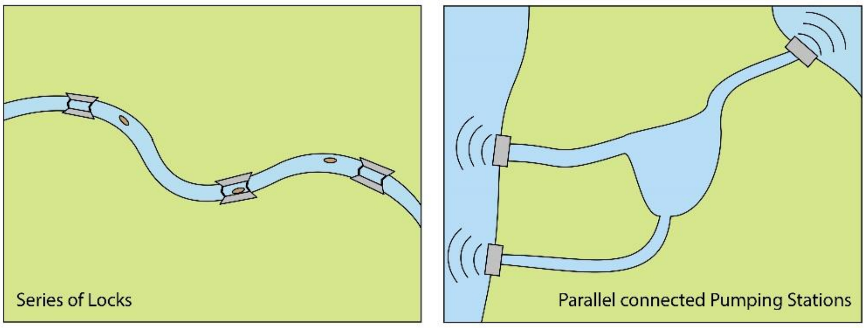


Figure 5 Serial and parallel connectivity of HCS (own illustration)

As mentioned, a technical complex network consists of multiple components with many interdependencies. Typical for problems in a technical complex network, is that these problems impact many network components. Problems in technical complex networks like water networks, are known as **wicked problems** (Edelenbos, Bressers, et al., 2013b). According to Weber and Khademian, wicked problems have three characteristics. Wicked problems are unstructured, cross-cutting and relentless (2008). Unstructured means that the causes and effects of the problem are extremely difficult to identify, model and predict. In the case of water networks, the physical dynamics of water are difficult to model and it is difficult to identify the impact of all influences. Cross-cutting means that the sub-problems of the complex network affect each other due to their interdependencies. This cuts across multiple organisational levels with numerous stakeholders. The different stakeholders have a different frame of perception on the problems that occur. Relentless means that problems are not going to be solved at once, since interventions have consequences for interdependent network components. These consequences are known as **wicked effects**. For the water network these are the conflicting performance requirements of the different functions in the network.

Since problems in a technical complex network impact many network components, these problems can be decomposed into sub-problems, on the basis of these network components. A solution to a technical complex problem is always a consideration of solutions to these sub-problems. What the preferred solution is, depends on the frame of perception. For instance, different solutions are preferred in a water network, depending on what criteria are measured to determine its performance.

Water managing organisations tend to focus on separately solving sub-problems, without much attention to the wicked effects (Edelenbos, Bressers, et al., 2013b). The object approach is such a focus. The performance of a HCS is always depended on functional demands of the network it operates in. The scope of the object approach is therefore too limited to understand the complexity of the network.

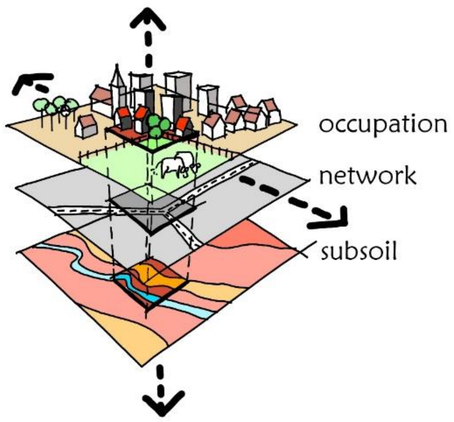


Figure 6 Dutch Layers Approach (Ruimtexmilieu, 2015)

Whenever spatial interventions are placed in the context of time, it shows that permanent spatial presence is a key characteristic of infrastructure. The relation between time and space in spatial planning is discussed by the **Dutch Layers Approach**. This approach is first formulated by De Hoog, Sijmonds and Verschuuren as a fundamental model for decision making about spatial planning in a dynamic future scope (Van Schaick & Klaasen, 2011). The model divides a spatial layout into three different layers, that all have their own time dynamics. As illustrated in Figure 6 the lowest, most permanent layer is the subsoil layer. This layer forms the morphological foundation which consists of soil, water and elevations. The estimated change period of this layer is 100-500 years. The second layer is the network layer. This layer consists of all infrastructure: civil structures, utility services, roads, rail- and waterways. The estimated change period is 50-100 years. The top layer is the occupation layer. This layer consists of public space, buildings, metabolism and population. The occupation layer changes every 5-50 years.

HCS are part of the network layer and therefore are designed to have a replacement period of 50-100 years. Changes in the occupation layer take place on a shorter term. The changes in the occupation layer are also known as **socio-economic change** (Bruggeman & Dammers, 2013). It is hard to predict what the long term demand on the other layers will be outside the intervention horizon of the occupation layer. This introduces uncertainty in the required performance of the lower layers. This uncertainty puts pressure on the long term investments in the network layer. On the other hand the network layer can limit the development of the occupation layer. This has an inhibiting effect on socio-economic progress. A good example of this effect is a lock chamber that becomes too small for the growing size of ships. Companies with bigger ships will divert to other ports that are accessible for these size ships. This will have a negative impact on the economic developments on the area behind the locks that cannot accommodate these larger ships.

The effects of the asymmetric timescale of the different layers are not only experienced on the short term, but also on the long term, due to the impact of climate change (Klein Tank, Beersma, Bessembinder, Van den Hurk, & Lenderink, 2014). Climate change takes place in the subsoil layer, and will for this reason pressure the long term requirements of the network layer. However, there are disputes to what extent climate change will impact the water network (KNAW, 2011). The predictions vary greatly and there are many factors that influence the water resource management. These factors are for instance: Temperature rise, sea level rise, increasing rainfall quantity and/or intensity, increasing river discharge, wind velocity, et cetera. Climate change is a long term dynamic, but due to its high complexity its impact is highly uncertain (Perry, 2015). Furthermore, the impact of climate change gets valued differently by different organisations, depending on the frame of perception (Keskitalo, Juhola, & Westerhoff, 2013).

With interventions that have long term and wicked effects, like the replacement of HCS, an object approach is incapable of addressing the problems or opportunities. The scope is too limited in consideration of the technical complexity of the water network and high uncertainty of the future developments (Edelenbos, Bressers, et al., 2013b; Kickert, Klijn, & Koppejan, 1997; Koppejan & Klijn, 2004).

2.1.2. The effects of the limited scope

It is now clear that the limited scope of the object approach does not consider the technical complexity and future developments in the water network. This section discusses what the effects of this limited scope are and how it causes a lesser advantageous economic and functional scenario. In this research it is assumed that interventions on HCS are efficient and effective in complying with short term requirements on an object level. However, the risk of problems appearing is outside of this scope, due to the network complexity and uncertainty of future developments, as discussed in 2.1.1.

With an object approach it is not possible to accurately predict the effects of an intervention in the technical complex water networks, due to the wickedness of the problems in the water network and the uncertainty of the future developments. According to Hertogh & Westerveld, large infrastructural projects that are addressed in isolation with a scope that lacks technical complexity and uncertainty, produce negative effects. When stakeholders only act from within their own frame of perception, there is a high probability that the proposed solution does not meet the requirements of the other stakeholders involved. It therefore produces unwanted effects and creates dissatisfaction among stakeholders (2010). Thus, in case of large infrastructure projects, there is a high risk of negative effects and dissatisfaction among stakeholders whenever there is a limited scope on technical complexity and future developments.

Additionally, Hertogh & Westerveld state that, through an isolated approach in a highly complex situation, interesting alternative solutions are possibly disregarded (2010). This remark suggests that, within large infrastructure projects, a limited action perspective is the direct effect of a limited scope. Additionally, Kolkman et al. state that scope determines the boundaries of the problems solution space and the allowable alternatives (2007). This is considered the action perspective in this research. Thus a limited scope, limits the action perspective. The limited action perspective entails a high risk of negative effects and misses out on opportunities.

These same relations can be observed in the rehabilitation and replacement of HCS. The object approach has a limited action perspective that consists of the choice of rehabilitation, replacement or postponing the intervention with measures taken on the object. There are no network wide changes possible in this limited action perspective (De Boer & Krantzberg, 2013; Edelenbos, Bressers, et al., 2013b). Likewise, the interventions on HCS can have negative effects, due to a limited scope on technical complexity and future uncertainty. Due to the long-service life of HCS, Asset Management organisations with a limited scope tend to focus on the worst-case scenario (Den Heijer, 2015). This relation is shown in Figure 7. The limited action perspective has a problematic scenario, because it results in interventions with a high economic and functional risk. The risks of these interventions are caused by three phenomena:

- The risk of lock-in situations or path dependence (David, 2006; van der Vooren, Alkemade, & Hekkert, 2012; Van Rhee, 2012)
- The risk of problem shifting (Edelenbos, Bressers, et al., 2013b; Lach, Rayner, & Ingram, 2005; Roelich et al., 2015; Van Leeuwen & Van Buuren, 2013)
- The risk of overinvestment (Lach et al., 2005; Van Rhee, 2012)

The first appointed risk, is the risk of creating **lock-in situations**, also known as path dependence (David, 2006). As the word suggests, a lock-in situation occurs whenever developments are stuck to only one situation (or path), in order to meet the future requirements. It is exceptionally expensive or functionally impossible to deviate from this situation. Therefore, there are no feasible alternatives in addition to the current strategy of the lock-in situation. This action perspective with a lack of feasible alternatives, can lead to forced inefficient or ineffective interventions whenever problems occur. For this reason these interventions have a high economical and functional risk (Van Rhee, 2012).

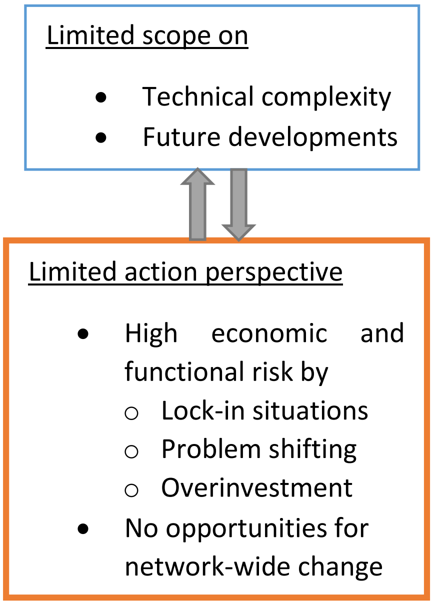


Figure 7 Theoretical framework: Action perspective in an object approach (own illustration)

There are multiple reasons how a lock-in situation can occur in the rehabilitation or replacement of HCS. The risk on lock-in situations is especially high when there are high investment costs involved and there is a high network interdependency (van der Vooren et al., 2012). This is both true in case of HCS. High **sunk cost** (initial investment cost that has been spend and can't be made undone) can create lock-in situations, because deviation from this strategy is considered a waste of resources. For example, whenever a boat channel is inefficient for transport due to four locks, the efficiency of the canal can be improved by replacing them with a fewer amount of locks. However, the infrastructure around these locks is designed for the specific situation. Changing the amount of locks also requires an adjustment to the infrastructure of the canal. Because of the high sunk cost in the current infrastructure, it is more likely that solutions are sought within the boundaries of the four lock situation, even though these are less effective at improving the transport flow. The channel is this way locked-in a situation with four locks (Tuin, 2013).

The more functional interdependencies exist within a network, the higher is the risk for a lock-in situation. As shown by the above example with the four locks, the infrastructure is shaped around the locks. The same goes for other functions and users in the network. In the same four lock situation, there can also be fish migration. The fish migration might be depended on a moderate water flow between the many locks. The lock can also simultaneously function as a bridge. This secondary function can be critical for nearby residents. All these independencies increase the probability on a lock-in, since interventions need to take all these factors into consideration. In this example, the locks have a permanent character, due to all the developments that took place around it. Since lock-in situations gradually develop over time, the limited scope on future development is the most influential factor for lock-in situations (Roelich et al., 2015; Van Rhee, 2012).

The more functional interdependencies exist within a network, the more the network is bound to this functional balance. Since in an object approach, performance is merely considered on an object level, the focus is mainly on the functions for which the object is designed. It is not focussed on all the functions in the network that the object might impact. Interventions with a limited scope, without a good understanding of the complexity, can disturb the functional balance, and disruptively impact other functions. For instance: the construction of a new sea lock can cause salinization of the canal, with a huge negative impact on the water quality (Haas & Drost, 2010). Measurements to restore the water quality after such an intervention, will be expensive and only mitigate the effect, but will not resolve the problem. This phenomenon is known as **problem shifting** (Roelich et al., 2015). Edelenbos et al. addresses problem shifting as *"problem displacement"* (2013b).

As the term problem shifting suggests, it is the risk of transferring the problems to other parts of the network or other networks with an intervention. The positive impact on performance from interventions is then experienced locally or user specific, whilst elsewhere or by different users the negative impact is experienced (Roovers, 2012). This can be physically, as well as functionally. In the example of the sea lock, there is a functional shifting of the problems. The lock is built to increase the performance of transportation, but causes problems for water quality. Measurements to compensate for the negative impact on the performance of water quality, may, in turn, restrict the performance of transportation. This back and forth displacement of the problem, increases the wickedness of the problem, and can cause a permanent functional imbalance in the network (Lach et al., 2005). Interventions from an action perspective with a limited scope on technical complexity, can cause a chain reaction of negative consequences. Individual objectives of organisations for solving societal problems, become dysfunctional on a larger network scale (Edelenbos, Bressers, et al., 2013b). The long term ambitions can get out of sight, as a result of the high recovery cost. This way, these interventions have the risk of creating an negative economic and functional impact (Van Leeuwen & Van Buuren, 2013).

The last effect of a limited scope on technical complexity and future developments, is an action perspective with the risk of **overinvestment**. Overinvestment means that the intervention is overly dimensioned and for this reason too many resources are invested into this intervention (Van Rhee, 2012). This is considered a waste. The infrastructure has high costs, but its potential is never fully utilized. These costs can be both investment costs, as well as operation and maintenance cost. An example is a large lock, that is dimensioned for freight ships, but is only used by small recreational ships. The investment costs and operational costs would have been far less if a smaller lock was constructed. Thus, the overall project would have been more efficient. Therefore the risk of overinvestments is mainly a direct economic risk.

Apart from the limited scope, overinvestments are a result from the tendency of avoiding public controversy, by public organisations (von Hirschhausen, Beckers, & Brenck, 2004). Especially in the water resource management, failure, like floods, have a high social and economic impact. Out of fear that HCS will fail and cause public controversy, public organisations tend to over dimension their interventions (Lach et al., 2005). Better be safe than sorry. A limited scope on the technical complexity of the network and the future uncertainties, results in an action perspective with the risk of overinvestment (Van Rhee, 2012).

A limited scope, limits the action perspective. There is no network wide change possible in this limited action perspective. Additionally, the limited action perspective entails a high risk on negative effects and misses out on opportunities. The risks are the effects of lock-in situations, problem shifting and overinvestment. These risks provide the object approach with a less advantageous economic and functional scenario. Since actions from a limited action perspective can increase the wickedness of the problems, it can worsen the understanding of complexity and future developments, assuming that the scope itself does not change. Therefore, the limiting action perspective can also have limiting effects on the scope.

2.1.3. Implications of a network approach on the action perspective

Now that it is clear what causes the lesser advantageous economic and functional scenario of the object approach, it is relevant to research what the impact is of a network approach. The literature is clear about the fact that a network approach is desired, in order to address problems in the technical complexity and future uncertainty of the water network. Bernardini et al. stress the absolute importance of an integral asset management strategy at network level (2014). Edelenbos et al. state that solutions of the problems in the water network can only be found beyond the boundaries of one organisation (2013b). Mens et al. mention that for strategic long-term decisions a systems approach is needed, which is considered a network approach in this research (2012). Van Vuren et al. discus that the first two steps in determining the problem and opportunities in rehabilitation and replacement of HCS, should consist of a proper description of the current and future water network, in compliance with the different stakeholders in the network (2015). It can be stated that a network approach is crucial in determining the actual problem or opportunities and therefore determining a better action perspective for the problems occurring in the water network.

Whilst in an object approach there is a limited scope on technical complexity and future uncertainty, a network approach can properly face the technical complexity and the future developments in the water network (Edelenbos, Bressers, & Scholten, 2013a). Hertogh and Westerveld state that in large complex infrastructure projects, actors cannot solely rely on their own perspective. A systems view enables actors to see a broader scope and allows them to see their actions and their position in relation to that of other actors (2010). By seeing the possible impact of an action on other actors, it is possible to understand the wicked effects in the network. The systems view of Hertogh and Westerveld can be considered a part of a network approach. Van Leeuwen and Van Buuren confirm the statement of Hertogh and Westerveld, by arguing that a multi organisational approach provides knowledge on how technical complex systems behave and are interconnected (2013).

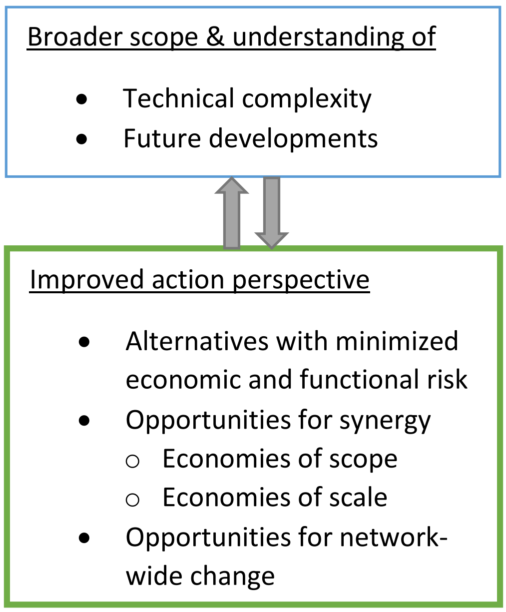


Figure 8 Theoretical framework: Action perspective in a network approach (own illustration)

Not only is it mentioned that a network approach helps understanding technical complexity. It is also argued that a network oriented approach helps to create a shared vision of the future. Through this shared vision a broader scope emerges with a view on long term developments and new opportunities (Van Eijndhoven, Frantzeskaki, & Loorbach, 2013). In a network approach multiple actors need to be involved and different scopes need to be integrated to understand the technical complexity of the water network (Zhou, Bekebreke, Mayer, Warmerdam, & Knepflé, 2013). Figure 8 shows what changes take place in a broader scope.

Water related issues can be handled effectively when addressed from a broad scope (Van Eijndhoven et al., 2013). Better understanding the technical complexity of the network and future developments though involvement of multiple actors, leads to new and relevant supported alternatives. It enhances unforeseen combinations of frames of perception and therefore innovative solutions (Edelenbos, Van Meerkerk, & Klijn, 2013; Van Buuren, Teisman, Verkerk, & Eldering, 2014). Dewulf et al. also state that throughout shared frames of perceptions, new strategies emerge (2013). So it can be stated that an increase of alternatives not only broadens the action perspective, but also improves it. In contrast to the object approach, network-wide changes are possible in the network approach (Edelenbos, Bressers, et al., 2013b; Van Eijndhoven et al., 2013). Instead of interventions on objects with a long term impact, additional alternatives with an impact on a shorter term, can emerge in a network approach. In a network, intermediate interventions for increasing the network performance can be taken. With these smaller steps, the same performance improvements can be achieved, as with intervention on one object. Without committing to a long-term worst-case scenario, lock-in situations, problem shifting and overinvestment, can be prevented (Van Rhee, 2012). Thus, the improved action perspective helps minimizing the economic and functional risk.

Apart from minimizing the economic and functional risks, a network approach also provides additional opportunities for **synergy** advantages, within this broader action perspective. In a network approach, synergy entails that: the combined action perspective of multiple actors have a greater effect than the sum of their individual action perspective. This makes alternatives of the combined action perspective potentially more effective and efficient (Van Rhee, 2012). Connecting values and the knowledge of multiple actors with a combined action perspective, enlarges the possibilities for multi-functionality of the network and have helps in maximizing the total value of the water network (Van Ast et al., 2013).

An increase of effectiveness that takes place due to a broader action perspectives, is also known as the **economies of scope** (Hijdra, 2014). Due to the wider network scope, the physical and functional cohesion of the network can be identified. This can have multiple benefits. For instance, in this way it can be identified that the same problem occurs in multiple places. A bigger intervention on one place can prevent unnecessary interventions in other places. A good example is when multiple regions have problems with flooding. Since pumping stations in a network are connected in parallel, a single central pumping station might be able to solve all local problems at once, instead of implementing a multitude of smaller local interventions. Because of the greater effectiveness of one central solution, the smaller interventions can possibly be postponed or completely abandoned. In general, this saves a large amount of resources (Franssen, van der Brugge, Krueger, & van der Heijden, 2012). Another potential benefit is, that different interventions for different functions can be clustered in a central intervention. Examples of these are energy turbines on discharge weirs. These are known as **exploitation combinations**. Exploitation combinations will increase the effectiveness of the intervention, by making the outcome richer and meaningful for more actors. De Bruijn and Ten Heuvelhof define this as substantive enrichment (2008).

The clustering of functions or projects does not only have advantages in terms of effectiveness. It also creates efficiency benefits. These are known as the **economies of scale** (Hijdra, 2014). Economies of scale implies that, whenever the total scale becomes greater, the unit price becomes cheaper. By clustering projects and budgets, this can be beneficial in multiple ways. For instance: the operations of a series of bridges and locks for the water transport can be done locally. However, it is much cheaper to operate all the HCS centrally at once. Furthermore, standardization of physical elements of HCS or parts of the implementation process, can have huge financial benefits (Multiwaterwerk, 2012). **Construction combinations** are possible as well. Construction combination is the clustering of different construction projects. A surplus in resources on one project can help solve a shortage in another. Examples of these are; the surplus of soil from an excavation that can be used as supplement for another project. Or, the combined use of heavy machines (like cranes) can save on construction expenses (Franssen et al., 2012; Röling et al., 2011).

On the basis of the literature and background research, it can be stated that through the broad scope of a network approach, an understanding of the technical complexity and future developments can come about. Knowledge about the complex effects of alternatives of the object approach, can increase the understanding of the network complexity. Due to this understanding, new alternatives emerge in an improved action perspective. The new alternatives make network-wide changes possible and can minimize the economic and functional risk. Furthermore, these new alternatives provide opportunities for synergy advantages. The economies of scale have a clear direct focus on greater efficiency. The synergy effects of economies of scope focus on the increase of effectivity. Therefore, the action perspective of a network approach is able to provide good economical and functional scenarios, by saving costs and/or improving network performance.

2.2. Decision making process

In order to realize the advantageous economic and functional scenario of the network approach, a decision making process should reach a decision about the action with this prospect. This section discusses the decision making process in relation to an object approach and a network approach. Institutional organisations do not seem to be capable of developing and implementing integrated visions and programs (Edelenbos, Bressers, et al., 2013b). This analysis determines how current Asset management of HCS is organised and how it is incapable of implementing a network approach. This is done by discussing how the decision making process functions in an object approach and how this changes in a network approach, when the entire network is considered and more actors get involved.

2.2.1. Current organisation of Asset Management of HCS

As already discussed in the introduction (1.1), Asset Management needs to be applied on HCS, since these HCS reach their end of service life. The end of service life can be caused by technical or functional failure. Both failures are measured by an impact on the performance of the HCS. The performance of an HCS is monitored and on the basis of performance levels it is determined whether the HCS fails its performance. This is illustrated in Figure 9. A HCS can have multiple functionalities and for each functionality a specific performance can be set-up. On the basis of monitoring the performance failure of HCS, it can be decided if an intervention is needed. The goal of interventions is to increase the performance of the HCS (Huibregtse et al., 2015; Schoenmaker, 2013).

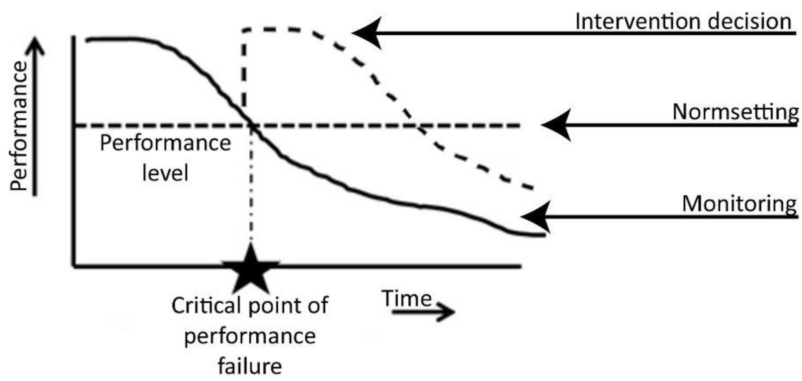


Figure 9 Graphical representation of asset performance (Huibregtse et al., 2015)

The typical organisational structure of Asset Management is illustrated in Figure 10. This figure explains the different roles and responsibilities within Asset Management (Den Heijer, 2015). Asset Management is performed on three organisational layers, all with their own responsibility in the organisation. The responsibilities are hierarchically organised. On top of this hierarchical structure is the strategic layer. In the strategic layer the functionality and necessary performance level of a water network is determined. This is executed by setting measurable norms for the performance levels of the lower layers. Typically the Asset Owner is responsible for executing the tasks of the strategic layer. The Asset Owner is the actor who on paper owns the assets and in general has the budget to operate, maintain and invest in the assets.

The second layer is the tactical layer. In the tactical layer the performance levels set by the strategic layer, need to be achieved. Therefore, the demanded network performance levels are specified to performance levels of the different assets. The failure risk of the network can be monitored by combining the data of the different assets. This is provided as feedback to the strategic layer. Per asset, interventions are prioritised and budgets determined. Typically the Asset Manager has the responsibility of executing the tasks of the tactical layer.

The third layer is the operational layer. In the operational layer the performance levels set by the tactical layer, need to be achieved. This is achieved by means of actively monitoring the performance and failure risk of the asset. Based on this monitoring data, operation and maintenance regimes are determined. Big interventions exceed the responsibility of the operational layer, therefore this layer provides feedback on the failure risks of the assets to the tactical layer. Typically a service provider has the responsibility of executing the tasks of the operational layer.

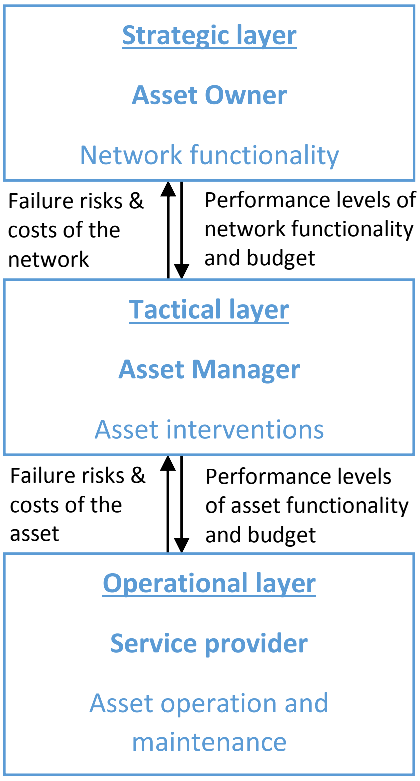


Figure 10 Organisational structure of Asset Management (Den Heijer, 2015)

When Figure 9 and Figure 10 are analysed together, it is possible to see the responsibilities of the different layers of Figure 10 in the graphical representation of Figure 9. It can be stated that, the graphical representation is the result of the interaction between the tactical and the operational level. The strategic layer is responsible for the norm setting, but the tactical layer makes a performance specification for an asset. The intervention decision is the responsibility of the tactical layer. This is based on the monitoring of the performance, provided by the operational level.

It is furthermore relevant to study differences in role of spatial scale and the time scale in the Asset Management organisation structure. In the organisational structure, within the strategic layer the performance levels are established in the spatial context of network. In the operational layer the performance level is monitored in the spatial context of an object. The transition between this spatial definitions takes place in the tactical level (Den Heijer, 2015). Multiple researches show that the strategic layer in the organisation often has a broad, more general, overview and that the operational layer has a specific spatial focus (Keskitalo et al., 2013; Vinke-de Kruijf, Kuks, & Augustijn, 2013) There is also a difference in the role time plays in the different organizational layers. In operational layer, mostly the present is of importance. If there is any planning, this only includes short term interventions. In the strategic layer the focus is on the long term. The transitions between these time definitions take place in the tactical level (Van Eijndhoven et al., 2013; Van Leeuwen & Van Buuren, 2013).

The organisational structure for Asset Management of Figure 10 is depended on a clear **line of sight** from decision making on the strategic level to the decision making on the operational level (IAM, 2014). A line of sight means that the whole organisation, from top till bottom, complies to the same goal. This is usually ensured by proper communication between the different layers (Keskitalo et al., 2013). The added value of Asset Management, is the linking of the strategic network performance to the operation and maintenance of assets. However, this setup is relatively new, especially in the water sector. According to Giel Klanker, senior advisor operation and maintenance of RWS, the communication line between the strategic level and tactical level did not exist in RWS until recently. The developments of functional strategies of a network were for a long time executed in a different department, than the department dealing with the decision making on rehabilitation or replacement of a HCS. There was no direct communication between both departments. Now that the direct communication line exists, there is still a lot of improvement to be made in the communication. For instance, there are performance models of objects and there are performance models of networks, but a model that integrates both does not exist (personal communication, October 19, 2015). It is assumed in this research, that the lack of communication between the different layers in the organisational structure of Asset Management, contributes to the use of the object approach.

Even though, when the line of sight in the organisational structure of Asset Management is improved, it is still far from a network approach in the Asset Management of HCS. In order to understand this, it is important once again to study the network complexity and the future uncertainty of section 2.1.1. A single asset management organisation addresses the problems in the network on the basis of its own frame of perception. Within The Netherlands, the governance of Asset Management on HCS is divided over multiple organisations. These organisations operate indepedently and are specialized in executing their responsibilities. Due to this specialisation, the organisations do not address the network in its complete technical complexity and future uncertainty (Edelenbos, Bressers, et al., 2013b). There is a institutional segregation on a horizontal level (Edelenbos, Van Meerkerk, et al., 2013). It can be stated that the limited scope of 2.1.1, is a result of this segregation. Figure 11 illustrates this relationship. The literature and background study reveals that the governance structure of the Dutch water network is segregated on two different levels (Edelenbos, Bressers, et al., 2013b):

- Geographical level
- Functional level

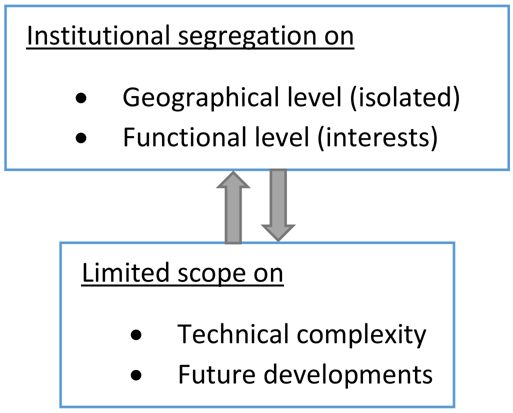


Figure 11 Theoretical framework: Effects on the scope of the governance structure of the object approach (own illustration)

On a geographical level, there is a strict segregation of responsibilities within the governance structure of the Dutch water network. There are clear borders on where the influence of different organisations ends. According to governance documents, a single governance organisation is responsible for the establishment of norms and performance levels within their regional system. This is the strategic decision making. For the Primary Waterways and the Main Water System this is the responsibility of the Ministry of Infrastructure and Environment (Min. I&E). For the regional water networks this is the responsibility of the provinces. In Figure 10 this role is allocated to the Asset Owner, which implies that this actor, apart from setting the performance levels of the network, also owns the assets. This is true for the Min. I&E. They own all HCS in their network and their executive organisation, RWS, does not. However, for the provinces the situation is more complicated. The regional division of ownership differs per function. The provinces are responsible for the land use and development, and the waterboards for the water resource management (De Boer, Bressers, Özerol, & Vinke-de Kruijf, 2014).

In general, all HCS with functions concerning the water resource management, like pumping stations and weirs, are owned by the waterboards. For HCS with the waterway function, like locks, the ownership is regionally segregated. The ownership depends on the agreements between the waterboards and provinces. This differs per province and even per region within the province. (Bijleveld-Schouten, 2012; Hendriks, Lambrechtse, & Posseth, 2013; Lamberigts & De Vuyst, 2008;

Lemkes, Delmeire, & Wegenwijs, 2012; Visser, 2011; Waterschap Reest en Wieden, 2010). Bridges supporting provincial roads are owned by the provinces. Bridges supporting local roads are owned by municipalities. If a provincial road crosses a lock, or if a local road crosses a regional waterway, it can happen that different parts of the same HCS are owned by different organisations. For instance, the Sint Sebastiaansburg in Delft is partly owned by the province and partly owned by the municipality (Provincie Zuid-Holland, 2013).

In the same way, there is always one organisation regionally responsible for the norm setting and one organisation responsible for achieving the norms. This includes making the necessary decisions on a tactical level, about prioritizing measures and distribution of the budget, in order to let their region preform to the goals and performance requirements. As shown in Figure 10, these actors are the Asset Managers. As already pointed out, RWS is the Asset Manager of the Primary Waterways and the Main Water System. On a regional level the situation is again more complicated. The regional division of executive responsibilities differs per function. The waterboards are the Asset Managers of the HCS concerning the water resource management. The HCS concerning transport functions can be the responsibility of the province, waterboards and the municipalities, depending on the region.

Depending on the Asset Manager, sometimes specific operational tasks are outsourced to contractors, but operational management is in general the responsibility of the same organisation. Therefore, in this research, the role of service provider and Asset Manager, as illustrated in Figure 10, are addressed as the same organisation.

Even though, the geographical segregation of responsibilities can be complicated locally, in the big picture of governance structure Dutch water governance, there is always one norm setting organisation (Asset Owner) and a single executive authority (Asset Manager) per region. It is important that a different organisation sets the norms for the executive authority. This way, an external organisation supervises the executing authority (Ministerie van Infrastructuur en Milieu, 2011).

There is not only segregation between the different Asset Management organisations on geographical level. Per regional water systems, different organisations can be responsible for HCS. Governance in water networks is typically divided into functional areas of expertise (Lach et al., 2005; Roovers, 2012). Which organisation is responsible for what role, depends on what function the HCS performs. So, there is also a segregation in the governance structure based on the functions of water network. That multiple sectors are dealing with water governance, is an outcome of the demand for different values and demands by society (Van Ast et al., 2013). Edelenbos et al. argue that the functional segregation will keep on increasing, since in society there is an increasing focus on specialisation. Specialisation has been the driving force for economic prosperity and wealth in the last decades (2013b). The increasing focus on specialisation can be interpreted as an increasing limitation of scope. For this reason it can be stated that scope also affects the institutional segregation.

Generally speaking, organisations execute the functions that fit their frame of perception, which has as a consequence, that the organisations have different interests. These interests arise from the organisational goals of the Asset Management organisation. Consequently, these organisations have a different frame of perception on network performance. (Edelenbos, Bressers, et al., 2013b; Edelenbos & Van Meerkerk, 2015). This is similar to large infrastructure projects. Hertogh and Westerveld state that stakeholders tend to interpret reality in line with their own interests, especially when the stakes are high (Hertogh & Westerveld, 2010). Since the frame of perception of the different organizations is not formally defined, the functional segregation is less transparent than the geographical segregation.

Many external organisations are depended on the actions of the Asset Management organisations and therefore try to influence the frame of perception of these organisations. An example of such a dependency is that efficient water transport is one of the main responsibilities of RWS. RWS is for this reason greatly influenced by the shipping industry. Another example is that water resource management is the main task of waterboards. Since water level and quality are of great interest to the agricultural industry, these organisations are represented within the board of the waterboard. Because the external organisations have financial or political power, they have powerful instruments for lobbying (Keskitalo et al., 2013). A good example of a successful lobby of powerful organisations, is the lobby of the municipality and port authority of Amsterdam, to convince the Min. I&E and the province of North Holland of constructing a new sea lock at IJmuiden (De Koning, 2009).

Both the geographical and the functional segregation of the governance structure of HCS, limit the scope of the Asset Management organisations. On the geographical level the scope of the organisations is limited to their specific region. The organisations operate as if their regions are isolated, because the systems beyond their regional borders are beyond their organisational authority. On the functional level the organisations do not have a broad scope, because this is not within their interests. Simply put: The Asset Managers are not allowed or are not willing to expand their scope to a network approach. The increasing specialisation of the Asset Management organisations in their own isolated region increases the institutional segregation.

2.2.2. Effects of the institutional segregation on the decision making process

The institutional segregation is a persistent issue in water governance. It is hard to resolve, due to rigid paradigms of current structures and practices and the constant pressure of the segregated forces (Edelenbos, Bressers, et al., 2013a). The decision making process of the object approach is a current structure with a major rigid paradigm. This structure provides the Asset Management organisations with a high degree of independence (Ministerie van Infrastructuur en Milieu, 2011). The relation between the institutional segregation and the decision making process is illustrated in Figure 12. The high degree of independence in a decision making process has multiple advantages:

- Tame problems with sufficient information (Edelenbos, Bressers, et al., 2013b; Lach et al., 2005)
- Clear liability and low controversy risk (Edelenbos, Van Meerkerk, et al., 2013; Gilissen, 2013; Kolkman et al., 2007)
- Clear budget and mandate (Franssen et al., 2012; Keskitalo et al., 2013)
- Fast action possible (Edelenbos, Bressers, et al., 2013b)

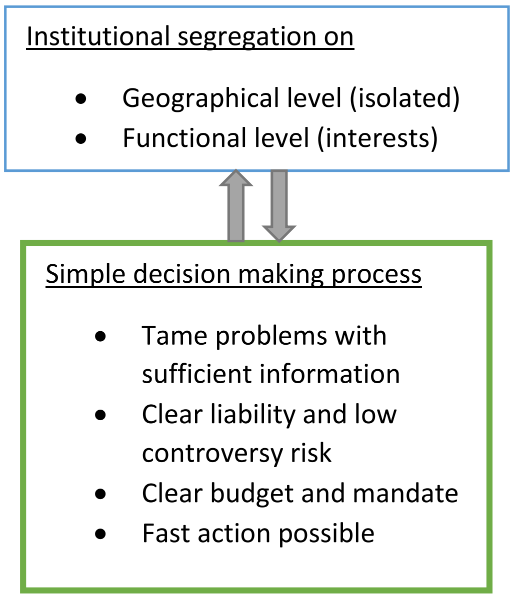


Figure 12 Theoretical framework: Causes object approach (own illustration)

Instead of taking the issues that play a role in other regions in consideration, organisations rather focus on their own region and address the water as a controllable resource. Asset Management organisations tend to transform confusing problems with many wicked effects into autonomous problems that they CAN address: **tame problems**. Tame problems are problems that can be solved through 'normal science'. The problems can be complicated, but due to their specialisation, the organisations have the appropriate amount of authority, expertise, equipment and money to address these problems (Edelenbos, Bressers, et al., 2013b). It is possible to address the problems as tame problems, because the organisations have all the required information about the region and the functions they have an interest in. The required information is known, since most of the operational management is performed in house. The solutions to these tame problems might have wicked effects. But, since these effects are beyond their regional or functional boundaries, these are not part of their scope. Consequently, these effects are often not noticed or even neglected (Lach et al., 2005).

The second characteristic, of the high degree of independency of the Asset Management organisations, is that they are bound by geographical and functional jurisdictions (Edelenbos, Bressers, et al., 2013b). Horizontal processes conflict with the vertical policy making structures. This therefore limits the freedom of organisations to do whatever they want (Edelenbos, Van Meerkerk, et al., 2013; Kolkman et al., 2007). This makes them liable for fulfilling their responsibilities, bound to their geographical borders and their functional authority (Gilissen, 2013). If their region fails in its performance, lawsuits and legal claims can follow when stakeholders are affected. In the regions where there are already a wide variety of stakeholders and responsibilities, that creates tension. This social impact often expresses itself in controversy. This is bad for the image of political organisations like waterboards and can harm the trust of the public in their organisation. To minimise controversy the Asset Management organisations tend to consolidate control over their own region (Lach et al., 2005). This way the organisations do not get to deal with legal issues and there is a low risk on controversy.

As already stated, with the appropriate amount of authority and budget, Asset Management organisations address the problems in their network. This budget and mandate is also one of the reasons these organisations invest in their own region. All organisations receive tax money as their budget. This money has often been **earmarked**, meaning that it is budgeted for a certain purpose. Consequently, use of the budget for other purposes needs to be accounted for and this causes a lot of procedural issues (Franssen et al., 2012). Especially since the budgets of the executive Asset Management organisations are financed externally, this earmarking has a crucial role. This money is invested with an objective in mind, an objective that the financing actor benefits from. The financers provide the Asset Management organisations with a clear mandate. For RWS this is state budget or external funding, like European funding. For waterboards this partly consists of tax money that is collected regionally from inhabitants and businesses and partly consists of National, provincial and European subsidies (Keskitalo et al., 2013). There is no problem as long as the budget is used for the mandate it is intended for.

Lastly, the clearly defined responsibilities and liabilities, limit the bureaucracy of the current object approach. Bureaucracy undermines the capacity for fast actions. These fast actions limit the transaction cost and emphasises the control of the organisation (Edelenbos, Bressers, et al., 2013b). Especially in the operational layer of the organisational structure the independency is valued, because of the possibility for fast actions. In case of failure of HCS, fast reaction is of great importance to reduce the impact of the failure.

The institutional segregation provides a structure for the decision making process by setting clear responsibilities, liabilities, budgets and mandates for the Asset Management organisations. The problems are framed as tamed problems, allowing the organisations to execute fast actions and have a low risk of public controversy. Opposing the disadvantageous economic and functional scenario that an object approach provides for the action perspective, it provides an advantageous scenario for the decision making process. There is a great chance that in the decision making process of an object approach, the process to reach a decision is efficient, and it is assumed that the output of the decision is effective within the frame of perception of the organisation. Therefore, it can be stated that there is a simple decision making process in the object approach. The success of the process ensures that organisations appreciate their independency, and can in turn increase the institutional segregation.

2.2.3. Implications of a network approach on the decision making process

In order to come to a network approach in Asset Management of HCS, the different Asset Management organisations need to be connected horizontally as well as vertically. Network management is the joint decision making on sharing resources and joint action (Edelenbos, Van Meerkerk, et al., 2013). The different organisations thus need to collaborate. Collaboration can threaten the independency that the organisations adhere to in the agreements on institutional segregation (Ministerie van Infrastructuur en Milieu, 2011). In the sense of their responsibilities and liability it is logical that organisations focus on their isolated region. When dealing with wicked effects and long term future developments, there is a need for a focus on network integration of the regions. An integral focus ensures that the organisations get an understanding of the complex network and the possible future developments (Van Buuren et al., 2014; Vannevel, 2013). Collaboration can be established through integration of regional segregation (Edelenbos, Bressers, et al., 2013b).

According to Edelenbos et al. regional integration is as much a part of the problem as it is the solution, as breaking down boundaries at the same time means creating new boundaries that again can hamper collaboration (2013a). Segregation is not effectively countered by merely implicating integration, because every organisation defends its own interests and responsibilities. Integral coordination in a network where actors act on the basis of their own frame of perception and interest, will only lead to competition instead of collaboration. Therefore, not only the regional segregation needs to be integrated, also the frames of perceptions and interests need to be synchronised (2013b). In order to overcome the habit of organisations of focussing on their own interest, it is necessary to make them conscious of their mutual dependencies on other organisations (Van Buuren et al., 2014). By creating awareness over mutual dependencies between organisations, the organisations get an incentive to look beyond their own interests and behave more cooperative towards other organisations. Harming the interest of another organisation will eventually backfire. It is argued that the awareness of mutual dependencies forms the foundation of the European Union (EU). There has been little conflict between the different counties in the EU, because this would harm too many interests (De Bruijn & Ten Heuvelhof, 2008). Vinke-de Kruijf et al. define the awareness of mutual dependency coherence. They also argue that without coherence, the integral approach is still segregated (2013).

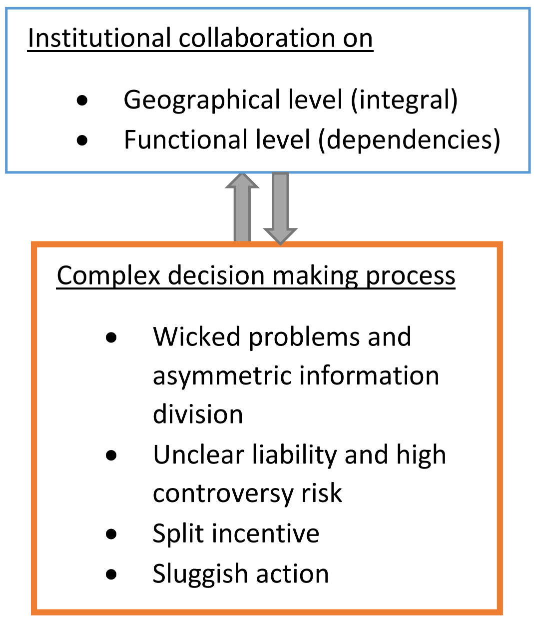


Figure 13 Theoretical framework: Opportunities and disadvantages of a network focus on decision making (own illustration)

Collaboration between the different Asset Management organisations is key in a network approach. In order to ensure collaboration in the governance, the institutional segregations need to be overcome. Geographically, the focus on isolated regions needs to make way for the an integral focus on the network. Functionally, the organisations need to address the mutual interdependencies, instead of their own interest. This is illustrated in Figure 13.

The disadvantage of the network approach is, that the structure for a simple decision process also changes. The only things that are certain about the decision making process in network approach are: the process is unstructured and the outcome uncertain (De Bruijn & Ten Heuvelhof, 2008; Roovers, 2012; Weber & Khademian, 2008). Hertogh and Westerveld define the conflicts that can arise between different stakeholders, due to their different interests, as dynamic complexity (2010). This dynamic complexity has the effect of turning the decision making process into a complex process. All the conditions that contribute to a simple decision making process in the object approach, turn into conditions that contribute to the complexity of the decision making process. The new conditions that make the decision making process complex are:

- Wicked problems and asymmetric information division (De Bruijn & Ten Heuvelhof, 2008; Dewulf et al., 2013; Vannevel, 2013)
- Unclear liability and high controversy risk (De Boer & Krantzberg, 2013; Edelenbos, Van Meerkerk, et al., 2013; Kolkman et al., 2007; Lach et al., 2005; Van Buuren et al., 2014)
- Split incentive (De Bruijn & Ten Heuvelhof, 2008; Franssen et al., 2012; Gillet, McKay, & Keremane, 2014)
- Sluggish action (De Bruijn & Ten Heuvelhof, 2008)

Due to the institutional segregation, different organisations have different information available on the tame problems in their region. When addressing the network integrally this information needs to be shared, so the wicked effects that exceed the current institutional boundaries can be understood. Through collaboration, an unbalanced flow of data emerges between the different organisations. According to Vannevel, this creates a field of tension and frictions between these organizations (2013). De Bruijn and Ten Heuvelhof define the unbalanced flow of information as the asymmetric information division. According to them this can result in **strategic behaviour.** Strategic behaviour is behaviour that is not determined by opinions, but is aimed at consolidating a power position. This results in strategic use of information. An example of this is, when an organisation only shares information in its own interest, to win an argument. Strategic use of information can end in **report wars**. This behaviour frustrates the collaboration and complicates the decision making process (2008). Dewulf et al. state that if the asymmetric information access is not recognized or addressed, report wars can end in **dialogues of the deaf** and stagnation of the decision making process. Dialogues of the deaf, take place when the communicating parties are unresponsive to the arguments of one another. The boundary between science and politics is blurred and there is no rational discussion possible (2013).

Due to the high impact of network failure on the water network, there is a strict liability agreed upon in the institutional segregation (Van Buuren et al., 2014). The vertical liability in institutional structure conflicts with a horizontal integral approach. In a network collaboration the strict liability becomes unclear, since the problems addressed exceed the responsibility of one organisation (Edelenbos, Van Meerkerk, et al., 2013). Especially, when there are too many institutional layers and roles and the problem are too large, the involved organisations lose faith in clear progress with properly defined liability (De Boer & Krantzberg, 2013). If there are conflicts of interest and distrust between the different organisations, than they are only interested in collaboration on the basis of legal agreements (Edelenbos, Van Meerkerk, et al., 2013). Legal agreements provide limited freedom in decision making processes (Lach et al., 2005).

The **legitimacy** of the collaboration is another concern that needs to be addressed. Legitimacy is the effectiveness and acceptance by external stakeholders of policy outputs. Collaboration can give the impression to stakeholders that the representative democracy for which they voted is ignored. For this reason they can start opposing the decisions made in collaboration. (Edelenbos, Van Meerkerk, et al., 2013). For instance, voters of a waterboard can get agitated when the waterboard negotiates conditions that go against their interests. Since this is controversial, opposition can get especially strong. Controversies mainly occur with the distribution of responsibilities and involves legal or political liability. Since the budgets of Asset Management organisations within the water systems in The Netherlands are financed by tax money, there are a lot of external stakeholders with interest (Kolkman et al., 2007). With such high pressure, organisations are hesitant of accepting measures that go against their interests. The risk of controversy dissuades organisations from collaborating and hampers the decision making process.

Earmarked budgets are inflexible and it costs a lot of effort to use them for other purposes. Organisations have no incentive to do this. For instance, organisations are often not willing to use budget for maintenance or construction. Even if the construction can save a lot of maintenance (Franssen et al., 2012). If it is permitted, organisations are often willing to share their resources and liability in collaboration, as long as the collaboration does not cost them any of their power. This results in collaborations that lack empowerment (Gillet et al., 2014). It is already discussed that strategic behaviour of organisations is aimed at consolidating their power position. Additionally, De Bruijn and Ten Heuvelhof state that strategic behaviour takes place between organisations even if the collaboration has mutual benefits (2008). If the interest in this benefit is unbalanced, it can result in a **split incentive**. Split incentive means, that one organisation profits more from a shared solution than the other and this other organisation has no real incentive in participating. However, this shared solution is depended on the power and resources of this other actor in order to succeed. (Franssen et al., 2012). Through split incentives organisations can use their power strategically, but doing this implies that the decision making process stagnates.

All the conditions discussed in this section, can have a paralyzing effect on the decision making process. Actors need time to comprehend the complete situation. This entails understanding the technical complexity of the network, as well as the interests and developments of the other organisations. Due to the dynamic characteristics of the network and the other organisations, this comprehending is a continuous process. All the consultation and alignment between the different organisations create a sluggish decision making process (De Bruijn & Ten Heuvelhof, 2008).

Due to the changing conditions of the decision making process, the simple unilateral process transforms into a complex process. In this process the only certainty is, that the process is unstructured and the outcome uncertain. The scenario of the decision making process is thus disadvantageous. However, opposing this scenario is the advantageous economic and functional scenario of the action perspective. Decisions resulting in mutual benefits enforce relations between organisations and can in turn increase the collaboration (De Bruijn & Ten Heuvelhof, 2008).

2.3. Theoretical framework

Throughout this chapter the theoretical framework is build up. The complete framework is shown in Figure 14. The theoretical framework is composed of two parts: The situation of the current Asset Management of HCS with an object approach and the proposed Asset Management of HCS with a network approach. The different approaches are outlined by a yellow dashed box. Both parts reflect one another in their outline, but their content is different. The main focus of this research is the action perspective and decision making process. Accordingly, these are the main building blocks of the theoretical framework. The red colour illustrates a disadvantageous prospect and the green colour an advantageous prospect. The blue text blocks are the underlying circumstances of the action perspective and the decision making process. The arrows illustrate causal relationships. The text in the middle of both approaches is the implication of the approach. These contribute to answering of the first two sub-questions and are discussed after the theoretical framework.

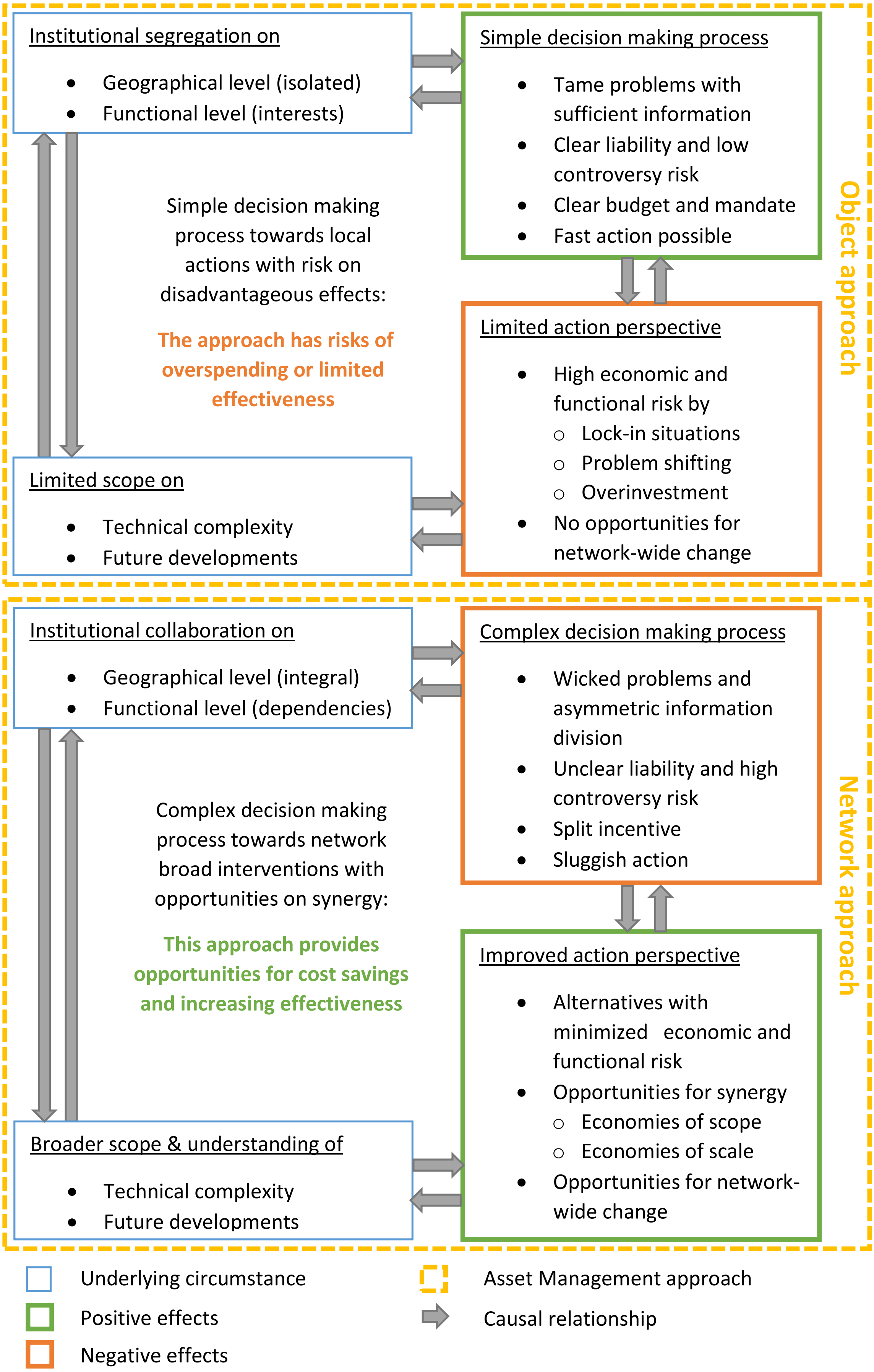


Figure 14 Theoretical Framework: Complete (own illustration)

The current object approach has a simple decision making process for local interventions. The positive effects of the interventions are experienced locally and temporarily. In an object approach, interventions merely focus on the function that the HCS primarily addresses. The executing organisation is specialised in this function, due to the institutional segregation. Because of the long service life of HCS, the interventions are aimed at a single long-term future scenario. Often the worst-case scenario is used. With such interventions, that do not appreciate the network complexity and future uncertainty, risks emerge in a broader network scope and in different future scenarios. There is the risk of problem shifting, overinvestments and the network gradually develops into a lock-in situation. There are no network-wide changes possible to overcome this situation. In addition, the object approach is deficient in addressing uncertain long-term developments like climate change. Consequently, an object approach has risks of overspending and/or limited effectiveness.

A network approach has a complex decision making process towards network broad interventions. The positive effects of the interventions can be experienced network-wide and in the long-term. In a network, intermediate interventions for increasing the network performance can be taken. The same performance improvements can be achieved, as with intervention on one object. However, without committing to a long-term worst-case scenario, lock-in situations, problem shifting and overinvestment, can be prevented. For this reason, the network approach can be efficient in addressing uncertain long-term developments like climate change. Additionally, by focussing on network interdependencies, there are opportunities for network-wide changes, with synergy possibilities for multiple stakeholders. Since a network approach prevents important risks of the current Asset Management approach, and since it has additional opportunities, it has a large contribution to the 10-20% cost savings the ROBAMCI study estimates. Consequently, a network approach has opportunities for substantial cost savings and increasing effectiveness, which are worth the effort of committing to a complex decision making process.

What is remarkable about both approaches illustrated in Figure 14, is the cyclic character. The different elements of both approaches have multiple reinforcing feedback loops. This makes both approaches a system with a self-sustaining feedback loop. A feedback loop, like the current object approach is difficult the escape. However, once a network approach is successfully implemented, this research forecasts that it will be self-sustaining. The next section discusses multiple strategies that were applied in the past in order to get to a network approach. The section discusses what strategy is feasible for application in the context of this research.

2.4. Strategy of implementing a network approach

Escaping the self-sustaining feedback loop of the object approach is not easily achieved. Edelenbos et al. state that segregation itself is persistent and cannot be solved. For this reason, the focus of strategies that implement a network approach, should be on working with the segregation rather than fighting it. Additionally, a network approach is not the result of a deliberate and planned action by one organisation. It should be the result of collaboration that leads to unplanned dependencies (2013a). It is not feasible for organisations to develop a strategic master plan for the collaboration (De Bruijn & Ten Heuvelhof, 2008). The complex nature of the decision making process needs to be faced with interaction between the different organisations (Hertogh & Westerveld, 2010). Only this way, network-wide problems can be addressed and the self-sustaining feedback loop of the object approach can be escaped (Edelenbos, Bressers, et al., 2013a).

Alignment of the frame of perception

Vinke-de Kruijf et al. argue that only two developments can trigger changes in governance practices. One development is an increasing problem pressure and the second development is as institutional change. As already discussed, institutional changes are incapable of implementing a network approach, therefore it is not considered as a strategy in this research. However, the rehabilitation or replacement of HCS is an increasing problem that pressures all organisations. Thus, it provides an opportunity for the implementation of a network approach. The impact of the trigger depends on three circumstances: the core values of the organisations, the frames of perception of the organisations and the interdependencies between the organisations. For the greatest impact, these three circumstances need to be in line with the trigger (2013).

The core values of organisations and interdependencies between organisations are underlying circumstances that are not easily influenced. Contrary to this, according to Hertogh and Westerveld, the perception of the problems and objectives by organisations is ambiguous and changing. The flexibility of the frame of perception can be a focal point of a strategy. The study of multiple large infrastructure projects by Hertogh and Westerveld, proves that alignment of the objectives from the concerned organisations, is crucial for the success of a project (2010). Edelenbos et al. go as far as stating that a synchronized frame of perception on the problems and the objectives of the concerned organisations is needed for establishing a complex decision making process (2013a). This statement is confirmed by Bettini et al. They state that it is important to bring organisations together to recognize shared problems. Subsequently, the limitations of the current institutional structure and knowledge about future plans and outcomes can be aligned. Once a collective frame of the problem is produced, a network approach can emerge (2013).

The method of Framing

In the past catastrophic events created a collective problem for all organisations and helped to bring about network broad actions (Keskitalo et al., 2013). Gradual problems like the rehabilitation or replacement of HCS do not have this effect. **Framing** can be used in order to create a collective problem without the presence of a catastrophic event. Framing is a method for managing perceptions and creating awareness and possible support for a particular frame of perception. Important is that the frame of perception is not projected on organisations, but that a frame is created in which organisations can fill in their own ideas. Through this frame the different ideas from multiple organisations can be matched. This way a widely supported network approach can be established (Verduijn, 2013). Framing is not only related to taking action, but is an action itself. Through establishing a shared frame of the problems, issues like dialogues of the deaf can be prevented (Dewulf et al., 2013). According to Van Ast et al., framing even helps connecting the values of different organisations (2013). Thus, by means of the shared problem frame, organisations get the opportunity to articulate common objectives.

A successful example of the implementation of a network approach through framing is the Delta Program. The Delta Commission managed to frame the climate change issue in such a way, that all relevant organisations could relate to the issue. The frame was strong due to its one dimensional formulation. Effects from climate change became a topic of discussion, creating a sense of emergency amongst the organisations. The Delta Program is now a widely supported program with concrete results (Van Buuren et al., 2014; Verduijn, 2013). Another successful example is the program for the development of the Southwestern Delta in The Netherlands. In this case, a steering group committee developed a convincing and appealing frame in which various developments were meaningfully connected. Each part works towards the shared goal of a sustainable future. By transcending the boundaries of the different projects in the region, it became possible to realise long term ambitions. All relevant organisations were united, in both the horizontal and vertical direction of the institutional structure. This entails all organisations responsible for the water network, in all layers of the hierarchical structure of Asset Management (as shown in Figure 10). The success of the steering group was mainly because, it showed sensitivity to the dependencies between the different organisations and they incorporated the different frames of perception in one bigger picture (Van Leeuwen & Van Buuren, 2013).

Problems in the network are often identified in the operational layer. These are departments of RWS and waterboards that responsible for the daily operations. However, the responsible managers in this layer are unable to address the problems due to limited responsibility, authority and funding. To enable this, support from strategic layer is needed (Keskitalo et al., 2013). In both of the successful examples, the collective problem frame was established in the strategic layer of the organisational structure and implemented top-down (Van Leeuwen & Van Buuren, 2013; Verduijn, 2013). The recognition of the problem frame in the strategic layer of the organisational structure is crucial for establishing a network approach. Additionally, the strategic layer provides the best possibilities for alignment between different organisations, because it has the broadest regional scope and a long term perspective. This layer mainly consists of policymakers for the Min. I&E and waterboards. For this reason, framing should initially focus on top-down implementation of a frame from the strategic layer.

In the example of the South West Delta, connection between all kinds of stakeholders horizontally as well as vertically worked. However, it proved a difficult task getting network broad plans accepted at a regional level (Van Leeuwen & Van Buuren, 2013). The same issue is noticeable in case studies of countries different from The Netherlands. In these countries there are water related problems that need to be addressed in a network broad sense. Like in The Netherlands, in most of these countries water related issues are addressed in a segregated institutional structure, with the focus on execution on a local level. Different strategies are used to let network broad initiatives take root in these segregated institutional structures. This proves to be an issue in multiple cases. In Finland a national climate adaptation policy was implemented in 2005. Although the policy had network support in the strategic layer, the policy was rarely implemented at the tactical or operational layer. The reason for this was: that a policy was projected on these layers, without giving it concrete tools for implementation. The tactical and operational managers of the organisations could not relate to the national policy and therefore did not take action. In Sweden a national Climate Bill was established in 2009. In just a few of the cases, implementation of the national bill at the tactical and operational layer was successful. The reason for this was, that the same requirements were given to all organisations, without considering the financial power of the different organisations. The smaller organisations were unable to finance the plans, so no action was undertaken. In the UK there was a national Climate Act initiated in 2007. Contrary to the other countries, this network broad initiative was implemented successfully. According to an interviewee in the case, the success was due to encourageming of tactical and operational managers of organisations, for preparing initiatives prior to the Climate Act (Keskitalo et al., 2013).

These case studies prove that the decision to implement a network approach cannot be externally imposed on independent organisations. Imposing such a decision, will only lead to resistance to the decision, which works counterproductive (De Bruijn & Ten Heuvelhof, 2008). Merely having a strategy concerning a top-down implementation, does not guarantee success in implementing a network approach (Edelenbos, Bressers, et al., 2013a). Also, in the operational layer the frame of perception of the organisations, should be in line with the organisational changes. In the operational layer, strategic plans get translated and concretized for the local situation. Without the acceptance of the operational layer, top-down initiatives will remain hollow concepts. A tool is needed for the operational layer, to align their frame of perception with the common problem frame. Hence, this problem frame can be translated and concretized to local solutions (Keskitalo et al., 2013).

Management game as a tool for initiating a network approach

Informal structures can help to create acceptance for formal top-down policies, since informal structures can overcome network segregation. (Bettini et al., 2013). An informal structure can be accomplished through the use of **arenas**. Arenas are informal spaces of interaction between the different organisations, that stimulate collaboration, so organisations learn the points of view of each other and are able to share a common frame. Through this arena a long term perspective of the network can be formulated. There is a risk of arenas becoming disconnected from their own organization, support base or working environment. Ideas in a stakeholder platform do not necessarily spread out beyond this platform. In order for the arena to have impact, connections need to be constantly reassessed and reconsidered, in the water governance process (Van Eijndhoven et al., 2013). Arenas in a network approach do not have a clear endpoint (De Bruijn & Ten Heuvelhof, 2008). Reflective spaces, like arenas, are best developed bottom-up, because the technical complexity of the network can be adequately understood at the operational layer (Edelenbos, Bressers, et al., 2013a).

An effective tool for overcoming network segregation is through playing a **management game**. A management game is a form of an arena in which organisations actively participate in a simulation of a complex network, comparable to their work field. On the basis of Triadic Game Design (this will be further elaborated upon in paragraph 4.2, dealing with game design theory) a management game consists of three basic principles: meaning, reality and play (Janssen, 2012). Through the actions of the players and reactions programmed in the game (play), the game enables the imposing of learning objectives (**meaning**) on the players. A shared problem frame should be the meaning element on which the game is based. The frame can be imposed on the players in the game, as a learning objective through the feedback loops, without being explicitly defined. A discussion after the gaming session should help to align the lessons learned by the players. A management game is a proper method to create an alignment between the different organisations in a bottom-up fashion. This alignment can be a frame in which the players collectively compose their long term plans. (Zhou et al., 2013). The simulation in the management game should be based on the experiences of the operational layer, because in that layer the impacts of the complex effects in the network are known best (reality). Additionally, composing the game in the reality of the operational layer, contributes to the acceptance of the problem frame. By being the game subject, operational managers of the organisations can align their frame of perception with the shared problem frame.

The decisions concerning the rehabilitation or replacement of HCS are taken in the tactical layer. This layer mainly consists of policy advisors from RWS and waterboards. The objective of a strategy for implementing a network approach in the Asset Management of HCS, is aligning the action perspective and influencing the decision making process in this layer. The feasibility of a strategy depends on its capability to accomplish this. The top-down framing and bottom-up gaming should increase the feasibility. Additionally, the tactical layer can serve as a link, bridging the gap between the strategic layer and the operational layer in the long term.

Strategy

The discussed method and tool, framing and gaming, have the risk of making the segregation between organisations worse, when these are facilitated and coordinated by an organisation that is involved in the process. When an organisation has self-interest in the collaboration, the frames they try out, can be experienced as biased. The other organisations can decide to stick to their own strategies, causing conflicts of interest. A neutral inter-regime party is able to prevent these suspicions from arising, by facilitating and coordinating the methods and mediating between the different organisations when needed (De Boer & Krantzberg, 2013).

On the basis of this section of literature and background study the third sub-question of the research can be addressed:

c) What can be a successful strategy to establish a network approach in the Asset Management of HCS?

Framing proves to be a proper method to align frames of perception on network problems of different organisations. Through this alignment a network approach can be established for a gradual problem, like the rehabilitation or replacement of HCS. A shared problem frame is best established at the strategic layer of the governance structure and thereafter implemented top-down. This layer has the authority and resources to establish a network approach and has the broadest network perspective to achieve the alignment.

As an informal arena, a management game proves to be a proper tool to overcome institutional segregation and can impose a shared frame on the players from bottom-up. The learning objective of the game should be, that the frame is established in the strategic layer. The simulated reality in the game should be based on experiences of the operational layer of the governance structure. Due to the latter, the operational managers of these organisations can align with the shared problem frame of the strategic layer. This way the network approach has the opportunity to receive support from every governance layer.

On the basis of the answer to the research question, the following strategy is proposed by this research: **"Framing from the top, gaming from the bottom"**

The objective of the strategy is to successfully implement a network approach on the tactical layer. The feasibility of a strategy depends on: capability to align the action perspective and influence the decision making process in this layer. This is accomplished by means of framing the perception of the relevant issues of all organisations involved. Establishing of the frame should take place horizontally in the strategic layer, and should be implemented top-down in the vertical direction of the governance structure. The tool of this strategy is a management game. This game incorporates the frame as learning objective and uses operational layer experiences for the simulation. The intension is, that this game is established bottom-up and gets to be played by all organisational layers. Further on in the research, the pilot of this management game will designed and tested.

The strategy is best coordinated and facilitated by an neutral inter-regime party, in order to prevent conflicts from taking place between the different organisations. Deltares is an ideal candidate for this role, since it is an independent institute of applied research in the field of water.

3 Explorative Case Study

This chapter is the second part of the exploratory phase of this study. The goal of this case study is to explore the field of Asset Management of HCS in practice. This exploration is used to validate and provide a practical example for the theoretical framework, and in this way deliver the definite answers to the first two research questions. Additionally, the case forms the basis of management game. The case study will provide a frame that will serve as the learning objective of the game and as practical experience for the reality of the game.

The first section of this chapter is the case study design (3.1). This section elaborates on how the case is set-up. Furthermore, it elaborates on how the data is handled and on the reason why this case and interviewees are selected. The second section is the case description (3.2). This section elaborates on how the network of the case study is technically and institutionally organized. The third section of this case study displays the results of an empirical analysis (3.3). This analysis is executed on basis of the theoretical framework. The fourth section is an analysis of the theoretical framework on the basis of the case findings (3.4). On the basis of these findings, the theoretical framework is analysed. The last section discusses the input of the case findings for the management game (3.5).

The interview set-up (Appendix D: Interview set-up of the case study), the interview coding (Appendix E: Coding of the case study interviews) and the entire empirical analysis (Appendix F: Complete empirical analysis of the case study) can be found in the Appendix of this research.

3.1. Case study design

In order to achieve the goal of the case study, it is important that the case study is consciously executed. This is achieved by a proper substantiation of the case study design. This section will discuss this design and its theoretical background. It starts with the case study set-up (3.1.1). The case set-up discusses how the case study is build up, what characteristics it has, of what parts it consists and what these parts add to the research findings. After the case set-up, the case selection is elaborated (3.1.2). This describes, what criteria were used for the selection of the case and what the limitations are of the selected case. After the case selection, the data handling is discussed (3.1.3). It discusses where the information comes from and how this information is transformed to usable research findings. Finally the interviewee selection is discussed (3.1.4), since interviews provide the empirical data of the case study.

3.1.1. Case set-up

The explorative phase of the research consists of a literature and background study for the design of the theoretical framework, and a single exploratory case study to validate and provide a practical example for the theoretical framework. Since a single case study is not a valid method to generalize findings, it cannot be used as a study on its own (Yin, 2009). However, the goal of this case study is not to provide results for the complete research, but merely to validate and concretize the theoretical framework of a literature and background study. Through this, it is possible to provide the definite answers to the first two research questions. Furthermore, the objective of the case study is to provide the management game with a frame and experiences.

This case study consists of four parts; the case definition, empirical analysis of the case on the basis of the theoretical framework, an analysis of the findings of the theoretical framework on the basis of the case study and input for the management game. For these four parts, two methods are subsequently applied: a *documentation research* and a series of *in-depth interviews* with key stakeholders from the case.

The documentation research is the *formal part* of the case study and forms the basis of the case description. The goal of the formal part of the case study, is to describe the physical and functional organization of the network of the institutionalized organization. The study will mainly deal with policy and institutional documentation. These documents describe the monitoring of the current state of affairs of the object and the network. The information of these documents will form the objective bases of the case study. The knowledge of the formal part, determines the important stakeholders that are approached for interviews and provide direction for the conversation of the interviews.

The in-depth interviews are the *empirical part* of the case study and this forms the basis of the analysis of the theoretical framework. In-depth interviews are semi-structured interviews designed to explore in depth, a general area of research interest (Legard, Keegan, & Ward, 2003). This interview approach fits the explorative case. In the interviews the topics of the theoretical framework form the topics that are discussed: the perspective of the interviewees on the network, the action perspectives in the network, the different actors and roles in the network and the decision making process. All these topics are discussed on the level of an object and a network approach. Hereby, it is possible to empirically analyse the theoretical framework.

How the interviews are designed and the findings of the interviews are analysed, in order to get the proper research data, is discussed in the section 3.1.3.

3.1.2. Case selection

Crucial is the case selection. Especially, for an analysis based on a single case study, it is important that the results of the case study are comprehensive enough for the research. In order to achieve valuable results, the case needs to comply to a series of criteria. The criteria are set-up in line with the case objective.

- *Representative for the research scope:* The problem of the case should emerge from the end of service life of one or multiple HCS.
- *Access to information:* There should be enough documentation about the case for the formal part of the case study, and the case may not be politically sensitive for the empirical part of the case study.
- *Sense of urgency:* The case needs to incorporate HCS that have reached their end of service life, or will reach this in the near future.
- *Complex:* The problems in the case need to be in a technically complex network and there needs to be a diversity of organisations involved.

The VONK pilot study executed by RWS has raised a suitable case candidate. VONK is elaborated upon in Appendix A: Research on Asset Management of HCS. Relevant for this research, is that VONK aims at linking the future replacement issues of HCS to the plans of the Deltaprogram, which is an initiative with a network approach. For this research, the project executed a case study about the pumping station complex in IJmuiden. The case was of an exploratory character and was not intended to deliver policy changes. The case study fulfills the goals of this research and is therefore selected for the case study of this research.

First of all, the case study of the pumping station complex in IJmuiden complies to all case requirements. The case study is representative for the scope of the research, because the functional performance of the pumping station complex is under pressure. The discharge water of the pumping station complex too often exceeds its water level norm, which is the norm on which the performance of the pumping station complex is measured (Klerk, 2015). Therefore, there are discussions about the future strategy of the pumping station complex. This also shows that there is a sense of urgency within this case. There is sufficient access to information about the case, because the case subject has already been part of a case study. This case is also being used for the research of the HCS work package of ROBAMCI and the TO2 project of HCS of the future (Den Heijer, 2015; Van der Brugge et al., 2015). These researches are simultaneously executed with this research. Another important aspect of this case is, that the contact details of the main stakeholders are directly available. Furthermore, the case subject is not a politically sensitive subject, thus stakeholders are open to provide information in interviews. The case has sufficient complexity since it has a large area with a complex physical cohesion and many different organisations are involved in the Asset Management within the case network.

Since the case of the pumping station complex in IJmuiden is used in multiple other researches, the question arises whether the case in this research creates any new insights. However, the focus of this research is different from the researches of VONK, ROBAMCI and TO2. These researches mainly focus on the technical complexity of the network. Instead of a risk, this is an advantage for using the pumping station complex case for this research. Since the network complexity has already been researched from multiple perspectives, there is a broad view on the complexity of the network. This broad view can be used for the case description of the important elements of the network for this research. The case study in this research distinguishes itself from the other researches, since it is the only research that goes into the decision making process. Additionally, the VONK research provides an opportunity to see wat kind of frame RWS uses to accomplish a network approach and what the impact was of this frame on the other organisations. Since the VONK study is executed by RWS, which has a clear own interest in the case subject. This makes that this research has the possibility to independently observe the results of the VONK case study.

3.1.3. Interview design and data handling

For the empirical analysis of the case study in-depth interviews are executed. In-depth interviewing is a qualitative research technique that involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation (Legard et al., 2003). In total six interviews were executed with seven respondents. The interviews were semi-structured and merely used some general topics as a guideline for the conversation. The interviews mainly focussed on the action perspective and decision making process in the case situation. On the basis of these topics 27 interview questions were set-up. The interview set-up can be found in Appendix D: Interview set-up of the case study.

The interview questions were not literally addressed, but were used to keep the conversations going when needed and helped as reminder to discuss certain topics. The questions that were asked were open-ended rather than closed-ended. The questions about the topics addressed both the factual courses of events and the opinion of the interviewee on this fact. When the answers were not sufficient, **probes** were used. Probes are responsive follow up questions designed to elicit more information. For instance questions like: Could you give me an example? Can you elaborate on that idea? Could you explain that further? Probes can also be non-verbal, like a pause or a raised eyebrow (Boyce & Neale, 2006). Each interview took about 60 minutes. All interviews were taped with the permission of the respondents. All interviews are written out and coded. All interview coding can be found in Appendix E: Coding of the case study interviews. Both the written out interview and coding, were e-mailed to the interviewees for verification and feedback. Not all interviewees responded to this e-mail.

The empirical data is analysed by the means of **coding**. Coding is a method of naming fragments by giving them a summarising label. It is a method to make sense of the unstructured data from the theoretical perspective through segmenting and reassembling (Boeije, 2010). The first step is segmenting. This is dividing the relevant interview output in elements. The seconds step is reassembling, also known as *"open coding"*. It is the process of examining, comparing, conceptualizing and categorizing the data. Based on the relationship between the different elements, the elements are grouped in categories. These categories are finding that not predetermined and are always based on interpretation. It is important not the confuse findings with data. Once the open coding is finished, it is important to reduce the extensive amount of make a distinction between the categories, by testing the importance of the categories. This determining of the core concepts is also known as *"axial coding"*. The key categories form the axes, the subcategories surround these axes. The important parts are often pre-determined by the interview topics. The result of the open and axial coding of the case study of this research is added in Appendix E: Coding of the case study interviews.

3.1.4. Interviewee selection

The contribution of this case study to the rich amount of information that already exists about the case, is the empirical data provided by in-depth interviews. Since the source of this data is the personal experience of the interviewees, a careful selection of interviewees is important. For this reason the interviewees are selected with the use of a couple criteria. All individual interviewees need profound knowledge of and experience in water resource management in the case network. In order to prevent a research from becoming bias, it is important to gain empirical insights from multiple perspectives. Therefore, the interviewees need to perform different roles within their organisation. They need to be persons that make decisions in the tactical layer as well as persons that make decisions in the operational layer. Additionally, the different types of organisations need to be represented by the interviewees.

The documentation research of the case study provides an overview of the organisations that are important in the decision making process in the case network. These organisations were contacted, to get the right interviewees.

The interviewees that were approached and agreed to be interviewed have these roles within their organisation:

- *RWS:* Program director VONK
- *RWS:* Network Manager Rijkswaterstaat Noord Holland
- *RWS:* Case director Spui-Gemaal IJmuiden in VONK
- *Hoogheemraadschap Hollands Noorderkwartier:* Senior policy advisor
- *Waternet:* Policy advisor
- *Hoogheemraadschap van Rijnland:* Advisor policy and research
- *Hoogheemraadschap van Rijnland:* Policy advisor

The interviewee selection fits the criteria. Six of the seven interviewees are senior staff members of their organization. The only interviewee that is not a senior staff member, is project manager of project VONK. So, all interviewees have profound knowledge of and experience in water management. Different roles of the organizational process are represented by the interviewees. Two of the interviewees are responsible for decisions on an operational level in their region, three interviewees are responsible for the decisions on a tactical level in their region and two interviewees are involved in projects that explore new policies on a strategic level. Lastly, the interviewees are selected from different organisations. This is illustrated in Figure 15. Three of the people that are interviewed work for RWS and the other four work for waterboards. RWS and waterboards have different functional responsibilities.

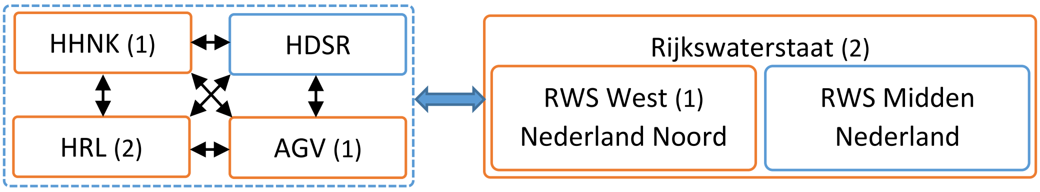


Figure 15 Interviewees within the organisational structure (own illustration)

3.2. Case description

The incentive to start the planning of rehabilitation or replacement of a HCS, is established whenever this HCS reaches his end of technical service life or end of functional service life on the short term. The incentive in this case, is the increasing pressure on the functional performance of the pumping station complex of IJmuiden, causing uncertainties about the end of the functional service life of the HCS (Tosserams, 2014). For this reason, the case description starts off with the pumping station complex of IJmuiden. The function that is under pressure sets the scope of the functions that are discussed in this case study. The functional cohesion in the network concerning this function determines the physical boundary of the case study.

In this section a definition of the network in the case is made. To make this definition, the section discusses the technical complexity (3.2.1) and the governance structure of the network (3.2.2). The technical organisation starts off with a description of the pumping station complex of IJmuiden. This description is succeeded by an explanation of the functional and physical network context of the pumping station complex. The governance organisation discusses what actors are concerned with the governance of the research and how these are formally and informally organised.

3.2.1. Technical organisation of the network

The pumping station complex in IJmuiden is of key importance for the **water discharge** from a large part of the north-west of The Netherlands. Figure 16 displays the map of the network area of this case study. This map forms the basis of the case study.

The pumping station complex at IJmuiden has more functions. It is part of the primary flood defence line, separates fresh and salt water and functions as a fish passage (Spierts, Vis, & Kemper, 2010; Tosserams, 2014). However, the discharge capacity is the function that is under pressure, so this function is the only one that is considered in the scope of this case study.

Appendix B: Introduction to water resource management gives an basic introduction about water resource management in The Netherlands. This appendix can be consulted for background information on how water management in The Netherlands is undertaken and what the importance is of water discharge within water management.

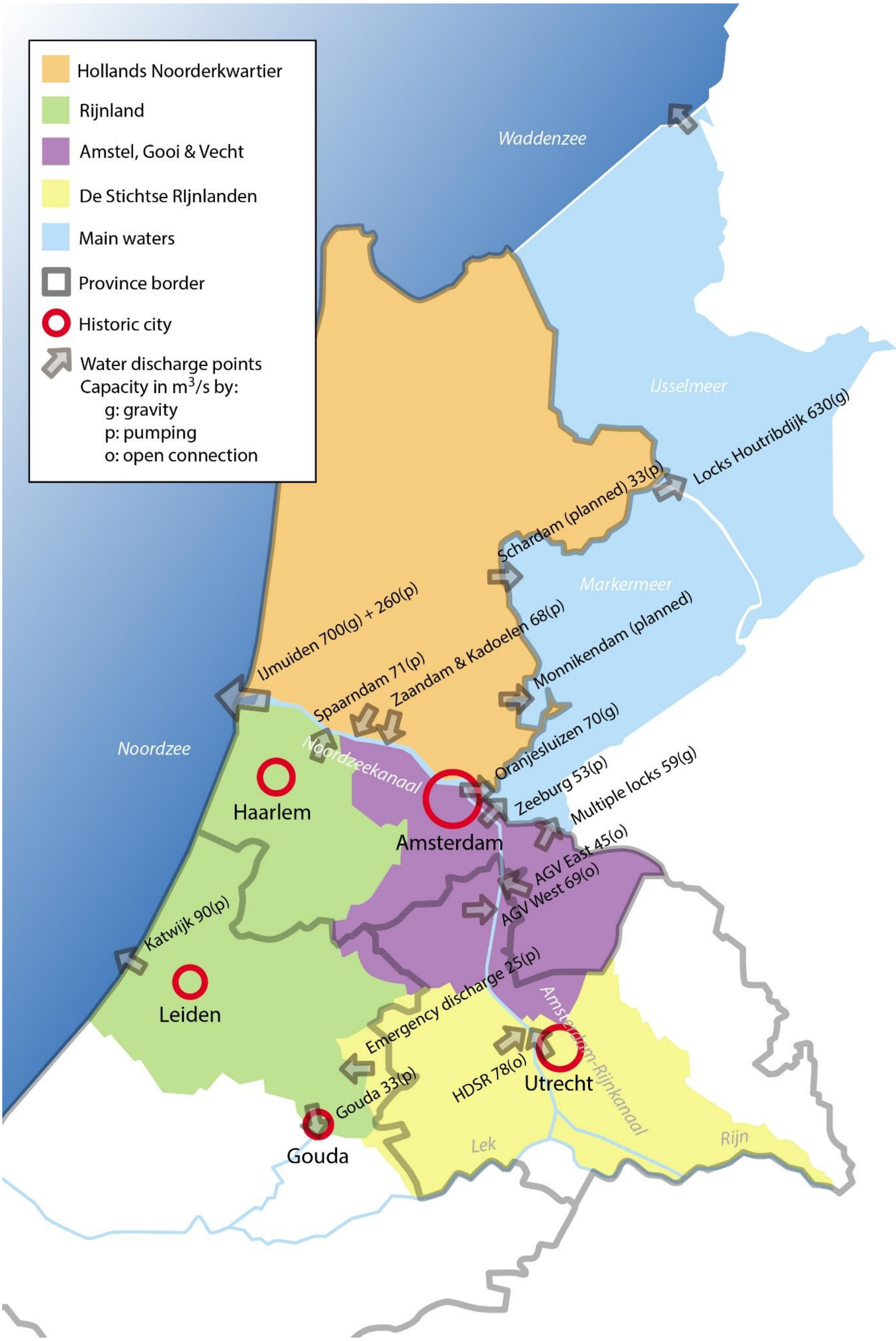


Figure 16 Map of the network defined around of Pumping station complex IJmuiden (own illustration)

As shown in Figure 16, the pumping station complex of IJmuiden is located at the sea estuary of the *Noordzeekanaal* (NZK) and *Amsterdam-Rijnkanaal* (ARK). Figure 17 shows photographs of one of the pumps and the pumping station complex. The complex consists of two parts. The southern part consist of weirs that can discharge water by gravity at low sea levels. The northern part is the pumping station itself. The pumping station can discharge at all times. The discharge by gravity through the weirs can lead up to 700 m^3/s, depending on the water level in the NZK and the sea level. The pumping station has a total of six pumps. Four pumps date back to 1975 when the original station was built, and have the designed capacity of 40 m^3/s. Two newer pumps were established when the station was expanded in 2004, and have the designed capacity of 50 m^3/s. The total discharge with the all six discharge pumps running, amounts up to 260 m^3/s (Tosserams, 2014; van der Wiel, Persoon, & Stiksma, 2013). To place this number into context: the total volume of lecture halls with 250 seats in the faculty of Civil engineering at the TU Delft, have a volume 1160 m^3 (Immerzeel, 2009). This means that the pumping station is capable of filling a room as big as one of these lecture halls within 4,5 seconds. This capacity makes it one of the largest pumping stations in Europe (De Nederlandse Gemalen Stichting, 2012). There is however a risk that the capacity of the pumping station in IJmuiden decreases or in extreme cases stops working. This can happen due to extreme sea level rises, which can take place at springtide and a strong north-western wind (Beuse, 2013).

Figure 17 Instalment of the new pump in 2004 (left) and a view of pumping station complex of IJmuiden (right) (beeldbank.rws.nl)

The pumping station complex of IJmuiden is the main discharge point of the NZK/ARK. The NZK/ARK is part of the Main Water System. The NZK and ARK are the main **discharge waters** for most of the coloured area shown on the map of Figure 16 (Van Baaren, 2010). A discharge water is a waterbody used for water discharge. This area determines the physical network boundary of this research. The area that makes use of the discharge at IJmuiden is spread over four regional water systems. These systems are: Hoogheemraadschap Hollands Noorderkwartier (HHNK), Hoogheemraadschap Rijnland (HRL), Hoogheemraadschap Amstel Gooi en Vecht (AGV) and Hoogheemraadschap De Stichtse Rijnlanden (HDSR). The water discharge, water catchment and the physical interdependencies of the regional water systems are elaborated upon in Appendix B: Introduction to water resource management.

The discharge waters of the NZK/ARK are located in and between regional water systems. The NZK/ARK are designated as a **water basin**. This is an artificial waterbody with no natural water supply and the in- and outlet of water can be controlled (Hooghart, 1986). The NZK/ARK have three main connections with other waters. They are connected to the river Nederrijn/Lek, the Markermeer and the North Sea. The catchment of the NZK/ARK goes from the start of the ARK at the Lek to the estuary of the NZK at the North Sea, which is the main water outlet at IJmuiden. The targeted water level of the NZK is -0,40 cm Nieuw Amsterdams Peil (**NAP**) (this is further elaborated upon in 3.2.2). NAP is the unit that is used for measuring the water level. All water levels in The Netherlands are measured relative to the fixed ground water level of Amsterdam.

The ARK starts with two canals that join together into one canal. One starting point is at the location where the river Nederrijn changes into the river Lek. The ARK is closed off from the river with the Princes Irene Sluis, because the river is elevated (+2,60 cm NAP). The second starting point is further downstream in the Lek. At this point the ARK is closed off from the river with the Princes Beatrix Sluis, this part of the river is also elevated (+0,30 cm NAP) (Rijkswaterstaat, 2015d). Since there are no pumping stations upstream of the ARK, it is only possible to led water in at the Princes Irene Lock and the Princes Beatrix lock (Filius & Van der Wiel, 2015). A constant water flow is needed to provide the cooling water of a power plant near Utrecht (Van den Hark et al., 2000).

The ARK flows into the NZK at the city of Amsterdam. The connection to the Markermeer is located at this end of the NZK. The NZK is closed off from the Markermeer by the Oranjesluizen. At the Oranjesluizen there is a pumping station for water inlet, but not for water outlet. So the only way to use the Markermeer for discharging, is through discharging by gravity. Depending on the water level of the Markermeer and the NZK, the Oranjesluizen can be used for water outlet. This discharge capacity can add up to 70 m^3/s. The targeted water level of the Markermeer is -0,40 cm NAP during winter and -0,20 cm NAP during summer. However, this water level can fluctuate, which also accounts for the water level in the NZK. There is a pumping station in the city of Amsterdam at Zeeburg, which can discharge water from the city thought a syphon into the Markermeer. This pumping station has the capacity of 53 m^3/s. Water of the Markermeer can be discharged, through the IJsselmeer, into the Waddenzee (Filius & Van der Wiel, 2015; Rijkswaterstaat, 2015d). The Markermeer and IJsselmeer are both part of the Main Water System.

It is evident by the above given quantities, that the pumping station complex of IJmuiden is of great importance for the discharge of water from the NZK/ARK (Van den Hark et al., 2000). Technically, the pumping station complex has its defects and complications, but the concrete structure is this of good quality. Since the other technical parts are mostly replaceable within their structure, there is no technical reason for rehabilitation or replacement of the complex. Therefore, the end of technical service life of the pumping station is something that takes place in the long term (Lee, 2012). However, the pumping station is expected to reach the end of its functional service life on a shorter term, despite its current capacity.

The end of functional service life of the pumping station complex is reached when the water network fails to reach its required performance level. However, there is no clear definition of the network failure in the case situation. The performance of the pumping station complex is measured on the basis of the water level in the NZK/ARK. As already mentioned, the targeted water level in the channel is -0,40 NAP, but may fluctuate between -0.30 NAP and -0.55 NAP. Floods are generally considered a network failure for the discharge of water. Nonetheless, beyond the level of -0,30 NAP no floods occur. This water level has nothing to do with flood risk (Beuse, 2013; Klerk, 2015). It is not known what flood risk applies to the different water levels. What makes it complex, is that not only the NZK/ARK can have a flood risk, but all adjacent regional water systems are also at risk. Flood risk is generally expressed as probability of flooding, set against the impact. The probability is for instance expressed as: the unit of 1/100 years, meaning that that the probability of the impact is once in a hundred years. The impact is expressed by the water level on which flooding takes place. Because the impact is not known, there is no failure risk norm for the NZK/ARK.

The impact of the risk norm is critical in determining the functional end of service life of an HCS. This can be observed by the fact that two reports, that use different impact norms, have completely different conclusions. Both of the reports use the same probability norm of 1/100 years. Tosserams uses the impact norm of -0,30 NAP and argues that the functional end of service life has already occurred on the basis of this norm. However, he adds that this might not be the case when a different water level is used (2014). This is proved by Van der Wiel et al. They use in their research, the norm of +0,20 NAP. With this failure risk norm, the network has no functional problems at all (2013). The norm used by Van der Wiel et al. seems out of place, since it is the only research with such a high positive number. Additional researches go as far as addressing the impact up till 0 NAP (De Wit, 2015; Van den Hark et al., 2000). From -0,20 NAP on, flooding starts to occur in the network, according to these documents. The question remains, what amount of damage these floods might cause.

It is predicted, that the performance of the water network will be under increasing pressure in the future, due to changing conditions. These changing conditions are: a rising sea level, more extreme weather and more high water levels at the Lek and the Rijn (KNMI, 2014; Van den Hark et al., 2000). This has the effect that, the time period for discharging by gravity decreases and that the performance of the pumping station at IJmuiden decreases. In contrast to the increasing amount of water that needs to be discharged, this can become problematic in the network.

3.2.2. Governance structure of the network

As already discussed in 3.2.1, the case network consists partly of the Main Water System and partly of regional water systems. This is roughly the institutional segregation in the horizontal direction of the case situation. This division is illustrated in Figure 18. In the entire width of the governance structure, the tactical and operational tasks are preformed within the same organisation.

In the Main Water System this is executed by two district departments of RWS. These departments are responsible for the daily operation and the rehabilitation or replacement planning of the HCS in the Main Water System. The HCS they are responsible for are: the pumping station complex at IJmuiden, the Prinses Irene and Prinses Beatrix Sluis, the Oranje Sluizen and the locks in the IJsselmeer area. This is illustrated in the map of Figure 16. Considering that the district departments are responsible for the pumping station at IJmuiden, it is not surprising that the case study of VONK was initiated by these departments (Tosserams, 2014).

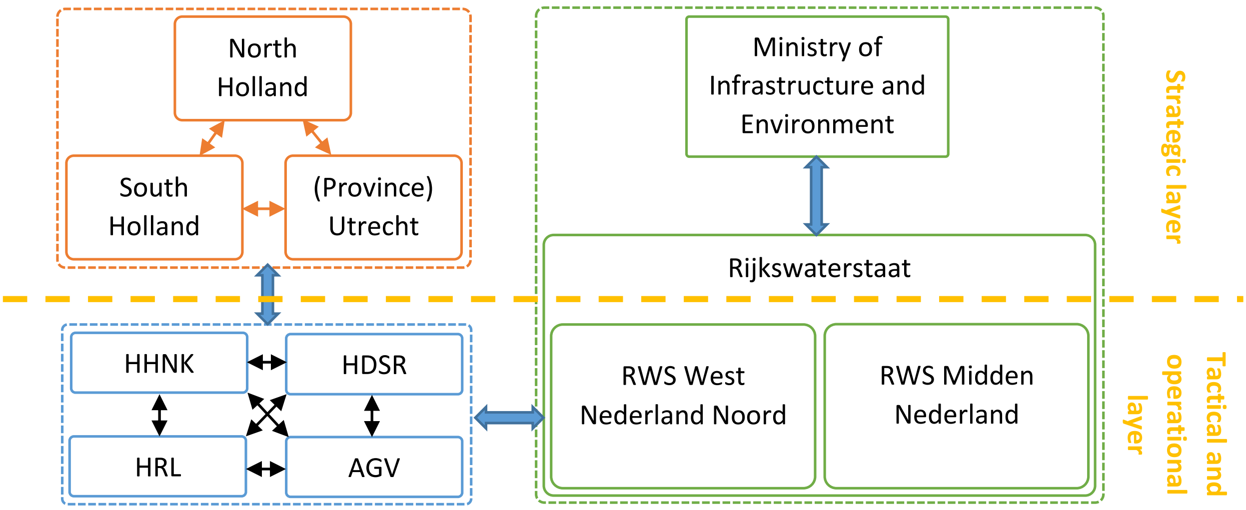


Figure 18 Governance structure of the case IJmuiden (own illustration)

In all regional water systems, waterboards are responsible for the daily operation and the rehabilitation or replacement planning of the HCS. The only exception is AGV. Waternet is the executional organisation of both AVG and the municipality of Amsterdam, considering water related issues. All the important HCS of the waterboards are illustrated in the map of Figure 16 (Tosserams, 2014).

For both RWS and the waterboards, the role of organisation in the tactical layer is limited. For RWS this is the Min. I&E. RWS is part of Min. I&E, thus not completely an autonomous organisation. However, being the executive organisation of Min. I&E, RWS has a great freedom in determining their policy and deploying plans and initiatives. This is executed in the national organisation of RWS. The tasks of Min. I&E consist mainly of approving plans and budgets. The HCS are owned by the ministry, in spite of this, they do not prescribe any norms for these HCS. For the waterboards, the tactical layer is executed by the provinces. Depending on the location, waterboards can have different provinces above them. This division is illustrated in the map of Figure 16. Depending on the hinterland, the provinces prescribe the norm for the flood probability to the waterboards. Since the waterboards lack expertise, this often happens in consultation with the waterboards. The waterboards own the HCS and determine their own policies, like the water levels. The role of the tactical organisations, is limited in both situations, therefore these organisations are not further discussed in the case study (Ministerie van Infrastructuur en Milieu, 2011).

There exists a formal institutional connection between the organisations on the operational layer. This connection is based on two formal agreements: the *Waterakkoord* and the *Peilbesluit*. Both documents contain agreements on actions, that need to be taken at certain water levels in the NZK/ARK. At a water level of -0,30 NAP, the interest of the water discharging will outweigh the interests of the shipping industry. Locks can be used for additional discharging by gravity. At -0,30 NAP RWS gets the authority to impose discharge limitations to the NZK/ARK, on the waterboards. At 0 NAP RWS gets the authority to impose a complete discharge stop to the NZK/ARK, on the waterboards (Beuse, 2013; Klerk, 2015).

3.3. Results of the empirical analysis of the case study

This section contains the results of the empirical analysis of the case study. The analysis is based on the theoretical framework of this research (2.3). Accordingly, the four main building blocks of the theoretical analysis: scope, action perspective, governance structure and decision making process, are the main topics discussed in this section. It is studied how the case situation relates to the conditions identified in the theoretical framework, and how this relates to the object and network approach. This section only shows the results of this study. The complete empirical study can be found in Appendix F: Complete empirical analysis of the case study. This arrangement of the subjects is based on the building blocks of the theoretical framework and therefore differ in chronology from the interview questions.

3.3.1. Scope & understanding

Figure 19 illustrates the blocks of the theoretical framework that this part of the empirical study addresses. It can be concluded that there is a limited scope on the technical complexity of the network and the future developments in this case situation. The scope is limited to network borders and HCS connecting the different regional systems. This limited definition and basic understanding of the technical complexity of the network is shared by all interviewees. However, they all lack an in-depth understanding of the technical complexity of the network. The exact impact of the wicked effects in their own systems is not known by the interviewees. For instance, the flood risk is not known. The water resource management activities in the case network merely focus on maintaining water levels, without knowing the risks of these water levels. As a result, the critical water level defined in the

Peilbesluit is not accurate. No problems occur in the network when this level is exceeded. Additionally, the exact performance of the pumping station complex of IJmuiden is not known. It is only certain that the pumping station does not meet its performance of 260 m^3/s and that this capacity decreases at high sea levels. How the different sea levels impact the capacity of the pumping station is also unknown. Apart from the lack of knowledge of their own systems, RWS and the waterboards do not know how the systems of the other organisations work and have a different interpretation of network failure. When discussing flood risk, RWS addressed the risk of floods taking place in the NZK/ARK area. Waterboards address the risks of regional floods due to discharge limitations. The organisations therefore have a different scope on the problems occurring in the network. There is however, a risk analysis of the complete network being developed, in collaboration with the different organisations.

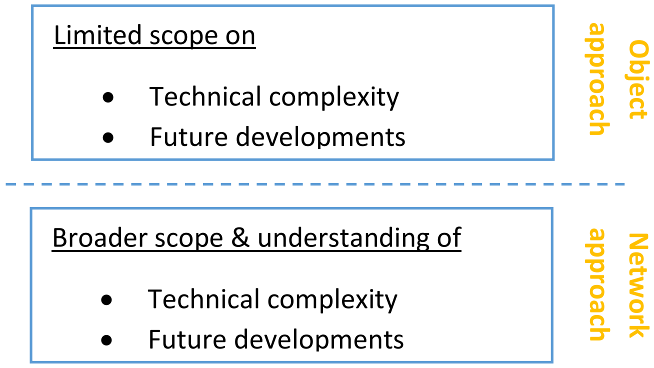


Figure 19 Theoretical framework: scope & understanding (own illustration)

In the operational layer, there is alignment between the different systems in the form of protocols and agreements. For the major part of the time, the case network works perfectly and no problems occur on the basis of these agreements. However, during critical times with high water levels, issues occur in the networks. Decisions on solving the issue are then made on the basis on informal contact between the responsible managers of the different organisations. Due to the informal contact, the scope of the network complexity depends on which managers are present. The protocols and agreements do not include anticipating measures. RWS and the waterboard value the importance of anticipating measures differently. This causes friction and accusations between the different organisations. There are however, plans to revise the Waterakkoord and increase the alignment between the different organisations in the operational layer.

There is little to no alignment in the tactical layer. Organisations plan and execute interventions on their HCS, without considering the network. As a result there are missed opportunities to increase the network performance. It is not clear whether not considering the network is a deliberate or an unconscious act. The organisations do not have knowledge of future developing plans of the other organisations. However, the initiation of the VONK study by RWS is a first introduction of network alignment in the tactical layer.

The most remarkable thing of this part of the empirical analysis, is something which is not explicitly mentioned. It is the fact that the rehabilitation or replacement of HCS is not perceived or addressed as a shared problem. When the pumping station at IJmuiden fails its performance, it is said that everybody feels the negative consequences. However, these negative consequences impact the operational layer, not the tactical layer. In the tactical layer the failure of the pumping station is an affair that only RWS needs to address. All organisations have the same attitude towards the construction of other pumping stations in the network. There is no alignment in problem perception between the different organisational layers. Since the actors do not address the problems in the tactical layer as shared problems, the organisations will also not automatically start looking for shared objectives in this layer.

3.3.2. Action perspective

Figure 20 illustrates the blocks of the theoretical framework that this part of the empirical study addresses. It can be concluded that in the case situation, there is a high economical and functional risk, due to the limited action perspective of the organisations. Different types of negative effects can be observed. Problem shifting mainly takes place in the functional context of the case network. Many interventions address a specific function, not considering the other functions present in the water bodies. Interventions in the network context that are focussed on the improvement of shipping transport, cause salinization problems that impact ecology and agriculture. Examples of these interventions are dredging canals and the realisation of new sea locks. The interviewees however mention that problem shifting is a declining phenomenon, since there is improved mutual monitoring.

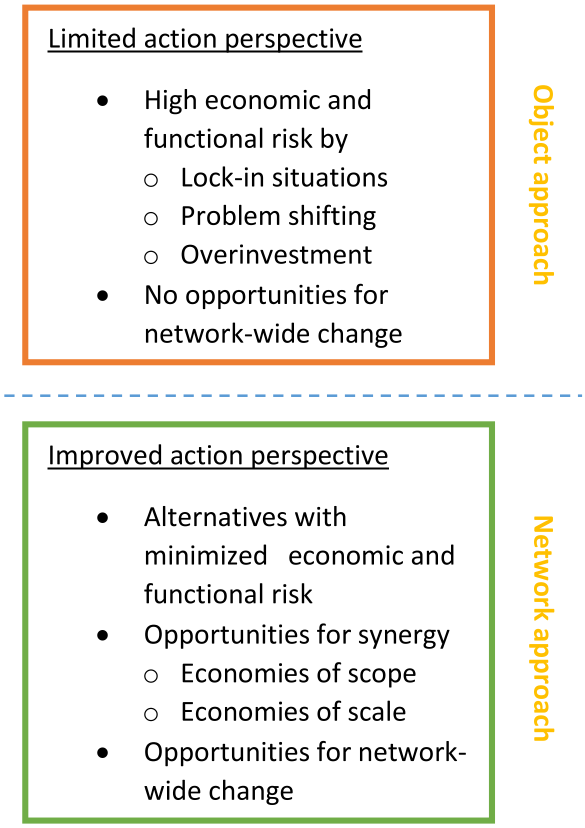


Figure 20 Theoretical framework: action perspective (own illustration)

The case situation suggests that the network is approaching a lock-in situation. Only few alternative solutions for improving the case network, instead of replacing the pumping station at IJmuiden, seem to be feasible. This is mainly caused by the failure of not considering the complete network context in recent interventions. The interventions on the pumping stations at Katwijk, Schardam and Monnikendam were merely focussed on the regional needs. Possibly, these pumping stations could have unburdened the case network, but this opportunity was not utilized. Due to the limited scope of the organisations, the actions perspective to improve the network has decreased and the risk of a lock-in has increased. Because of its key role in the network, postponing an intervention on the pumping station of IJmuiden can lead to a great decrease in network performance. Due to this, it is arguable that the network is already in a lock-in situation. Replacing the pumping station at IJmuiden will make the network even more depended on this HCS. This can be the final push in reaching a lock-in situation.

In order to prevent the negative effects from taking place and to make network-wide changes, interventions with a network-wide support are needed. This is understood by the interviewees from RWS and it is the reason they started the VONK pilot. The clustering of budgets can be interpreted as a synergy opportunity. However, both RWS and the waterboards count on each other to come up with a solution for the network problems. They do not consider taking the initiative and request a financial contribution of the other organisations for their plans.

The case situation provides multiple alternatives to improve the network performance. When these are addressed from the perspective of the functional end of service life of the pumping station at IJmuiden, the alternatives can be divided into four categories. The first category is increasing the performance of the HCS itself. In this case, this mean increasing the discharge capacity of the pumping station in IJmuiden. This is the option RWS has from an object approach, which takes place in the tactical layer. The second category is the reduction of the load that puts the performance under pressure. In this case, this is done by reducing the water load in the network, by alternative discharge routes and operation alignment. This category is established in a network approach and takes place in the operational and the tactical layer. The third category is the reduction of risk. In this case this is reducing the flood impact, by allocation emergency storage areas. This category is established in the network approach, in the tactical layer. The fourth category is norm specification. In this case this is defining the failure risk. This category is established in the network approach, in the strategic layer. Only the first of these four categories exist in the action perspective of the object approach. The other three categories are only possible in the network approach.

3.3.3. Governance structure

Figure 21 illustrates the blocks of the theoretical framework that this part of the empirical study addresses. The blocks consider the governance structure of the objects approach and network approach. However, the formal structure is already discussed in 3.2.2, since this is well documented. This sections focusses on the interests and dependencies of the organisations in this governance structure, since these findings emerged from the empirical study.

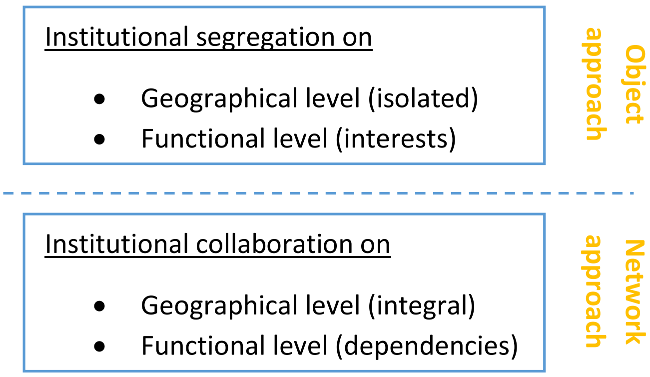


Figure 21 Theoretical framework: Institutional structure (own illustration)

It can be concluded that the integration that takes place between the different organisations, is mostly based on informal contact. There is no formal policy of communication and there are no formal rules for collaboration. The different organisations have diverging interests. Their interests can be driven by functions present in the waterbodies, that are not part of the case definition. The self-interest of the organisations is strong, due to a large amount stakeholders that are active in their regions. Additionally, there are strong interdependencies between the organisations considering water resource management. On the basis of this paragraph the following table can be drafted:

Organisation	Interest	Dependency
RWS	• Shipping industry: pass ability of the NZK/ARK • Limitation of use of pumping complex IJmuiden for cost reduction • Postponing the replacement of the pumping station	• Waterboards: Regional water storage • HRL & HHNK: Alternative discharge routes
HRL	• Voters: determine the policy • Agricultural sector: part of the executive board • Greenports: very sensitive to high water levels	• RWS: Discharge at IJmuiden and water
HHNK	• Voters: determine the policy • Agricultural sector: part of the executive board	• RWS: Discharge at IJmuiden and water
AGV	• Voters: determine the policy • Agricultural sector: part of the executive board	• RWS: Discharge at IJmuiden and water

	• Municipality of Amsterdam: Industry and businesses	• HRL & HHNK: Regional water storage and alternative discharge routes
HDSR	• Voters: determine the policy • Agricultural sector: part of the executive board	• RWS: Discharge at IJmuiden and water • HRL & HHNK: Regional water storage and alternative discharge routes

Table 1 Interest and dependencies of Asset Management Organisation

All interviewees favour a network approach, but they also express that everybody needs to take care of their own issues, before they can start accepting demands from other organisations. Most waterboards have internal struggles to satisfy the needs of their stakeholders. RWS and waterboards are depended on the support of their stakeholders for the execution of their policy, since they have limited authority over the hinterland. For instance, support of stakeholders is be needed for the assigning of construction permits. The waterboards in particular, express that RWS does not act within the interest of the water resource management and focusses too much on the shipping industry.

Due to the key role of the pumping station complex of IJmuiden in the network, the waterboards seem to be more depended on RWS than vice versa. This accounts mainly for the operational layer. In the tactical layer RWS is depended on the waterboards for local interventions, as an alternative to having to replace the pumping station complex in IJmuiden.

3.3.4. Decision making process

Figure 22 illustrates the blocks of the theoretical framework that this part of the empirical study addresses. It can be concluded that, in general, the water resource management is well organised in The Netherlands. There is little public attention for interventions on HCS in the case situation. The decision making process is relatively simple. However, all circumstances discussed in Figure 22 that complicate the decision making process, exist in the case situation and therefore threaten the success of the network approach.

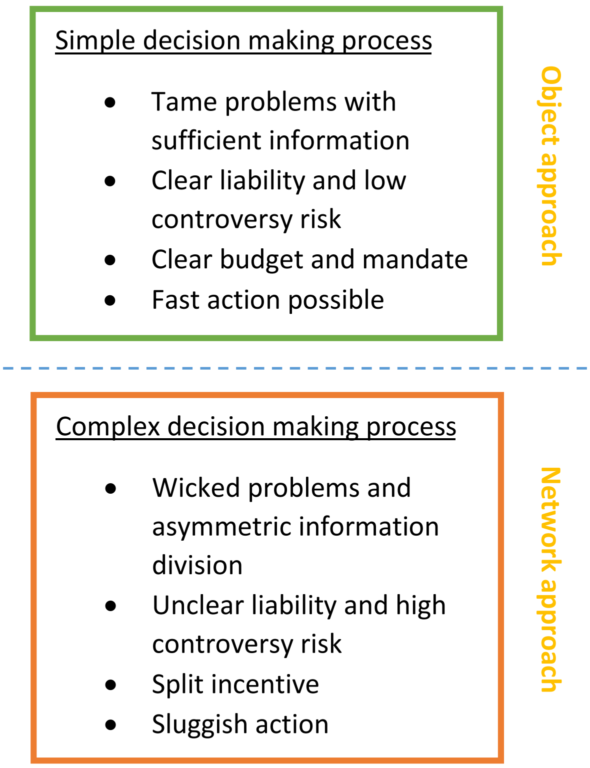


Figure 22 Theoretical framework: Decision making process (own illustration)

Currently, in the case situation the problems are mainly approached as tame problems. The determination of the end of service life of the network is mainly based on technical failure of HCS. There is little known about the limits of the functional performance of the network, since this is found too complex. Merely focussing on the technical end of service life makes it more difficult to prevent failure. Sharing of information is seen as important step towards collaboration and improving the network performance. On the basis of sharing views on future developments, clear shared norms can be defined and shared decision making will be simpler. However, the alignment of information and knowledge proves to be technically difficult and there is lack of trust between the organisations. Different organisations use different systems that are difficult to align, and not all wicked effects are easily transformed into data. Additionally, organisations are restrained into sharing their information, since they fear that the (sometimes sensitive) information is misused. Also occasionally, waterboards do not trust the information that RWS delivers. Despite the difficulties, there are currently some shared initiatives dealing with the alignment of data in the case situation.

One of the reasons waterboards are restrained about sharing information, is the risk that stakeholders in their region will abuse the information for legal procedures. Local measures aimed at unburding the network are not without risk for their own region. Due to the limited authority over the hinterland, the waterboards have the public involved in their decision making process. Especially alternative solutions that emerge in a network approach, like emergency discharge areas, cause a lot of regional opposition. Stakeholders make use of the media to create controversy and enforce actions of the waterboards in their favour. Controversy sometimes forces waterboard to irrational decision making. Expensive in effective measures get taken, just to create a positive image for the general public. This unpredictable behaviour harms the trust in collaboration. Waterboards seem to be more sceptical about liability issues and controversy than RWS.

What also harms the trust, is the fact that all organisations fail to put aside their own interest. They all want to benefit from the collaboration and therefore come up with demands. The interviewees see it as the only way to get the plans approved within their own organisation. The demands set by the different organisations often conflict with the interest of other organisations. This results in split incentives. One organisation has the authority, but no interest in a certain action. Another organisation has in interest in this action, but not the authority. Cultural differences between the different organisations also cause conflicting interests. The conflicting interests harm the trust and result in back and forth judging remarks between waterboard and RWS interviewees. Waterboards blames RWS for not taking their demands serious. RWS suggests that the waterboards might oppose collaboration, because they fear this threatens their right to exist.

Because of all these circumstances, the interviewees expect the decision making process to slow down and diverge from the actual problems in a network approach. Particularly, when short terms actions are needed, a network approach is undesirable.

Despite the threats that a network approach imposes on the decision making process, all interviewees look back satisfied on their collaboration in VONK study. Even though the goal of VONK was never to come to concrete results in the case situation, the interviewees see possibilities for network collaborations in the future. It might be that in reality, the threats to the decision making process turn out to be less a problem than expected.

3.4. Analysis of the theoretical framework on the basis of the case findings

The theoretical framework proved to be suitable for the case analysis. Most of the observations of the case study correspond to the circumstances that were identified by the framework. Nonetheless, there are some unexpected aspects discussed in the case study. These new insights provide nuances for the usage and understanding of the framework. Additionally, in the case study some possible additional circumstances are identified to complement the framework. In total there are nine new insights defined. These insights are arranged in the same order as the paragraph topics of the empirical analysis.

Scope & understanding

1. **It is not unequivocally determined when there is a functional end of service life.** In case of the pumping station complex in IJmuiden, it seems a debatable issue. The many variables make it a complex problem. In addition, different organisations interpret the information differently. In particular, a clear norm proves to be crucial in determining this moment.

2. **The case situation does not have an object approach, that is as strict as the theoretical framework describes.** Most organisations have an internal focus in their policies, but these are focussed on finding a balance within their own system. Therefore the perspective of the organisation is limited to the region, rather than the isolated HCS. In the operational layer there are already inter-organisational alignments. However, most of the alignment takes place through informal contact. The actors are aware of the network and its functional cohesion. In this layer, the first initiatives to align the water resource management of the different organisations have been undertaken.
3. **The rehabilitation or replacement of HCS is not perceived or addressed as a shared problem.** When the pumping station at IJmuiden fails to reach its performance level, it is said that everybody feels the negative consequences. However, these negative consequences impact the operational layer, not the tactical layer. In the tactical layer the failure of the pumping station is an affair that only RWS needs to address. All organisations have the same attitude towards the construction of other pumping stations in the network. There is no alignment in problem perception between the different organisational layers. Since the actors do not address the problems in the tactical layer as a shared problem, the organisations will also not automatically start looking for shared objectives in this layer.

Action perspective

4. **The additional actions that emerge in a network approach can be categorized.** Figure 23, which is used to determine the end of service life of a HCS, can show how these categories of actions contribute to the Asset Management. This figure illustrates the performance of one HCS. With an object approach the only possible action, is an intervention on the HCS, in order to increase the performance. In Figure 23, this is illustrated by the possible intervention decision. In a network approach is it possible to reduce the load that puts the performance under pressure. This can be done by means of an intervention elsewhere in the network or through better alignment of operations. The reduction of the load has as effect, that the performance curve of Figure 23 will drop less steep. Additionally, in a network approach risk reduction measures can be taken. This has as an impact that the performance of Figure 23 moves up. Lastly, in a network approach the norm can get more specified. This has as an effect, that the norm line can move down and delays the determination of the end of service life. All three alternative categories that emerge in the network, allow postponing the intervention on the HCS.

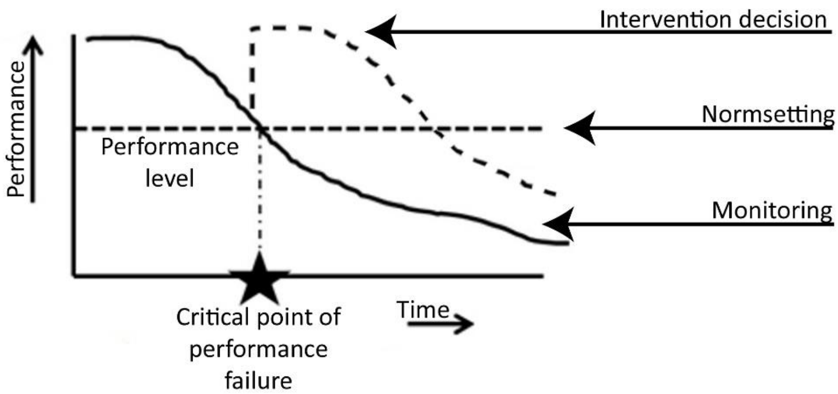


Figure 23 Graphical representation of asset performance (Huibregtse, Donker, & Schelland, 2015)

5. **Underinvestments occur in the case situation.** By not addressing the complete network in the planning of interventions, the potential increase of network performance is not fully utilized.

This increases the risk of a lock-in situation and has as an effect that big interventions on HCS are not postponed. There are no signs of overinvestment in the case situation.

6. **RWS and the waterboards count on each other to come up with a solution for the network problems.** They do not consider taking the initiative and request a financial contribution of the other organisations for their plans. For this reason synergy opportunities do not get utilized.

Governance structure

7. **Interdependencies in the network can differ per organisational layer.** It is difficult to align the dependencies between the organisations, since they occur in different layers. The waterboards depend on RWS in the operational layer, whilst in the tactical layer RWS depends on the waterboards.

Decision making process

8. **The waterboards in the case situations, have internally quite some issues, due to public involvement.** The decision making process for interventions on HCS is relatively simple in an object approach. However, issues with stakeholders emerge when decisions consider alternative regional solutions or when there is critical situation in the operational layer. Consequently, the decision making process for the regional managers is not necessarily simple.
9. **There seem to be more issues that influence the decision making process.** Culture, trust and the right to exist have not been discussed in the theoretical framework, but are explicitly named by the different interviewees. In particular trust proves to play a critical role in the success of a collaboration. These aspects might limit the flexibility of organisations in adapting new frames of perception. Therefore, trust can play an important role in the success of applications, that need to establish a network approach.

Most new insights provide nuances for the use and interpretation of the theoretical framework. For instance the distinction between the object approach and the network approach is not as strict as the framework suggests. Circumstances suitable of both approaches can occur in the same case situation. In addition to the nuances, the case study provides some circumstances that complement the theoretical framework. For instance, an in-depth research of the role of trust, can contribute to the decision making process block. The new insights merely address details of the theoretical framework. In the general sense, the theoretical framework adequately addresses aspects that occur in the case situation. Therefore, no drastic changes are needed for the theoretical framework. On the basis of this framework, enriched with the findings of the case study, it is possible to provide the answers to the first two sub-questions of the research:

a) What are the implications of an object approach for the action perspective and decision making process for the Asset Management of HCS?

The current object approach has a simple decision making process towards interventions on HCS. Regional stakeholders can oppose actions in the operational layer or local alternative interventions in the tactical layer. Therefore, the decision making process towards these kind of decisions can be complicated. The positive effects of the interventions are experienced locally and temporarily. In an object approach, interventions merely focus on the function that the HCS primarily addresses. The executing organisation is specialised in this function, due to the institutional segregation. Because of the long service life of HCS, the interventions are aimed at a single long-term future scenario. Often the worst-case scenario is used. Determination of the end of service life mainly focusses on technical failures. With such interventions that do not appreciate the network complexity and future uncertainty, risks emerge in a broader network scope and in different future scenarios. There is the risk of problem shifting, overinvestments, underinvestments and that the network gradually develops into lock-in situation. There are no network-wide changes possible to overcome this situation. In addition, the object approach is deficient in addressing long-term developments with uncertain results, like climate change. Consequently, an object approach has risks of overspending and/or limited effectiveness.

b) What are the implications of a network approach, for the action perspective and decision making process for the Asset Management of HCS?

A network approach has a complex decision making process towards network broad interventions. The decision making process is complex since decisions need me be agreed upon by multiple organisations. Issues with local stakeholders that occur in the object approach make organisations cautious about collaboration, since it can mean an increase to an already demanding public involvement process. Additionally, the organisations are restrained towards collaboration due a lack of trust in the other organisations. However, they do have the tendency to wait for other organisations to take initiative in improving the network performance. In reality the threats can turn out to be more positive, like in the pilot study of the VONK. The participants recognized the positive effects of the network approach and were positive about extending the collaboration.

The positive effects of the interventions can be experienced network-wide and in the long-term. Only in a network approach it is possible to accurately address functional end of service life. In a network intermediate interventions to increase the network performance can be taken. The same performance improvements can be achieved, as with an intervention on one object. Contrary to an object approach, without having to commit to a long-term worst-case scenario, lock-in situations, problem shifting and overinvestment, can be prevented. The possible actions in an increased action perspective in a network approach can be divided into four categories: Actions to improve the performance of the HCS, actions to reduce the load that pressures the network performance, actions that reduce the failure risk and actions to specify the performance norms. Due to this action perspective, the network approach can be efficient in addressing uncertain long term developments like climate change. Additionally, by focussing on network interdependencies, there are opportunities for network-wide changes, with synergy possibilities for multiple stakeholders. In order to use interdependencies as a starting point, the different organisational layers need to be aligned, because the interdependencies can differ depending on the layer. Since a network approach prevents important risks of the current Asset Management approach, and since it has additional opportunities, it has a large contribution to the 10-20% cost savings, that the ROBAMCI study estimates as the achievable benefit of improving the Asset Management of HCS. Consequently, a network approach has opportunities for substantial cost savings and increasing effectiveness, which are worth the effort of committing to a complex decision making process.

3.5. Input for the management game

In addition to the feedback on the theoretical framework, the case findings form the basis of management game. The case study will provide a frame that will serve as the learning objective of the game and provides practical experience for the reality of the game.

Frame

By reviewing the VONK project, it can be concluded that it was successful as a pilot project of the Delta Program. Despite the fact the project led to discussions and some accusations back and forth between RWS and the waterboards, there is also an increasing understanding of the interdependencies. All interviewees are satisfied with the insights the project has given them and have indicated that they want to extend the collaboration. It is difficult to assess what the exact impact of VONK was, since it is not known in this research how the situation was, before the project. On the basis of the positive notions of the interviewees, it is assumed that the project improved the relationship between the different organisations.

The VONK project however failed in aligning the problem perception of the all the involved organisations. The rehabilitation or replacement of HCS is not perceived or addressed as a shared problem in the tactical layer. With the replacement of the pumping station complex in IJmuiden in mind, this is probably an effect that RWS desired. As discussed in paragraph 2.4, creating a shared perception of the problem is a promising strategy in order to establish a network approach. Framing is practically suitable for the alignment of problem perceptions. Therefore, the idea that the rehabilitation or replacement of HCS is a shared problem in the tactical layer, is the frame that the management game will carry out as the learning objective.

Probably one of the reasons why waterboards do not accept the functional end of service life of the network as a shared problem, is that the VONK project is initiated by RWS. By initiating a frame in which there is strong own interest, the targeted organisations can experience this frame as biased and therefore oppose it. Another initiative discussed in the Decision making process paragraph of Appendix F: Complete empirical analysis of the case study, is *Slim Water Management* (SWM) (English: Smart Water Resource Management). SWM is network initiative in the operational layer, that proves to be successful in Brabant. Possibly the reason for this success is, that SWM is initiated as part of the Delta Program. The Delta commission does not have any personal interest in the content of the outcome. Therefore, for this case situation the game can be of added value, as long as it is set-up and facilitated by a neutral organisation, assuming the game has the desired effects.

Management game simulations

The operational issues of the case seem a promising subject of the simulation that the management game. Promising is the fact, that all organisations have a strong self-interest. For RWS this is only discharging water from the NZK/ARK when needed. For the waterboards this is discharging as much superfluous water as possible to the NZK/ARK. When every organisation fulfils his own interest during a critical situation, they together create a high risk of network failure. If the network fails and RWS needs to give out discharge limitations, some waterboards will feel the negative consequences. This situation is well suited for a gaming situation. Every organisation can personally profit most from focussing on their own interest, however there is a risk that they feel the consequences if the network fails. By putting aside their interest, they will not experience the high profit, but the risk of network failure diminishes. Therefore the sum of all profits of the organisations will be higher in the situation where the organisations choose for the shared interests over their own interests.

The case situation has had quite some critical situations, but never has an extreme disaster occurred. However, there is a risk that this can happen if two incidents coincide. This fact is promising for the game design, because it allows extreme problems in the simulation, so they are as realistic as possible and close to a real life situation.

A last promising case situation for the design of the management game, is the difference of the regional situations for the different organisations. On the operational layer, two waterboards are almost completely depended on the other organisations. Two waterboards have possibilities to help the other waterboards. One can discharge into the sea, the other into the Markermeer. RWS is not harmed by the high water levels in the NZK/ARK, but has the possibility to help the waterboards with anticipating measures before a critical situation occurs. On the tactical layer, all organisations can profit from the waterboards finding alternative discharge routes or emergency storage areas. This imbalance in interdependencies makes for an interesting gaming situation.

4 Management Game

This chapter is the application phase of this study. The goal of the application phase is to design and test of the management game, as the pilot of the proposed strategy of this research. The objective of this strategy is to align the frame of perception of all organisations, from both the horizontal and vertical direction of the governmental structure, in order to successfully implement a network approach. The learning objective which the management game attempts to convey, is the idea that the rehabilitation or replacement of HCS is a shared problem for all organisations. This frame will be conveyed to the participants. The simulation of the game is inspired by the observations that are acquired in the case study. Through the testing of the game, this chapter will conclude in the answer to the fourth and final sub-question of the research.

The first section is the management game theory section (4.1). This section elaborates on how the literature approaches the design of a management game. The second section is the game design (4.2). This section elaborates on the design steps that have led the final game. It explains why certain design choices are made and how the game requirements are achieved. This includes a summary of feedback sessions and game try-outs. The third section is the game manual (4.3). In this section it is elaborated upon how the final version of the game is set-up and played. The last section deals with the game results (4.4). This section discusses the score results and feedback afterwards, from the game participants. On the basis of this section the sub-question is answered.

The complete management game design process (Appendix G: Complete management Game Design process), the management game elements (Appendix H: Management Game Elements) and the game session results (Appendix I: Game session results) can be found in the Appendix.

4.1. Game design theory

A commonly applied method for game design is **Triadic Game Design** (TGD), first formulated by Harteveld. TGD argues that the design of a game must focus on three important aspects: Reality, Meaning and Play. Reality is the extent to which the game is related to domain and practices, for which it is being developed. The meaning is the learning objective that the game needs to convey to its participants. Play is how the game is experienced by the participants (2011).

In order to ensure that the designed game has the desired effect, it is important that the game is immersive and relevant. In order to achieve this, the game complies with seven criteria. The first four criteria help to create an immersive game environment. The last three criteria help to create a relevant gaming experience (Zhou et al., 2013):

- **Flexible and reusable**: The game should be usable for, or adaptable to, a range of similar situations and different learning contexts.
- **Dynamic**: The game needs to react on the actions of participants.
- **Transparent**: The results should be clear and understandable for all participants.
- **Fast and easy to use**: The gaming time should be relatively short and non-experts should be able to play it.
- **Integrative:** The game should consider different aspects, layers of design and decision making in a holistic and systematic way.
- **Interactive:** The game should support a the negotiation process among participants.
- **Communicative:** The game should be able to convey meaning and insight to stakeholders about problem structure, alternatives, and different perspectives.

A game is typically build up out of the following standard elements: components, environment, ruleset, game mechanics, information, interface, theme, players and context (Janssen, 2012). All elements used in the management game of this research, can be found in Appendix H: Management Game Elements.

The game should be designed by means of an iterative design process. By repeatedly playing (try-outs), evaluating, revising and adapting, playing and so on, the game gets to be designed in an empirical process. Theories about game design elaborate upon some tips to improve the game quality and ensure the desired effects. These tips are the following (Janssen, 2012):

- Make the first playing experience obvious. An obvious first playing experience will enhance the attention and willingness to improve the performance.
- Make the effects of the player's actions visible. It can be tempting to model subtle choices, but this way the learning objectives will not be clear to the participants. Choose a model or game elements that clearly visualise the impact of the choices.
- Provide the participants with a mutual goal. Even though the roles of the participants are different, a mutual goal creates balance.

4.2. Game design

The objective of the management game pilot is to align the frame of perception of all participants, in order to successfully implement a network approach. The learning objective that the game conveys is the idea that the rehabilitation or replacement of HCS is a shared problem for all organisations. In order to reach this objective, the game is designed and evaluated on its validity and its relevance (Zhou et al., 2013). The validation concerns the ability to simulate a realistic and immersive game. This is evaluated by fulfilling the first four criteria discussed in paragraph 4.1. The relevance concerns the ability to convey new insights to the participants. This is evaluated by fulfilling the last three criteria discussed in paragraph 4.1.

This section discusses how the game is designed to achieve its objective. This is elaborated on by addressing the games basic principles (4.2.1) and by providing a summary on the iterative design process (4.2.2). The complete design process and an elaboration on the main dilemmas and solutions of the game can be found in Appendix G: Complete management Game Design process.

4.2.1. Basic principles

The basic principles of the management game are based on the structure of TGD. Therefore the starting point of the game design focusses on the meaning, play and reality.

Meaning (learning objective)

As already mentioned, the learning objective that the game carries out is that the rehabilitation or replacement of HCS is a shared problem of all organisations. This is the perception the game needs to convey to all participants players. Since the learning objective is very specific, it is important that the game starts off with a more general lesson. This lesson functions as a stepping stone for learning the more specific learning objective. The more general lesson that the game addresses is, similar to the lesson of **Game Theory**. This entails that, in order to achieve the best results for the group, collaboration is needed instead of competition (Levine, 2008).

An additional learning objective that the game tries to convey on the participants, is what collaboration really implies. As discussed in this research (paragraph 2.2.3), there is more to collaboration, than just communication. In order to achieve a proper collaboration with the best total results, it is important to know some crucial factors of collaboration. First, there is the role of information. Without shared information, people can perform strategic behaviour and misunderstandings can emerge. Second, there is the role of interest. A self-interest can cause people to behave strategically and different interests can cause conflicts. The effects of both factors can harm the collaboration, which has a negative impact on the total results. This learning objective is appreciated as a bycatch, additional to the main learning objective. Therefore, it plays a smaller part in the determination of the game relevance.

Play

It is important for the validity of the management game, that the gameplay is immersive. An important factor for a game to be immersive, is that it is entertaining. For this reason the game is non-digital. A common misconception is that a management game should make use of digital components. In some cases much more simple gaming instruments can be very effective, since not using digital screens encourages interaction between the players. Non digital games are often experienced as more easy to use. A lot of effort is put into the game design, in order to achieve this gameplay experience (Janssen, 2012).

In addition to the non-digital design, the gameplay needs to be dynamic. Therefore the game will consist of multiple rounds with variable characteristics. Another dynamic aspect is that, the participants have different roles in the game. The different roles have different characteristics and a strong self-interest, but the game is in balance, since all roles have the same mutual goal. The mutual goal is preventing the game situation from failing, since this harms the performance of all participants.

Reality

Realism of the gameplay is another important aspect of the game validity. As discussed in paragraph 3.5, the game simulation is a simplification of the network situation of the case. The main simulation of the game is based on operational issues of the case. The simulation focusses on the potential danger of two coinciding incidents. During these critical events most problems occur on a regional level, due to discharge limitations. The dilemmas for the regional operational managers in such an event, form the basis of the main simulation.

In addition to decisions in the operational layer, the game also addresses decision making in the tactical layer. The regional situations for the different organisations vary greatly in the case situation. Some organisations are completely depended on other organisations for interventions, that increase the network performance of the network. Other organisation have alternative opportunities to increase the performance of the network, by realizing alternative discharge routes or emergency storage areas. This imbalance in interdependencies forms the basis of the additional gameplay layer.

The roles in the game correspond to the organisations in the case. All actors have a strong self-interest, but are interdependent. Every organisation can personally profit from low costs by focussing on their own interest. However, there is a risk that they feel the consequences of high costs if the network fails. By putting aside their interests, they will experience the higher costs, but the risk of network failure diminishes. Therefore the sum of all costs of the organisations will be lower in the situation, where the organisation choose for the shared interests over their own interests.

4.2.2. Iterative design process: feedback rounds

The management game is developed by means of multiple iterative feedback rounds. After every round the game was redesigned. After the last feedback round the game was finished. Table 2 shows a summary of all the feedback rounds.

Respondents	Duration	Goal session(s)	Feedback

Gaming experts, Deltares and TU Delft (3 respondents)	2x 1 hour	Feedback on game ideas	Minimize the variables. Focus on one layer: water resource management. Do not use RWS as a role in the game. It differs too much from the other roles.
MSc. Students, Various TU Delft (8 respondents)	2x 1,5 hour	Testing game set-up and scenarios	There is no incentive to perform strategic behaviour. The scenario with the greatest differences along players proves most promising.
Professionals, Various (8 respondents)	2x 1 hour	Testing pilot version including presentation	Rules where not clear and confusing at the start. The monetarisation of the problems are too easily negotiable.
MSc. Students, Technology Policy Management TUD (4 respondents)	2 hours	Testing of the game with an additional controversy factor	Controversy factor makes the game work good. Incorporate tactical layer by means of a big map with investment possibilities.

Table 2 Feedback/try-out sessions management game

The game is designed in four rounds. After every version of the game, one or two feedback sessions were held with different respondents. In total 23 respondents helped designing the game by either discussing or playing the game. The final version of the game, was the fifth version. The complete design process can be found in Appendix G: Complete management Game Design process, including illustrations of the different versions and the dilemmas and solutions that occurred in the process.

4.3. Game manual: Deltego

The game that is designed for this research is called "Deltego". The name is a merging of the words "delta" and "Stratego". The word delta stands for the game environment. The game is about a water resource management situation in The Netherlands, which is known to be a river delta. Stratego is a famous board game in which two players try to beat the army of the opponent. In order to let the players of Deltego convey the learning experience, it is important that the players start of competitive. By referring to it with the name to a competitive game, the name contributes to this sense. Additionally, in Stratego for both players the army of the opposing player is hidden. The same is done for the regional water systems of the players in Deltego.

This section first discusses how the game is played (4.3.1) and secondly explains how it is attempted to convey the learning objectives to the participants (4.3.2).

4.3.1. Game procedure

The game is played by four participants and is led by a game master. All four participants of the game sit around a table, with a big map functioning as a game board, in the middle. The map is illustrated in Figure 24 (larger figures of the game can be found in Appendix H: Management Game Elements, including all presentation slides). In front of every player there is a copy of the game rules, two "investment decision" forms, four score forms, an evaluation from and a personal playing monitor. All forms and the screens are placed upside down. The management game makes use of a presentation on a big screen, that explains the context and the rules of Deltego. The game consists of eleven rounds, including presentations beforehand and afterwards, and a feedback round. To finish the game within an hour, and the prevent the rounds from becoming tedious, there is a maximum set time per round.

Context (5 min)

The presentation starts off with a short introduction to water resource management. This introduction is similar to the introduction in Appendix B: Introduction to water resource management. The introduction ensures that participants inexperienced in the field of water resource management understand the game context. Additionally, it ensures that all participants have comparable basic understanding at the start of the game.

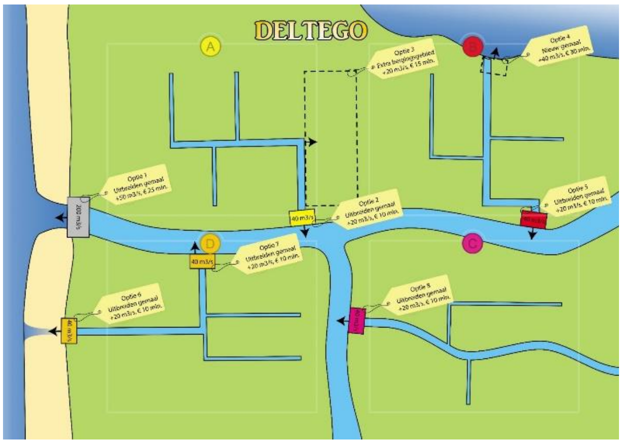


Figure 24 Deltego: Game board (own illustration)

Pre-round: Investment decision (5 min)

With the explanation of water resource management in the mind, the participants are asked to study game map and in particular focus on the eight investment options. The participants are asked to turn over their first investment decision form and rank the interventions from most favourable to least favourable for their own system. At the back of their personal monitor, the participants can see which role they have. These coloured letters of the roles correspond with the letters on the game map. This way they known which regional system of the game network they control. There are four options, one per region, of enlarging the pumping station, discharging into the main discharge water. The other four options are:

- Realising a larger pumping station for the main discharge area towards the sea. This option is not part of any regional system.
- Realising emergency storage capacity in the system of regional manager A.
- Realising an additional pumping station directing the discharge away from the network. This option is in the system of regional manager B.
- Realising a larger pumping station towards the sea in the system of regional manager D.

After being filled in, the forms are handed in at the game master.

Rules (5 min)

The next round is an additional presentation by the game master, who explains the game. The explanation starts off with the game situation. All actors are water resource managers connected to the same discharge water that discharges into the sea. Because of a high sea level, the capacity of the pumping station at the sea has decreased, and therefore the network performance has also decreased. In addition to the high sea level, there is heavy rain expected, putting the network performance under pressure.

Subsequently, the rules of the game are explained. For the explanation of the rules, the participants are allowed to turn over their personal playing monitor. This playing monitor is illustrated in Figure 25. The figures stay the same throughout the game. The rules are presented as follows:

"Every participant has a personal monitor with a view of their own regional system. This monitor shows all useful system information in times of crisis. In the bottom left of the screen, the amount

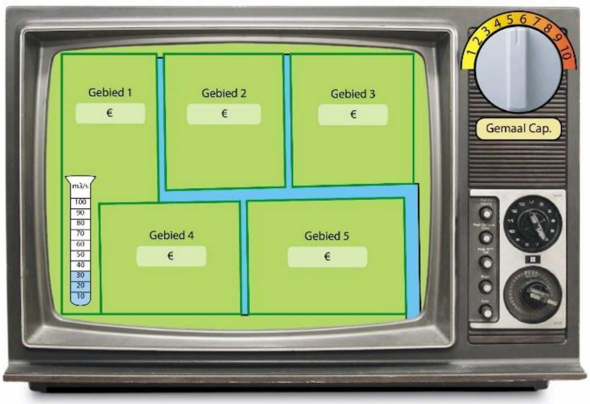


Figure 25 Playing monitor (own illustration)

of rain in your system is shown. This water load can be discharged in the main discharge water. Discharge of water is free of charge and can happen in quantities of 10 m^3/s. There is however a maximum capacity that you can discharge. Firstly, your pumping station can discharge a maximum of 40 m^3/s. Secondly, the total capacity of the main discharge water is 100 m^3/s. When this discharge water capacity is exceeded, the water body will flood. For every 10 m^3/s that this capacity is exceeded, all players together will experience €40 mln. of damages. Instead of discharging, the water can also be temporarily stored in areas within their own system. Every area can store 10 m^3/s. The cost of storage varies per area. Additionally, storage in the own area creates negative publicity. This is indicated by the amount of angry emoji. As a regional manager you want to limit your costs as much as possible and avoid negative publicity. It is now up to you to decide what you are planning to do with the water load that has fallen in your system. How much of the water load are you discharging and how much are you storing?"

Gaming round 1 (5 min)

The initial playing round starts directly after the explanation of the rules. In this round the participants are not allowed to consult or negotiate with each other. They are told to keep the information of their monitor to themselves. The participants are only able to see the rain load that has fallen on their own system. They do not know the water load of the other participants. In total there is a water load of 210 m^3/s divided over the different regional systems. In order to prevent the network from failing, the participants together need to store 110 m^3/s in their own systems.

The participants have to fill in the first score form. In this form the participants write their operational choices down. The game master looks if the maximum discharge capacity of the network is exceeded. If this happens the game master announced the total penalty costs and the participants need to recalculate their personal costs. In addition to the costs, the game master looks at the negative publicity that each participant has caused. The participant, or participants, that have the greatest amount of negative publicity, receive a penalty for letting down their own system. This penalty is a button of large negative emoji, as shown in Figure 26.

Figure 26 Controversy penalty

Gaming round 2 (10 min)

The second round corresponds with the first playing round, except the participants are now allowed to negotiate. Every participant still decides about their own actions, but now they have the opportunity to align their actions in order to prevent the network from failing. Financial compensations are allowed and can be filled in on the score form. The game master uses the negotiating time to calculate the total score of the prior round. Especially during this round, the game master keeps an eye on the round time and warns a minute before the end of the round, to let the participants finish up the negotiations. After handing in the score forms and handing out the new controversy penalty to the participant with the most negative publicity, the second round is finished.

Gaming round 3 (10 min)

The third round again corresponds with the round played before it. The only addition to this round, is that the participants now have to share their personal information. It is possible to take the screens out of the monitors. One of the screens used in the game is illustrated by Figure 27. The sharing of information is done by all participants taking out their screens and placing them on the game board. All information is now visible and aligned for all participants. This round continues the same way as the prior round.

Gaming round 4 (5 min)

The fourth round and final round of the operational gameplay again corresponds with the prior played round. The only addition to this round is that an announcement is show in the presentation. This announcement entails that the negative publicity does not play a role in the game anymore. This round continues the same way as the prior round.

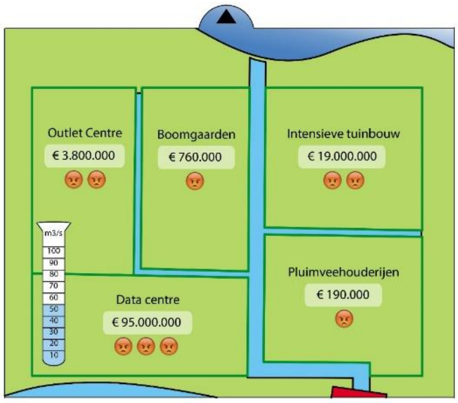


Figure 27 Personal information screen (own illustration)

Post-round: Investment decision (5 min)

Once the last score forms are handed in, the participants are asked to turn over and fill in their last investment decision form. In the same way as the investment decision prior of the operational gameplay, the participants are again asked to rate the investments options from the most favourable to the least favourable of option, for improving their own system. During this round the game master calculates the score of the last round and makes an overview of all the total scores.

Presentation after and discussion session (5 min)

When all participants handed in their second investment decision form, the game master takes the floor again. The game master first elaborates on the scoring process throughout the game. It is expected that the total score of all participants increased every round. After the scores the game master elaborates on the case on which the game is based. This way he places the game in its realistic context. Together with the participants he shortly discusses what the management game entails for the case situation.

Filling in feed form (5 min)

After the discussion round, the participants are handed a feedback form. The form consists of fifteen questions on which Deltego can be rated. The management game ends after the participants have filled in and handed in their feedback forms.

4.3.2. Learning objective set-up

Through the game procedure, it is attempted to convey the learning objectives that are discussed in paragraph 4.2.1 to the participants. To achieve this, different means are used.

The first learning objective that the game addresses, is the more general lesson. This lesson entails that, in order to achieve the best group results, collaboration is needed instead of competition. This lesson is conveyed through a first obvious gaming experience. As discussed in paragraph 4.1, such an experience enhances the attention of the participants and their willingness to improve their performance. This is important since this contributes to the acceptance of the learning objective. The first experience is a negative feedback loop, that the participants receive after the first gaming round. With a strong self-interest and no communication allowed, the participants likely cause the water network to fail. As negative feedback, all players receive a cost penalty, which is disproportionate to the cost that could have prevented it. This feedback intends to make participants understand that merely focusing on their own system, does not pay off, since their systems are interdependent. Consequently, they should learn that there is a common interest in preventing the water network from failing.

In addition to the penalty of costs, the player(s) who the accepted most damage compared to the other players, receives a personal controversy penalty. This penalty was nothing more than a button of an angry looking Emoji, like Figure 26, that was handed out to that player(s). The angry Emoji symbolises the angry inhabitants of the players region. Through this penalty, the players are supposed to learn that performing worse than the other players is punished. This way, they have a self-interest and show competitive behaviour. The controversy factor is added, because in the first game try-outs, the players started working together after the first round. With only the penalty of costs, there was merely a common interest and damaging costs turned out to be easy exchangeable. This imposed two threats to game outcome. Firstly, due to the lack of self-interest, the game was not considered realistic. Secondly, due to the lack of realism, the learning objective of the game was less clear and less easily accepted. Adding controversy to the game proved to solve both problems in the try-outs. It worked well, because controversy is not exchangeable nor expressible in monetary terms for compensation.

The learning objective that conveys that there is more to collaboration, than just communication, is conveyed through a differing set-up of the gaming rounds. The different set-ups are illustrated in Figure 28. Two crucial factors of collaboration are addressed in the game: The role of information and the role of interest. Without shared information, people can perform strategic behaviour and misunderstanding can emerge. Self-interest can cause people to behave strategically and different interests can cause conflicts. These learning objectives are conveyed by adjusting the set-up of each round. Both factors are represented as factors that harm the collaboration and have a negative impact on the total game score. In the second round communication is allowed, but all players have a strong self-interest and private information. In the third round the players still have a strong self-interest, but all information is shared. The last round self-interest becomes common interest, since the controversy factor is removed. It is expected that, by removing one by one the hurdles that block collaboration, the total cost will decrease each round. By means of the improving results each round, the game attempts to convey the importance of information and interest for good collaboration. The results are tracked, in order to determine and proof afterwards, if the factors have the desired impact on the collaboration.

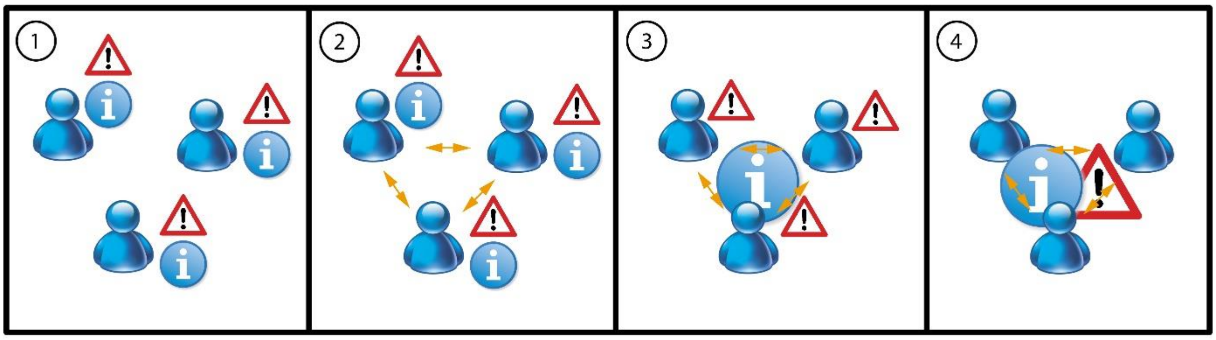


Figure 28 Different set-ups of the gaming rounds (own illustration)

The main learning objective of the game is that the rehabilitation or replacement of HCS is a shared problem of all organisations. This should be conveyed to the participants by aligning the decision making in the operational layer with the decision making in the tactical layer. In order to make the learning objective obvious, but not explicit, a simple means is used. As in reality, investment decisions on HCS are based on improving the network performance. The water resource management game showed that the water network of the game, reached its end of functional service life. Therefore, the players gets a choice of eight possible investments, with the instruction to rank all investment choices from most favourable to least favourable for their own system. All players have some investment options in their own system. However, for all players most of the favourable investments are located outside their system. Investment options 1,3,4 and 6 are the favourable options that improve the network performance, options 2,5,7 and 8 are not.

The players are supposed to understand after the game, that the investment option to improve their own system, is not necessary found in their own system, but also in other systems. When the players appreciate these interventions more than the interventions in their own system, they show an understanding of the fact that, the rehabilitation and replacement of HCS is a network-wide problem. The participants rank the investment decision twice: once prior to the gaming rounds and once afterwards. This is written down on a form which is handed to the game master. There is room on the form to elaborate upon the choice of the decisions. By comparing the output of both forms, it is examined if the participant gained the learning objective as a new insight.

After the game, the game leader shows and explains the case on which the game is based and starts a group discussion on what the experiences of the participants mean for the case situation. The players are asked to explain their new insights in a feedback form. If these insights are shared among the different participants, the frame of perception on the problems of the different participants, is possibly aligned.

4.4. Game results and discussion

In order to see if the management game pilot delivers the required results, an analysis is made on the basis of two measuring methods. The first analysis method makes use of the in-game actions that the players performed. This is partly based on the scores per round. These show whether the total results in the game gradually improve throughout the rounds. On basis of this, it can be determined if the collaboration improved. The other part of the analysis on in-game actions, is based on the investment decisions. The top three most favourable investment decisions, that are written down by all players before and after the game, are compared. If the favourable decisions are ranked in the top three more often after the game than before, it is prove that the players value the rehabilitation and replacement of HCS as a network-wide problem. This is because, the most favourable interventions are executed in the system of the another player. In addition to the ranking, some participants have substantiated their decisions on the forms.

The second analysis of the game is based on the feedback form and discussion afterwards. This analyses focusses on the validity and the relevance. The feedback form mainly consists of statements that need to be scored and there are some open questions for the further elaboration of certain topics.

4.4.1. Game sessions

In total three game sessions were executed for this research. Two sessions were executed at the TU Delft with students. The second session was executed at Deltares with experts on water resource management. At this gaming session there were five people present. Since the game is designed for four players, one person did not participate in playing the game. This person did join the discussion and filled in a feedback form. Not all the participants are experts and none of them have to make the same decisions from the game in real life. However, the objective of the management game pilot in the context of this research, is to test if the frame that it conveys in the game, leads to the required new insights. For this research objective, all participant have to have profound technical and managerial knowledge. In order to make sure all participants had the same understanding on the basic concepts of water resource management, a short introduction to the subject was given prior the game. All sessions had the duration of one hour. This included the presentation beforehand and the feedback session afterwards. An overview of all sessions can be seen in Table 3.

Session	Participants	Duration
1.	MSc. students, various TU Delft (4 respondents)	1 hour
2.	Professionals, Deltares	1 hour

	(5 respondents)	
3.	MSc. Students, Construction Management and Engineering TUD (4 respondents)	1 hour

Table 3 Gaming sessions definite game

4.4.2. Results

This section discusses the analysis of the total game scores per round and the analysis of the top three rated investment decisions, before and after the game. The complete overview of the game results are to be found in Appendix I: Game session results.

Game round	Session 1	Session 2	Session 3
1	€ 163.250.000,00	€ 161.415.000,00	€ 162.980.000,00
2	€ 10.350.000,00	€ 12.450.000,00	€ 13.150.000,00
3	€ 46.300.000,00	€ 10.900.000,00	€ 12.700.000,00
4	€ 9.900.000,00	€ 9.900.000,00	€ 9.900.000,00

Table 4 Total costs of the game session

Table 4 shows the total score of all rounds in the three gaming sessions. All gaming sessions displayed the intended results, which are discussed in paragraph 4.3.2. In every gaming session the total costs deceased nearly every round, and therefore the results increased. The only round which does not show the improvement, is round three of the first gaming session. The network failed in this round. This was not the intention, but was a result of a misunderstanding between the participants. The network failed drastically in the first round of all gaming sessions, causing large penalty costs. In every second round there was at least one player exaggerating his/her damages, claiming that other organisations needed to take the initiative. The scores of the different players showed a great variety in this round (the standard deviations of the different games are shown in Appendix I: Game session results). In every third round there was a focus on aligning the costs and the controversy in the negotiation. The personal costs were more equal, however this was not the optimal total score. In the fourth round of every game, the most optimal total score was achieved in all gaming sessions. The improvement of the total score is interpreted in this research as a learning curve. On the basis of this scores it is determined that the collaboration improved throughout the game.

	Session 1	Session 2	Session 3
Before	7	7	7
After	10	11	10

Table 5 Total amount of favourable investments in the top 3 of investment decision form (from a total of 12)

Table 5 shows how many times favourable investment options were ranked in the top three of every player. As discussed in paragraph 4.3.2 the favourable investment options are option 1,3,4 and 6. An overview of the rankings of all participants can found in Appendix I: Game session results. Since the game has four players, a maximum of 12 favourable scores can be reached. Prior to every session, the participants already valued seven favourable investment options in their top 3. The reason for this, are two elements that are embedded in the game. Firstly, player roles A, B and D have one of the four favourable interventions in their own system. Prior to the game most participants are likely to value the investment in their own system highest. This entails that in every gaming session these three favourable interventions would be rated high at least once prior to the game. Secondly, the favourable option 1, is an intervention on the pumping station at the main discharge water and this option is not located one of the participants systems. It was created like that, so most participants would see the value of this investment. This makes the score of seven favourable investment options in top 3 of all participants, a logical result of elements embedded in the game.

After the gaming session, nearly all top 3s consisted of all favourable measures. This includes multiple investment options in other systems. Some of the top 3s still included an option that was not favourable, but these were interventions in a players own system. Due to the limited time of one hour, in which the players could have gained new insights, and due to the fact that the second investment decision round took place before the case explanation, it can be stated on basis of the in-game data, that the game succeeded in conveying the learning objective that rehabilitation or replacement of HCS is a network-wide problem.

4.4.3. Feedback and conclusion

This section discusses the analysis of the feedback form in combination with the discussion after the case explanation. The feedback form, as it was handed out to the players, can to be found in Appendix H: Management Game Elements. The complete scoring of the feedback form can to be found in Appendix I: Game session results.

	General impression	Average Rating	Standard deviation
1	General rating of the game	4,31	0,48
2	Rating of the game location	4,25	0,75
3	Rating of the information about the game before hand	3,46	0,88
4	Were the rules clear? Yes/No	9x Yes / 4x No	
5	Rating of the game tempo and duration	4,15	0,55
6	Rating of the game facilities	4,38	0,65
7	Rating of the information about the game afterwards	4,62	0,51
	Realism and concretising		
8	Rating of the realism of the game	4,00	0,71
9	Rating of the practical use	4,31	0,48
10	Rating of the extent to which the game fulfils the expectations	4,08	0,51
	User experience		
11	Rating of the entertainment	4,31	0,63
12	Rating of the comprehensiveness	4,00	0,71
	Reflection		
13	Rating of the added value of the game	4,54	0,52
14	Rating of the ability to create new insights	4,15	0,80
15	Rating of to what extend the game stimulates different decisions	3,85	0,90

Table 6 Average feedback form ratings and the standard deviation: 1 = bad, 2 = mediocre, 3 = fine, 4 = good, 5 = excellent

Table 6 shows the average score and the standard deviation of multiple subjects on which the participants rated the game. The first part of the feedback form evaluates the validity of the game, by examining if the game is immersive. To examine this, the general impression, the realism and the entertainment experienced by the participants are evaluated.

The first seven statements considered the general impression of the game. On the basis of these scores conclusions can be drawn on the quality of the game. All participants were unanimously positive about the quality of the game. Especially, the explanation of the case context after the gaming sessions, was valued as nearly excellent. This is highest average score on the feedback form. However, this maybe the result of the low valuation of the information given prior to the game, which received the lowest average score on the feedback form. Of the four times that the rules explanation was valued as unclear, three times happened in the same gaming session (the evaluation scores per session are shown in

Appendix I: Game session results). This might have been dependent on the explanation of that specific session.

Statements 8-10 considered the realism of the game. As discussed in paragraph 4.2, realism of the game contributes the validity of the game. This is, because the realistic content makes it easy for the participants to empathise with the situation. The same accounts for the rating of the practical use and the game expectations. If the players do not see a practical use, they will care less about the learning objectives. If the players are disappointed about the game, they will less easily accept the content. In line with the reality and concreting statements, statements 11 and 12 of the user experience, contribute to the acceptance of the learning objectives. If the players enjoy the game and find the content understandable, they are more likely to accept the contents new insights. In the discussion, it appeared that most players enjoyed the game and especially appreciated that the game managed to simplify such a complex issue.

Since all these statements are rated as ‘good’ or higher, it can be concluded that the management game pilot was experienced as immersive. The validity of the game is therefore considered sufficient. Based on this, it can be stated that there is a great chance that the participants accepted the learning objectives of the management game. It must be added, that none of the game participants are in reality involved in the type of decision making, the game is about. The results of these people can be different. On the basis of this fact, no far-reaching conclusions can be drawn on the ability of the game to convey the learning objective to real life managers. The results on the participants are however promising.

Times mentioned	**New insight (generalisations of the insights the participant wrote on their feedback form)**
8	It is important to collaborate in water resource management, in order to find an optimal solution
7	For the long-term investments, it is important to consider the complete network
4	Water related problems are a national problem

Table 7 Most frequently mentioned new insights

The second part of the feedback form evaluates the relevance of the management game by examining the new insights of the participants. In order to analyse the extent to which the game manages to convey its learning objectives to the participants, statements 13-15 of the feedback form and the results in Table 7 are used. This table shows the most frequently mentioned new insights on the feedback form. The respondents had room to discuss multiple insights on the form. Consequently, the amount of mentions does not correspond to the amount of respondents.

On the basis of the rating, the participants indicate that the game succeeded in providing them with new insights and they acknowledge the added value of the game. It has to be mentioned that the participants were new to the problem situation. Therefore, it is important to look into the content of the new insights, in order to value them. The impact of the game on the decision making of the participants, is scored relatively low. It is not possible to derive any conclusion from this rating, since the participants do not make similar decisions in real life.

As discussed in the paragraph 4.3.2, the game has as objective to convey three insights to the participants. The first learning objective is that, in order to achieve the best group results, collaboration is needed instead of competition. The second learning objective is that collaboration is not merely a result of communication, but a result of more aspects, like open sharing of information and aligning of interest. The third and main learning objective of the research, is that the rehabilitation or replacement of HCS is a shared problem of all organisations.

Eight of the thirteen respondents have indicated that collaboration is important in water resource management, in order to come to an optimal solution, which was a new insight for them. It is not a perfect score, but there was a limited time period for the respondent to play the game and fill in the feedback form. Additionally, there is a possibility that some participants already had this insight or found it too evident to mention, and for this reason, did not write it down as a new insight. Furthermore, the data of the in-game actions shows an learning curve. Therefore, the impact of the game is valued as positive, and it can be stated that the game succeeded in conveying this first insight.

Only a few respondents mentioned that they gained new insights on the importance of information and a common interest for successful collaboration. This was a disappointing result. The reason for this, is probably that this learning objective was too subtle. As discussed in paragraph 4.3.2, it was attempted to convey the learning objective by changing the set-up of the gaming rounds. The idea behind this differient set-up was not elaborated upon and it was also not addressed in the case explanation or the discussion. For this reason, this learning experience has proven to be too far-fetched. However, since it was bycatch and not the main learning objective the game intended to convey, this disappointing result is valued as less essential for the overall conclusion. It is more important that the participants learned the importance of collaboration, instead of learning what factors play a role in collaboration.

Seven of the thirteen respondents have indicated they gained new insights, on the importance of considering the complete network for long term investments. This entails that more than half of the respondents, address the rehabilitation or replacement of HCS as a shared problem. These respondents thus learned the main learning objective of the game. Also for this insight, the limited time to play the game and to provide the feedback, should be kept in mind. Participants could have valued the insight as not evident and not written in down on the feedback form. The data of the in-game actions confirms a learning curve for most respondents, since the favourable options are valued more often as the highest Therefore, it can be stated that the game succeeded in conveying the main learning objective to most of its participants.

On the basis of these results, it can be concluded that most participants of the management game pilot, experienced most of the learning objectives as new insights. The management game pilot provided insights into the importance of collaboration between organisations in both the operational and the tactical layer. They understood that the problems in the rehabilitation or replacement of HCS are best addressed in collaboration. The relevance of the game is therefore considered sufficient. It must to be added, that none of the game participants are in real life involved in the type of the decision making the game deals with. The results of people dealing with these situations in reality, can be different. On the basis of this fact, no far-reaching conclusions can be drawn on the ability of the game to convey the learning objective to real life managers. The results on the participants are however promising.

By creating immersive gameplay and by conveying new insights on the participants, the validity and relevance of Deltego are both found to besufficient. The objective of the game is to align the frame of perception of all organisations, from both the horizontal and vertical direction of the institutional structure, in order to successfully implement a network approach. All participants had a positive attitude towards using the game as an interactive instrument to build connections. As a tool, a management game proves to be a promising informal arena, that is able to frame the problem perception of the different participants. However, on the basis of these three gaming sessions, without participants that make the decisions the game deals with, in real life, it is not possible to determine if the learning objectives can be spread over complete organisations and multiple institutional layers. Therefore, it cannot be concluded that the game can establish a network approach in real-life.

Nonetheless, on the basis of its validity and relevance of the pilot, it can be concluded that a management game is a useful instrument to apply the strategy of framing among the participants. On the basis of these findings, it is possible to provide the answer to the last sub-questions of the research:

d) Can a network approach be established through the application of a management game?

By means of the design and application of a management game pilot, it can be concluded that a management game is a useful instrument to apply the strategy of framing among the participants. Due to the immersive gameplay and the relevance of the content, the game succeeded to align the frames of perception of the participants. However, on the basis of these three gaming sessions, without participants that make the decisions of the game, in real life, it is not possible to determine if the learning objectives can be spread over complete organisations and multiple institutional layers. Therefore, it cannot be concluded that the game can establish a network approach in real-life.

5 Discussion

In this chapter the findings of the research are discussed. This research addresses the possibilities of applying a network approach in the Asset Management of HCS. The relevance of the study is determined by its managerial implications and limitations. Firstly, in this chapter the managerial implications of the analysis used in this study, and the findings that resulted from this, are discussed (5.1). Through this section, the practical use of this research will be illustrated. In addition to the use, the limitations of the analyses and findings are discussed (5.2), in order to put the relevance in perspective. Lastly, feedback is given on the research methods (5.3).

5.1. Managerial implications

The analysis of this research is based on three applied methods: a literature and background study, a case study and the design and application of a management game. Through these three methods a statement is made about the possibilities of the proposed network approach. This section will address the managerial implication of the proposed approach and the different methods.

5.1.1. Network approach

Through the literature study and the case study, it became clear that the rehabilitation or replacement of HCS is best addressed by means of a network approach. By alignment of the Asset Management agendas and setting up of collaboration between all responsible organisations in a water network, it is possible to achieve an improved action perspective. In this new action perspective the risk on negative (wicked) effects is diminished, network-wide changes become possible and the water network of The Netherlands has the opportunity for cost savings and an increased effectiveness.

This does not entail that the current object approach should be fully denounced. In reality there is not a strict “black-and-white” division between an object approach and a network approach, as this report suggests. The case study proves that already elements of a network approach are applied, alongside the use of an object approach. Using both approaches alongside each other makes sense, instead of merely applying a network approach. On the operational level an object approach will always be needed for the monitoring of the HCS. Only in this way, it is possible to determine in the network approach, which HCS are critical. In some instances in the tactical layer, an object approach can be favourable over a network approach, especially due to its possible fast reaction to short-term problems. Also in that case, it is an advantage to have knowledge of the network, since only than the impact of the intervention can be foreseen. For this reason, the object approach should always be used in combination with a network approach. The initial approach should be a network approach. For the reason of exploring opportunities alone, this is worth the effort.

5.1.2. Theoretical framework

By setting up the theoretical framework, it became clear that the current object approach of the Asset Management of HCS in The Netherlands is a self-sustaining feedback loop. By means of the case study, the theoretical framework proved to be an ideal tool for revealing the crucial factors that sustained this feedback loop. Additionally, the framework can be used to reveal what the main threats and opportunities are for a network approach. The threats are mainly uncovered by focusing on possible conflicts between different organisations and functions. The opportunities can be found by focussing on dependencies and possible shared problems and objectives. For these purposes the theoretical framework proved to be proper instrument. The general set-up of the framework is for all types of HCS, making it applicable to a broad range of cases.

5.1.3. Strategy “Framing from the top, gaming from the bottom”

The strategy of “Framing from the top, gaming from the bottom”, entails the establishment of a frame in the strategic layer of the governance structure and imposing this frame top-down on participants, through a management game, based on experiences in the operational layer. The strategy of applying the method of framing in the tool of a management game, is established by means of a literature and background study. Through successfully designing and testing a game based on this strategy, it proves to be a promising strategy for multiple network oriented problems. However, the success of the approach depends on the initiating party. It is recommended that the strategy is facilitated by a neutral party, in order to avoid accusations of being biased. This can nullify any positive effects.

5.1.4. Management game "Deltego"

The basic principle of the design of Deltego are the differences in problem perception between stakeholders and the operational issues of the case situation. For instance: which functions and performance levels need to be considered in the network. These prove to be an inspiring foundation for a management game. On the basis of the positive evaluation and the new insights the participants gained through the game, it can be concluded that the management game is successful in conveying learning objectives on the participants. Due to the simplifications of complex issues, it proves to be a proper instrument to align the frame of perception of multiple participants. Since the game design is simple, it is easy to adjust to other case situations. Therefore, Deltego can be used as an informal arena for different water network situations. In addition, the game can be used for educational purposes. Since participants with no background in water management were able to play the game, it proved to be a good introduction to the subject.

5.2. Limitations

This section will address the limitations of the different methods used in this research.

5.2.1. Theoretical Framework

The theoretical framework is merely established on the basis of the literature and background study. The background research included some practical examples, however these did not account for all elements of the framework. The case study identified some deficiencies of the theoretical framework. The framework addresses circumstances that have an influence on the decision making process, but does not analyse the course of the decision making process in-depth. Therefore elements, like the role of trust, are not discussed.

Additionally, the theoretical framework is aimed at the rehabilitation or replacement of all types HCS. However, it is not certain that a network approach is equally favourable for all types of HCS. For instance, the characteristics of a pumping stations differ a lot from a lock. The theoretical framework combines all types of HCS under the same header. Consequently, there is not an in-depth analysis of the effects of the object and network approach, considering specific types of HCS.

5.2.2. Strategy

The strategy of this research is merely based on the literature and background study. By means of the methods applied in this research it is impossible to conclude whether the this strategy is feasible. The feasibility can get determined by researching its ability to align action perspectives and influence the decision making process. There is however no empirical proof provided by this research, that can conclude that the decision making process in real-life gets influenced by this strategy.

5.2.3. Case Study

For the case study objective of testing and interpreting the theoretical framework, and forming an inspiration for the management game design, one case study was considered as being sufficient. However, one case study has some limiting effects on the research. The case study focusses only on one function in the water network. There were other functions influencing the system, but in consideration of the pumping station complex in IJmuiden, these were not considered relevant.

Therefore the tensions between different functions in the network, remain underexposed in the case study. Furthermore, the case study focusses on the functional end of service life of the HCS in the network. In the case situation, the technical end of service life of the HCS, was not considered an issue.

5.2.4. Management Game

Since Deltego is designed on the basis of one case study, the game mainly focusses on water discharging. It elaborates merely on the processes, rather than the technical aspects. In addition, not all stakeholders that are present in real-life, have a role in the game. Especially RWS has an important role in the case on which the game is based. However, it proved to be difficult to incorporate RWS as a role that would be meaningful and entertaining to play. Therefore, a crucial actor was not addressed, even though the learning objectives of the game also apply to RWS.

The game is tested with students and experts, but no participants who are actually involved in the case field. The game shows the potential to align the frames of perception of the participants. However, the number of participants was small, particularly for far-reaching conclusions. In addition, the participants do not make the decisions of the game, in real-life. The game outcome may therefore be different, if real-life decision makers participate in the game. To know if the alignment of frames of perception also applies for complete organisations and in all institutional layers, it should be tested on participants who actually make the decisions in real-life.

5.3. Feedback on the research methods

In addition to an analysis of the results of the research methods, it is relevant to discuss the interaction between three different methods in this research. The literature and background study provided insights in a broad range of subjects. The method proved to be ideal for identification and broadening of all kinds of relevant subjects. However, the method was not sufficiently able to provide an in-depth analysis, since it provided mostly theoretical data. Empirical data is needed for the deepening of the subjects.

The case study proved to be an ideal method for obtaining empirical data. The literature and background study and the case study complemented each other well. Because these methods complement each other, they also highlight each other deficiencies. By means of the case study, the deficiency of the literature and background study proved to a lack of nuances. Vice versa, the deficiency of the case study proved to be the large amount of material and data. It proved to be difficult to come to concrete results and findings.

In addition to the more classical research methods, a management game was used in the research. This method consisted of designing and applying a management game on the basis of the case finding. Simplifying the complex content of the case for the game design, proved helpful for prioritizing the relevance of the case findings. Due to this attempt to simplify the complexity of the case findings, it became possible to grasp its complexity. This way designing the management game contributed to the formulation of case findings. However, the use of a management game for obtaining research data and concrete results proved to be difficult and time consuming.

6 Conclusions & Recommendations

This chapter presents the conclusion of the research (6.1) and provides recommendations for future research and recommendations for Deltares in particular (6.2). The conclusion consists of the answer to the main research question.

6.1. Conclusion

The main research is composed of four sub-questions. Through analysing the answers of all the sub-questions, the answer to the main research question can be formulated. This section covers subsequently all sub-questions, in order to come to the final conclusion of this research.

a) What are the implications of an object approach for the action perspective and decision making process for the Asset Management of HCS?

The answer to sub-question 'a' is based on the literature and background study and the case study. The current object approach has a simple decision making process towards interventions on HCS. Regional stakeholders can oppose actions in the operational layer or local alternative interventions in the tactical layer. Therefore, the decision making process towards these kind of decisions can be complicated. The positive effects of the interventions are experienced locally and temporarily. In an object approach, interventions merely focus on the function that the HCS primarily address. The executing organisation is specialised in this function, due to the institutional segregation. Because of the long service life of HCS, the interventions are aimed at a single long-term future scenario. Often the worst-case scenario is used. With such interventions that do not appreciate the network complexity and future uncertainty, risks emerge in a broader network scope and in different future scenarios. There is the risk of problem shifting, overinvestments, underinvestments and the network gradually develops towards a lock-in situation. There are no network-wide changes possible to overcome this situation. In addition, the object approach is deficient in addressing uncertain long-term developments, like climate change. Consequently, an object approach has risks of overspending and/or limited effectiveness.

b) What are the implications of a network approach for the action perspective and decision making process for the Asset Management of HCS?

The answer to sub-question 'b' is based on the literature and background study and the case study. A network approach has a complex decision making process towards network broad interventions. The decision making process is complex since decisions need me be agreed upon by multiple organisations. Issues with local stakeholders that occur in the object approach make organisations cautious for collaboration, since it can mean an increase of an already demanding public involvement process. Additionally, the organisations are restrained towards collaboration due a lack of trust in the other organisations. However, they do have the tendency to wait for other organisations to take initiative in improving the network performance. In reality the threats can turn out to be more positive, like in the pilot of the VONK study. The participants recognized the positive effects of the network approach and were positive about extending the collaboration.

The positive effects of the interventions can be experienced network-wide and in the long term. Only in a network approach it is possible to accurately address functional end of service life. In a network intermediate interventions for increasing the network performance can be taken. The same performance improvements can be achieved, as with an intervention on one object. Contrary to an object approach, without having to commit to a long-term worst-case scenario, lock-in situations, problem shifting and overinvestment, can be prevented. The possible actions in an increased action perspective in a network approach can be divided into four categories: Actions to improve the performance of the HCS, actions to reduce the load that pressures the network performance, actions that reduce the failure risk and actions to specify the performance norms. Due to this action perspective, the network approach can be efficient in addressing uncertain long term developments like climate change. Additionally, by focussing on network interdependencies, there are opportunities for network-wide changes, with synergy possibilities for multiple stakeholders. In order to use interdependencies a starting point, the different organisational layers need to be aligned, because the interdependencies can differ depended on the layer. Since a network approach prevents important risks of the current Asset Management approach, and since it has additional opportunities, it has a large contribution to the 10-20% cost savings, that the ROBAMCI study estimates as the achievable benefit of improving the Asset Management of HCS. Consequently, a network approach has opportunities for substantial cost savings and increasing effectiveness, which are worth the effort of committing to a complex decision making process.

c) What can be a successful strategy to establish a network approach in the Asset Management of HCS?

The answer to sub-question 'c' is based on the literature and background study. Framing proves to be a proper method to align frames of perception on network problems of different organisations. Through this alignment a network approach can be established for a gradual problem, like the rehabilitation or replacement of HCS. A shared problem frame is best established at the strategic layer of the governance structure and thereafter implemented top-down. This layer has the authority and resources to establish a network approach and has the broadest network perspective to achieve the alignment.

As an informal arena, a management game proves to be a proper tool to overcome institutional segregation and can impose a shared frame on the players from bottom-up. The learning objective of the game should be the frame is established in the strategic layer. The simulated reality in the game should be based on experiences of the operational layer of the governance structure. Due to the latter, the operational managers of these organisations can align with the shared problem frame of the strategic layer. This way the network approach has the opportunity to receive support of every governance layer.

On the basis of the answer to the research question, the following strategy is proposed by this research: **"Framing from the top, gaming from the bottom"**

The objective of the strategy is to successfully implement a network approach on the tactical layer. The feasibility of a strategy depends on capability to align the action perspective and influence the decision making process in this layer. This is accomplished by means of framing the perception of the relevant issues of all organisations involved. Establishing of the frame should take place horizontally in the strategic layer and should be implemented top-down in the vertical direction of the governance structure. The tool of this strategy is a management game. This game incorporates the frame as learning objective and uses operational layer experiences for the simulation. The intension is, that this game is established bottom-up and gets to be played by all organisational layers.

The strategy of this research is merely based on the literature and background study. By means of the methods applied in this research it is impossible to conclude whether the this strategy is feasible. The feasibility can get determined by researching its ability to align action perspectives and influence the decision making process. There is however no empirical proof provided by this research that can conclude that the decision making process in real-life gets influenced by this strategy.

The strategy is best coordinated and facilitated by an neutral inter-regime party, in order to prevent conflicts from taking place between the different organisations. Deltares is an ideal candidate to take this role, since it is an independent institute of applied research in the field of water.

d) Can a network approach be initiated through the application of a management game?

The answer to sub-question 'd' is based on the design and application of the management game pilot Deltego. It can be concluded that a management game is a useful instrument to apply the strategy of framing among the participants. Due to the immersive gameplay and the relevance of the content, the game succeeded to align the frames of perception of the participants. However, on the basis of these three gaming sessions, without participants that make the decisions in the game in real life, it is not possible to determine if the learning objectives can be spread over complete organisations and multiple institutional layers. Therefore, it cannot be concluded that the game can establish a network approach in real-life.

How can a network approach be beneficial to the future rehabilitation or replacement of the hydraulic civil structures in The Netherlands?

The sub-questions 'a' and 'b' contribute to the answer of the main research question, by determining whether the network approach is beneficial to the rehabilitation or replacement of HCS in The Netherlands. The answer to this is: Yes. On the one hand, the current object approach does not appreciate the complexity of the water network, resulting in risk of implementing sub-optimal solutions in the water network. By enabling the possibility to align the action perspectives of multiple organisations, a network approach diminished these risks and has additional opportunities for costs savings and an increased effectivity. Therefore, based on this research, the network approach is the recommended approach for the future rehabilitation or replacement of HCS in The Netherlands.

However, in the answers to the sub-question 'a' and 'b', the issue emerges that an object approach is a self-sustaining feedback loop that is difficult to abandon. Collaboration needed for a network approach, is not established by itself. Therefore, the sub-question 'c' and 'b' contribute to the answer of the main research question, by determining HOW a network approach can be implemented. Sub-question 'c' provides the strategy, sub-question 'd' determines whether the application of this strategy was successful. The strategy is formulated as "Framing from the top, gaming from the bottom". The strategy is considered promising, since it focusses on the alignment of the frame of perception, on the problems in the water network. Through a shared problem frame, collaboration can emerge between different organisations. However, the strategy is not empirically substantiated, therefore the feasibility of achieving a network approach through this strategy is unknown. In order to test this strategy, the management game pilot 'Deltego' was designed and tested. The tests sessions proved that the game is successful at conveying a shared frame of perception of the problem on the participants. However, since none of the participants is actively involved in the decision making in real-life, it cannot be concluded that the alignment will also take place at in organisations and between organisations in real-life. Accordingly, the answer to the main research question is:

A network approach can be beneficial to the future rehabilitation or replacement of HCS in The Netherlands, whenever collaboration takes place between the responsible organisations. This collaboration can be established by introducing a shared problem frame on the responsible organisations. However, the feasibility of this strategy cannot be determined on the basis of this research. Alignment of the frame of perception of the problems can be achieved by means of a management game. Even though the results of the game sessions were promising, is too far-fetched to conclude that the alignment will also take place at in organisations and between organisations in real-life on the basis of this research.

6.2. Recommendations…

6.2.1. … for future research

Apply the management game on a larger scale and in practice

Additional research is needed to know to what extent a management game can influence organisational behaviour and bridge multiple governmental layers. The management game should be applied on a larger scale, and should be played with representatives of the responsible organisations as participants.

Perform an in-depth research into the rehabilitation or replacement of specific types of HCS

Additional research should be performed on specific HCS, in order to learn for what kind of HCS a network approach is most profitable. This way it can be determined whether organisations should embark on establishing a network approach for Asset Management for HCS.

Research the possibilities and limits of inter-organisational Asset Management

Asset management aligned over multiple organisations, should be studied in a more general sense. This way it is possible to determine what aspects of Asset Management are most promising to align, on the basis of their impact and their feasibility.

Research the feasibility of the proposed strategy

The strategy of “framing from the top, gaming from the bottom” is merely based on theory. In order to research the feasibility of the strategy, and empirical analysis should be performed. This can be done by means of case studies in which similar strategies are applied, or real-life application of this strategy.

Deepen out role of trust in the theoretical framework provided by this research

In the case study, the role of trust emerged as an critical factor. The exact role of trust in the theoretical frame work is yet to be analysed. It is believed that through analysing this, the framework can be improved. Additionally, strategies to achieve a network approach may emerge.

6.2.2. … for Deltares

Apply the theoretical framework of this research as a tool for assessing case situation on their chances of success.

Use the theoretical framework as a tool to explore which water networks in in The Netherlands are potentially improved with a network approach. The theoretical framework is a tool which is easy to use for an early assessment of a water network situation.

Further develop and use the management game as an product

The management game is easily understandable, has a catchy meaning and is enjoyable to play. It can be used for establishing collaborations, like in this research, but also for other purposes. For instance educational or promotional purposes. The analogue game has its charms, but it probably is a good idea to make the game digital. By having a program to do the calculations for the participants, there is more time in the game for the players to communicate. Additionally, a program automatically calculates the results and is easier adjustable with different scenarios.

Take on an facilitating role in the rehabilitation or replacement of HCS for establishing network approaches

There is a lot of potential lost due to stubborn managers of governmental organisations. There are very few organisations in the water sector that can take on the role of a neutral party, that can facilitate a network approach. Provinces, Min. I&E or companies have self-interest in water governance and therefore there is a risk that establishing a network approach fails. Deltares has profound knowledge of the water network and has no direct interest in the water governance. This makes Deltares an ideal candidate.

Encourage the Delta Commission to make the rehabilitation or replacement of HCS a central issue in the Delta Program

The Delta Program focusses on making The Netherlands future proof for climate change. However, by not incorporating the rehabilitation or replacement of HCS they miss an important link in achieving this. This encourages the water managers to apply a network approach for the Asset Management of HCS. In addition, more network wide initiatives can be initiated in the Delta Program.

7. References

beeldbank.rws.nl. De nieuwe pomp voor het gemaal IJmuiden worden door middel van een zwaar transport wagen van een ponton naar het gemaal getransporteerd ten behoeve van de uitbruiding van het gemaal IJmuiden ID273930. Retrieved 22-10, 2015, from https://beeldbank.rws.nl/MediaObject/Details/De_nieuwe_pomp_voor_het_gemaal_IJmuiden_worden_door_middel_van_een_zwaar_transport_wagen_van_een_ponton_naar_het_gemaal_getransporteerd__ten_behoeve_van_de_uitbruiding_va_273930

Bernardini, P., van Vuren, S., van der Wiel, W., Wolters, M., Roovers, G., & Tosserams, M. (2014). *Integrative Framework for long term reinvestment planning for the replacement of hydraulic structures*. Paper presented at the PIANC World Congres, San Francisco.

Bettini, Y., Rijke, J., Farrelly, M., & Brown, R. (2013). Connecting Levels and Disciplines: Connective Capacity of Institutions and Actors Explored *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.

Beuse, P. H. (2013). *Waterakkoord voor het Noordzeekanaal en Amsterdam Rijnkanaal*. Rijkswaterstaat.

Bijleveld-Schouten, A. T. B. (2012). [Toedeling vaarwegbeheer].

Boeije, H. (2010). *Analysis in Qualitative Research*. London: SAGE Publications Ltd.

Bos, F., & Zwaneveld, P. (2014). Reële opties en de waarde van flexibiliteit bij investeringen in natte infrastructuur; Lessen op basis van de vervangingsopgaven rondom het Volkerak-Zoommeer en de Grevelingen *CPB Achtergronddocument*. Den Haag: Centraal Planbureau.

Bosch-Rekveldt, M. G. C. (2011). *Managing project complexity: a study into adapting early project phases to improve project performance in large engineering projects.* (PhD Thesis), Delft University of Technology.

Boyce, C., & Neale, P. (2006). *CONDUCTING IN-DEPTH INTERVIEWS: A Guide for Designing and Conducting In-Depth Interviews for Evaluation Input*. Watertown: Pathfinder International.

Bruggeman, W., & Dammers, E. (2013) Deltascenario's voor 2050 en 2100. *Nadere uitwerking 2012-2013* Den Haag: Ministerie van I&M.

Brugman, C., & Kerssens, J. (2015). Kadernota Activeringsbeleid: Activeren, waarderen, afschrijven en financieren. Heerhugowaard: Hoogheemraadschap Hollands Noorderkwartier,.

Centraal Planbureau. (2014). Reële opties en de waarde van flexibiliteit bij investeringen in natte infrastructuur; Lessen op basis van de vervangingsopgaven rondom het VolkerakZoommeer en de Grevelingen *CBP Notitie*. Den Haag: Centraal Planbureau.

David, P. A. (2006). Path dependence – a foundational concept for historical social science. *The Journal of Historical Economics and Econometric History, 1*(2).

De Boer, C., Bressers, H., Özerol, G., & Vinke-de Kruijf, J. (2014). *Collaborative water resources management: What makes up a supportive governance context?* . Paper presented at the 7th ECPR General Conference, Bordeaux.

De Boer, C., & Krantzberg, G. (2013). Great Lakes Water Governance: A Transboundary Inter-Regime Analysis *Water Governace as Connective Capacity*. London: Ashgate Publishing Limited.

De Bouwcampus. (2015). Levendige en waardevolle bijeenkomst grip op de Maas. Delft: De Bouwcampus.

De Bruijn, J. A., & Ten Heuvelhof, E. F. (2008). *Management in Networks*. New York: Routledge.

De Koning, B. (2009). Crisis Sluis. Retrieved 22/10, 2015, from http://www.hpdetijd.nl/2009-07-03/crisis-sluis/

De Nederlandse Gemalen Stichting. (2012). Rijksgemaal Ijmuiden. Retrieved 21-10, 2015, from http://www.gemalen.nl/gemaal_detail.asp?gem_id=264

De Wit, A. (2015). Gevolgen Inundatie. Utrecht: WitteveenBos.

Deltacommissaris. (2012). Bijlage H Vervangingsopgave Nate Kunstwerken *Deltaprogramma 2013*: Ministerie van Infrastructuur en Milieu.

Deltacommissaris. (2014). *Deltaprogramma 2015: Werken aan de delta*. Den Haag: Deltacommissie.
Den Heijer, F. (2015). Risk and Opportunity Based Asset Management for Critical Infrastructures: Koepelplan 2015-2018. Delft: Deltares.
Dewulf, A., Brugnach, A., Termeer, C., & Ingram, H. (2013). Bridging Knowledge Frames and Networks in Climate and Water Governance *Water Goverance as Connective Capacity*. London: Ashgate Publishing Limited
Edelenbos, J., Bressers, N., & Scholten, P. (2013a). Conclusions: Towards a Synchronization Perspective of Connective Capacity in Water Governance *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.
Edelenbos, J., Bressers, N., & Scholten, P. (2013b). Introduction: Conceptualizing Connective Capacity in Water Governance *Water Governance as Connective Capacity*. Farnham: Ashgate Publishing Limited.
Edelenbos, J., & Van Meerkerk, I. (2015). Connective capacity in water governance practices: the meaning of trust and boundary spanning for integrated performance. *Current Opinion in Environmental Sustainability, 12*, 25–29.
Edelenbos, J., Van Meerkerk, I., & Klijn, E. H. (2013). Creating Legitimacy in Water Governance Networks through Complexity Sensitive Management *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.
Filius, P. C. P., & Van der Wiel, W. D. (2015). ROBAMCI Asset management: Inventarisatie ETL uit Rink en VONK. Papendrecht: Iv-Infra B.V.
Franssen, R., van der Brugge, R., Krueger, I., & van der Heijden, J. (2012). Omgaan met omgevingswensen bij de Vervangingsopgave Natte Kunstwerken (VONK). Delft: Deltares.
Gijsberts, A. N. (2011). Capaciteitsmanagement van Bruggen en Sluizen Breda: Rijkswaterstaat

NHTV internationaal hoger onderwijs Breda
Gilissen, H. K. (2013). *Adaptatie aan klimaatverandering in het Nederlandse waterbeheer: Verantwoordelijkheden en aansprakelijkheid.* Universiteit Utrecht, Deventer.
Gillet, V., McKay, J., & Keremane, G. (2014). Moving from local to State water governance to resolve a local conflict between irrigated agriculture and commercial forestry in South Australia. *Journal of Hydrology, 519, Part C*(0), 2456-2467. doi: http://dx.doi.org/10.1016/j.jhydrol.2014.08.031
Haas, H., & Drost, H. (2010). Nieuwsbrief over zoet-zoutvraagstukken: Zoet-zout. Den haag: RWS Waterdienst.
Harteveld, C. (2011). *Triadic Game Design: Balancing Reality, Meaning and Play*. London: Springer-Verlag.
Harvard. (2015). Research Methods: Some notes to orient you. Retrieved 07-09, 2015, from http://isites.harvard.edu/fs/docs/icb.topic851950.files/Research%20Methods_Some%20Notes.pdf
Heemskerk, F. (2012). Toenemend belang van economische diplomatie voor Nederland. *International Spectator, 64*(2), 70-72.
Hendriks, A., Lambrechtse, A., & Posseth, J. (2013). Doelmatigheidsstudie Vaarwegbeheer Flevoland: Berenschot.
Hertogh, M. J. C. M., & Westerveld, E. (2010). Playing with Complexity. Rotterdam: Erasmus Universiteit Rotterdam.
Hijdra, A. (2014). Waardecreatie in infra projecten: Een essay over twaalf principes. Massachusetts: MIT.
Holland.com. Cijfers en Feiten over Nederland. Retrieved 22-11, 2015, from http://www.holland.com/be_nl/pers-1/article/cijfers-en-feiten-over-nederland.htm
Hooghart, J. C. (1986). Verklarende hydrologische woordenlijst. Den Haag: TNO.
Huibregtse, J. N. (2015). *Vervangingsopgave Natte kunstwerken: Workshop NKWK 21 april, Aan de slag!* Powerpoint. STOWA. Bussum
Huibregtse, J. N., Donker, J. F., & Schelland, M. (2015). Memo: Stuwen Nederrijn-Lek. Delft: TNO.
IAM. (2014). *Asset Management – an anatomy* (Vol. 3). Bristol: The Institute of Asset Management.

Immerzeel, W. J. (2009). Bouwtechnisch onderzoek dachtlicht in auditoria Delft: Delft University of Technology.
Janssen, M. (2012). *Serious Gaming within the Dutch flood risk management – the MLS game.* University of Twente, Twente.
Kaufman, S., Elliott, M., Shmueli, D., Burgess, G., & Burgess, H. (2013). Frames, Framing and Reframing. Retrieved 20/12, 2015, from http://www.beyondintractability.org/essay/framing
Keskitalo, C., Juhola, S., & Westerhoff, L. (2013). Connecting Multiple Levels of Governacne for Adaptation of Climate Change in Advanced Instustrial States *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.
Kickert, W. J. M., Klijn, E.-H., & Koppejan, J. F. M. (1997). *Managing Complex Networks: Strategies for the Public Sector*. London: SAGE Publications.
Klein Tank, A., Beersma, J., Bessembinder, J., Van den Hurk, B., & Lenderink, G. (2014). KNMI'14: klimaatscenario's voor Nederland. Utrecht: KNMI.
Klerk, W. J. (2015). Draaiknoppen systeemanalyse gemaal/spuicomplex IJmuiden. Delft: Deltares.
KNAW. (2011). Klimaatverandering, wetenschap en debat. Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen.
KNMI. (2014). Hoe vaak komt extreme neerslag zoals op 28 juli tegenwoordig voor, en is dat anders dan vroeger? Retrieved 22/10, 2015, from http://www.knmi.nl/kennis-en-datacentrum/achtergrond/hoe-vaak-komt-extreme-neerslag-zoals-op-28-juli-tegenwoordig-voor-en-is-dat-anders-dan-vroeger
Kolkman, M. J., Veen, A. v. d., & Geurts, P. A. T. M. (2007). Controversies in water management: Frames and mental models. *Environmental Impact Assessment Review, 27*(7), 685-706. doi: http://dx.doi.org/10.1016/j.eiar.2007.05.005
Koppejan, J. F. M., & Klijn, E.-H. (2004). *Managing Uncertainties in Networks: A Network Approach to Problem Solving and Decision Making*. London: Routledge.
Kunz, N. C., Moran, C. J., & Kastelle, T. (2013). Implementing an integrated approach to water management by matching problem complexity with management responses: a case study of a mine site water committee. *Journal of Cleaner Production, 52*(0), 362-373. doi: http://dx.doi.org/10.1016/j.jclepro.2013.03.018
Kuypers, F., Lejour, A., Lemmers, O., & Ramaekers, P. (2012). Export draagt 29 procent bij aan Nederlandse economie. Retrieved 20/11, 2015, from http://www.cbs.nl/nl-NL/menu/themas/dossiers/globalisering/publicaties/artikelen/archief/2012/2012-3561-wm.htm
Lach, D., Rayner, S., & Ingram, H. (2005). Taming the waters: strategies to domesticate the wicked problems of water resource management. *International Journal of Water, 3*(1). doi: 10.1504/IJW.2005.007156
Lamberigts, P., & De Vuyst, S. (2008). Concept Strategienota Hoogheemraadschap van Delfland Bouwstenen voor het Waterbeheerplan 2010-2015: Hoogheemraadschap van Delfland.
Lautze, J. (2014). *Key Concepts in Water Resource Management: A Review and Critical Evaluation*. Abingdon: Routledge.
Lee, C. L. (2012). Analyserapport Waterbouw – Gemaal IJmuiden (25A-001-09). Amersfoort: DHV b.v.

IV-Infra b.v.
Legard, R., Keegan, J., & Ward, K. (2003). In-depth Interviews *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. London: SAGE Publications Ltd.
Lemkes, J., Delmeire, J., & Wegenwijs, A. (2012). Wateragenda Zuid-Holland 2012-2015. Rotterdam.
Levine, D. K. (2008). *Economic and Game Theory: What is Game Theory?* Los Angeles: UCLA, Department of Economics.
Ligtvoet, W., & Knoop, J. (2014). Kleine kansen – grote gevolgen: Slachtoffers en maatschappelijke ontwrichting als focus voor waterveiligheidsbeleid. Den Haag: Planbureau voor de Leefomgeving.

Mackor, R. (2011). Aadorp blijft bottleneck Almelo-De Haandrik. Retrieved 24/11, 2015, from http://www.nieuwsbladtransport.nl/Nieuws/Article/tabid/85/ArticleID/19647/ArticleName/AadorpblijftbottleneckAlmeloDeHaandrik/Default.aspx

Mens, M. J. P., Kwakkel, J. H., De Jong, A., Thissen, W. A. H., & Van der Sluijs, J. P. (2012). Begrippen rondom onzekerheid. In Kennis voor Klimaat (Ed.). Delft.

Ministerie van Infrastructuur en Milieu. (2011). Bestuursakkoord Water. Den Haag: Ministerie van Infrastructuur en Milieu.

Multiwaterwerk. (2012). *MultiWaterWerk: verkenning vervanginsopgave van de natte kunstwerken*: Rijkswaterstaat.

Nederlandse Waterschapsbank N.V. (2015). Over NWB Bank. Retrieved 21/11, 2015, from https://www.nwbbank.com/over-nwb-bank.html

NOS. (2015). Tientallen miljoenen euro's schade aan VU medisch centrum. Retrieved 22/11, 2015, from http://nos.nl/artikel/2056765-tientallen-miljoenen-euro-s-schade-aan-vu-medisch-centrum.html

O'Mahoney, T. (2015). *TO2 Kickoff Workshop: Functionele levensduur*. Presentation. Deltares. Delft.

Perry, J. (2015). Climate change adaptation in the world's best places: A wicked problem in need of immediate attention. *Landscape and Urban Planning, 133*(0), 1-11. doi: http://dx.doi.org/10.1016/j.landurbplan.2014.08.013

Provincie Zuid-Holland. (2013). Werkzaamheden St. Sebastiaansbrug. Retrieved 22/10, 2015, from http://www.zuid-holland.nl/onderwerpen/verkeer-vervoer/vaarwegen/vaarwegen/vaarwegen/rotterdam-den-haag/werkzaamheden-st/

Rijkswaterstaat. (2014). Basiskaarten: Vervangingsopgave Natte Kunstwerken. from http://www.deltaportaal.nl/webmap/category/vonk/

Rijkswaterstaat. (2015a). IJmuiden: bouw nieuwe, grote zeesluis. Retrieved 19/11, 2015, from http://rijkswaterstaat.nl/water/projectenoverzicht/ijmuiden-bouw-nieuwe-grote-zeesluis/index.aspx

Rijkswaterstaat. (2015b). MultiWaterWerk: Standaardisatie bij nieuwe sluizen. Samen naar de slimste sluis ter wereld. Den Haag: Rijkswaterstaat.

Rijkswaterstaat. (2015c). Stremming scheepvaart sluis Farmsum in verband met spuien. Retrieved 24/11, 2015, from http://www.rijkswaterstaat.nl/over-ons/nieuws/nieuwsarchief/p2015/11/stremming-scheepvaart-sluis-farmsum-in-verband-met-spuien.aspx

Rijkswaterstaat. (2015d). Waterstand tov NAP. Retrieved 22/10, 2015, from http://www.rijkswaterstaat.nl/kaarten/waterstand-tov-nap.aspx

Roelich, K., Knoeri, C., Steinberger, J. K., Varga, L., Blythe, P. T., Butler, D., . . . Purnell, P. (2015). Towards resource-efficient and service-oriented integrated infrastructure operation. *Technological Forecasting and Social Change, 92*(0), 40-52. doi: http://dx.doi.org/10.1016/j.techfore.2014.11.008

Röling, I., Roos, I., Franssen, R., van der Brugge, R., Ottow, B., Van der Heijden, J., & Prins, R. (2011). Slim combineren met de Meerwaardescan Besparen van kosten, verhogen van meerwaarde en versnellen van het proces. Den Haag: Rijkswaterstaat.

Roovers, G. J. (2012). *De systeembenadering van professionals als drager van de besluitvorming in het rivierbeheer.* Delft University of Technology, Delft.

rotterdam.nl. waterveiligheid in de rijn-maasdelta. Retrieved 22-10, 2015, from http://www.rotterdam.nl/waterveiligheidinrotterdam

Ruimtexmilieu. (2015). Lagenbenadering.

Saunders-Smits, G. N. (2013). *Get Ready: Academic Writing, General Pitfalls and (oh yes) Getting Started!* AE4010 – Research Methodology. Lecture. Technical University Delft. Delft.

Scheepvaartkrant. (2015). ASV tekent bezwaar aan tegen stremmingen grote zeesluis Delfzijl. Retrieved 24/11, 2015, from http://www.scheepvaartkrant.nl/default.asp?id=13221

Schoenmaker, R. (2013). *Asset Management & Performance Mgt*. CME 1210 Integration and Orientation. Lecture. Delft University of Technology. Delft.

Spierts, I. L. Y., Vis, H., & Kemper, J. H. (2010). 3D telemetrie onderzoek naar schieraalmigratie bij maal- en spuicomplex IJmuiden. Nieuwegein: VisAdvies BV.

Technische Adviescommisse voor de Waterkeringen. (1997). *Leidraad waterkerende kunstwerken en bijzondere constructies*. Delft: Rijkswaterstaat.

Tosserams, M. (2013). Bijlage C: Vervangingsopgave Natte Kunstwerken *Deltaprogramma 2014*: Rijkswaterstaat.

Tosserams, M. (2014). Bijlage F: Vervangingsopgave Natte Kunstwerken *Deltaprogramma 2015*: Rijkswaterstaat.

Tuin, H. G. (2013). *New canalization of the Nederrijn and Lek – Design of a weir with fibre reinforced polymer gates which is made using a structured design methodology based on Systems Engineering.* University of Technology Delft, Delft.

Urich, C., & Rauch, W. (2014). Exploring critical pathways for urban water management to identify robust strategies under deep uncertainties. *Water Research, 66*(0), 374-389. doi: http://dx.doi.org/10.1016/j.watres.2014.08.020

Van Ast, J., Bouma, J. J., & Bal, M. (2013). Values Connecting Societies and Water Systems *Water Governance as Connective Capacity*. London: Ashgate Publication Limited.

Van Baaren, M. (2010). Amsterdam Waterbestendig. Amsterdam: Waternet.

Van Baars, S., Bezuyen, K. G., Colenbrander, W., Kuijper, H. K. T., Spaargaren, C., & Vrijling, J. K. (2009). Hydraulic Structures: Lecture notes CT3330. Delft: Delft University of Technology.

Van Buuren, A., Teisman, G. R., Verkerk, J., & Eldering, M. (2014). Samen verder werken aan de Delta: De governance van het Nationaal Deltaprogramma na 2014. Rotterdam: Erasmus University.

Van den Hark, M. H. C., Beuse, P. H., Brouwer, M., Vos, S. M., Bootlink, M. T. L., Lammers, J. W., & Slikke, M. J. v. d. (2000). Uitbreiding gemaalcapaciteit Amsterdam-Rijnkanaal/Noordzeekanaal: Waterhuishoudkundige onderbouwing capaciteit en capaciteitsverdeling. Utrecht: Rijkswaterstaat.

Van der Brugge, R., De Bel, M., & Klerk, W. J. (2015). *Ontwikkeling Systeemaanpak Asset management t.b.v. VONK*. TO2 project Natte Kunstwerken van de Toekomst Systeemspoor. Deltares. Delft.

Van der Vlist, M., & Van der Velde, J. (2015). *Infrabeheren in een onzekere toekomst*. Presentation. PBL. Den Haag.

van der Vooren, A., Alkemade, F., & Hekkert, M. P. (2012). Effective public resource allocation to escape lock-in: The case of infrastructure-dependent vehicle technologies. *Environmental Innovation and Societal Transitions, 2*(0), 98-117. doi: http://dx.doi.org/10.1016/j.eist.2012.01.003

van der Wiel, W. D., Persoon, E., & Stiksma, G. (2013). LCC-optimalisatie Gemaal IJmuiden - Korte en Lange Termijn: Iv-Infra b.v.

Van Eijndhoven, J., Frantzeskaki, N., & Loorbach, D. (2013). Connecting Long and Short-term via Envisioning in Transition Arenas *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.

Van Leeuwen, C., & Van Buuren, A. (2013). Connecting Time Spans in Regional Water Governance: Managing Projects as Stepping-stones to a Climate Proof Delta Region *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.

Van Marrewijk, A. (2013). *Masterclass: Een hernieuwde kijk op bestaande praktijken* Presentation. VU Amsterdam. Amsterdam.

Van Rhee, G. (2012). *Handreiking Adeptief Deltamanagement*. Utrecht: Stratelligence.

Van Schaick, J., & Klaasen, I. T. (2011). The Dutch Layers Approach to Spatial Planning and Design: A Fruitful Planning Tool or a Temporary Phenomenon? *European Planning Studies, 19*(10), 1775-1796.

Van Vlimmeren, S., De Reuver, W., & Van Vlimmeren, T. (2014). *Management & Organisatie in Balans*. Roosendaal: Uitgeverij Van Vlimmeren B.V.

Van Vuren, S., Konings, V., Jansen, T., Van der Vlist, M., & Smet, K. (2015). *Dealing with aging of hydraulic infrastructure: an approach for redesign water infrastructure networks*. Paper presented at the IAHR World Congress, Den Haag.

Vannevel, R. (2013). The Pentatope Model: A holistic approach for analysing and reviewing environmental complexity. *Sustainability of Water Quality and Ecology, 1–2*(0), 10-23. doi: http://dx.doi.org/10.1016/j.swaqe.2014.06.001

Verduijn, S. (2013). Framing Strategies and Connective Capacity in Water Governacne Policy: The Case of the Second Delta Committee *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.

Vinke-de Kruijf, J., Kuks, S., & Augustijn, D. (2013). Connective Capacity in a Dynamix Context: Changing Water Governance Structures in Romania *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.

Visser, J. (2011). Bestuursakkoord 2011-2015 krijgt steun Gelderland [Press release]

von Hirschhausen, C., Beckers, T., & Brenck, A. (2004). Infrastructure regulation and investment for the long-term—an introduction. *Utilities Policy, 12*(4), 203-210. doi: http://dx.doi.org/10.1016/j.jup.2004.09.002

Vrijling, J. K., & Verlaan, J. G. (2013). Financial Engineering *Reader CME2300*. Delft: Delft University of Technology.

Waterschap Reest en Wieden. (2010). Wie doet wat? Retrieved 29-09, 2015, from http://www.reestenwieden.nl/thema'/bestuur-organisatie/samenwerking-0/doet/

Waterschap Vallei Eem. (2012). Nota waardering en afschrijving vaste activa (Vol. Waterschap Vallei Eem). Apeldoorn.

Waterschapservices. (2015). GeoVoorziening Waterschappen. Retrieved 20/11, 2015, from http://waterschapservices.webgispublisher.nl/Viewer.aspx?map=gv_ws#

Weber, E. P., & Khademian, A. M. (2008). Wicked Problems, Knowledge Challenges, and Collaborative Capacity Builders in Network Settings. *Public Administration Review, 68*(2), 334-349. doi: 10.1111/j.1540-6210.2007.00866.x

Wessels, J. (2014). Natte Kunstwerken. Retrieved 10-06, 2015, from https://www.tno.nl/nl/aandachtsgebieden/leefomgeving/buildings-infrastructures/infrastructuur-wegen-spoor-sluizen-bruggen-en-tunnels/natte-kunstwerken/

Wikipedia. (2015). Decision-making. Retrieved 22/11, 2015, from https://en.wikipedia.org/wiki/Decision-making

Yin, R. K. (2009). *Case Study Research Design and Methods: Fourth Edition*. Thousand Oaks: SAGE Publishers Ltd.

Zhou, Q., Bekebreke, G., Mayer, I., Warmerdam, J., & Knepflé, M. (2013). The Climate Game: Connecting Water Management and Spatial Planning through Simulation Gaming? *Water Governance as Connective Capacity*. London: Ashgate Publishing Limited.

Zuiderzeeland. (2015). Stuwen in Flevoland. Retrieved 24/11, 2015, from http://www.zuiderzeeland.nl/werk/werk-in-uitvoering/waterpeilbeheer/stuwen-flevoland/

Appendix A: Research on Asset Management of HCS

The first initiative in The Netherlands is project VONK *(Dutch: Vervangingsopgave Natte Kunstwerken)*. VONK is a pilot study with the aim to link the future replacement issues of HCS to the plans of the Deltaprogram. This initiative was included in appendix of the Deltaprogram. Since the project is executed by RWS the main focus are ±650 HCS of the Primary Water Networks. VONK consists of several stages. The first stage was the inventory stage. The inventory stage was an initial mapping of all relevant HCS and their estimated replacement year, by adding up the initial design life time to the delivery year. The second step in the project is the development of a sensitivity test. Instead of the single replacement year, the sensitivity test delivers per HCS a probability distribution of the replacement moment. The replacement period is determined by the technical end of service life or the functional end of service life. To determine the probability distribution of the end of the technical service life, an inventory is made of the risks of all HCS. This studies are also known as RINK studies (Dutch: Risico Inventarisatie Natte Kunstwerken). RINK addresses the reliability and availability of the HCS. For the functional service life, an analysis of HCS' network is executed. On the basis of the different Deltascenarios, the future requirements and performance is estimated. The scenarios provide a second probability distribution of the end of service life. The final step in VONK is the design of possible policy pathways. This is a mapping of the action perspective, based on risk assessment and future requirements. (Deltacommissaris, 2012; Tosserams, 2013, 2014).

Also a number of research institutes within The Netherlands conduct research on Asset Management of HCS. There is one coalition funded by the Ministry of Infrastructure and Environment (Min. I&E) which consists of Deltares, TNO and Marin, and is called 'TO2: Hydraulic civil structures of the future' *(Dutch: Natte kunstwerken van de toekomst).* The research project received funding for one year. In the research the combined expertise of the three institutes is used to further the developments in Asset Management of HCS. Marin is an expert institute in effects of hydraulics of ships. TNO is an innovation based institute, with expertise in the field of construction materials. Deltares is a specialized institute in water-soil dynamics and hydraulics. Together these institutes provide a broad knowledge basis. The project is divided into three tracks; functional service life track, a technical service life track and a systems track. The technical service life track focusses on monitoring methods and probabilistic risk assessments of HCS. The functional service life track focusses on an optimal performance of locks. The systems track analyses the system impact and opportunities following from a broader systems scope. In a number of cases the combined expertise is used to develop strategic interventions options.

Another initiative from RWS is 'Multiwaterwerken' (MWW), which is translated as multifunctional HCS. MWW is a joint project with Deltares as knowledge institute and Van Hattum en Blankevoort and IPV Delft as commercial parties. The project is a collaboration within the so called golden triangle of knowledge, governance and market sectors. Each party brings in specific experience and expertise to the project. The joint project of MWW explores the possibilities in standardization of locks and weirs. This does not only consider the design, but also the planning and construction. With the aim to reduce costs. This initiative focusses on a specific type of HCS and therefore has a more limited scope as the TO2 research project (Multiwaterwerk, 2012).

ROBAMCI (Risk and Opportunity Based Asset Management of Critical Infrastructures) is an initiative that is set up by Deltares in cooperation with 16 institutional, commercial and research partners. It is a multi-year project with the goal to set-up an Asset Management framework for the public infrastructure sector. The project is divided into multiple work packages (WP). Every track focuses on a specific type of infrastructure and one of these tracks is about HCS. ROBAMCI is very much focused on individual infrastructures and explores the relationship between multiple the different types of infrastructure (Den Heijer, 2015).

Appendix B: Introduction to water resource management

The Netherlands got their name because of the low level of the surface area of the country. More than a quarter of The Netherlands (26%) is located below sea level and in the lowness of on some places reaches up to -6,5 meters under sea level (Holland.com). This land level is formed throughout history by the mining of peat and poldering of former waters and sea areas. Due to the hydraulic pressure of the elevated water areas, like the sea, ground water comes to the surface of the low regions. This water needs to be discharged out the low regions in order to keep the land dry and safe for usage. A schematic representation of the discharge process is illustrated in Figure 29. The discharge of the water out of the low regions is pumped up to elevated discharge waters through pumping stations. Especially is the lower areas discharge takes place in multiple elevations. The water finally ends up in a main discharge water that discharges the water into the sea.

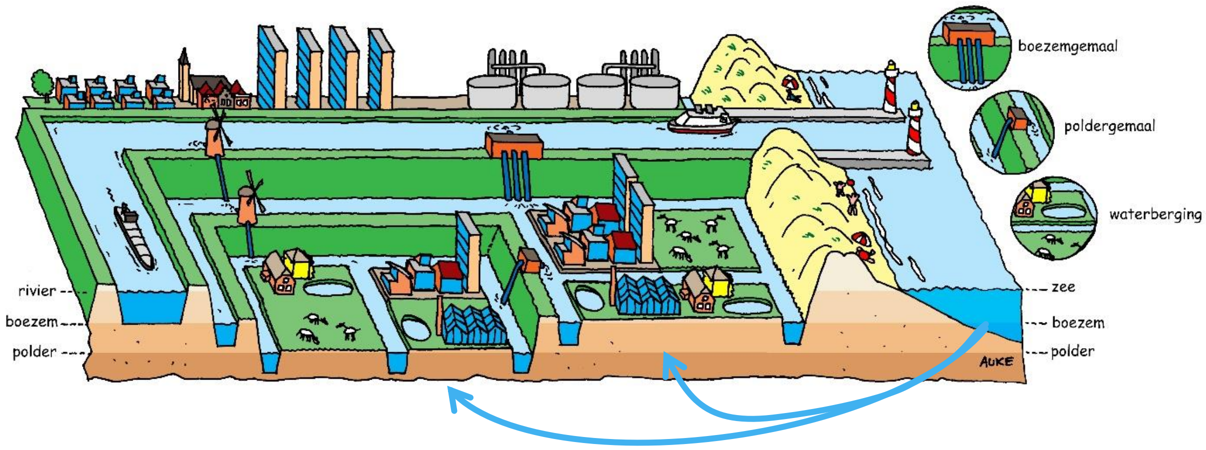


Figure 29 Schematic representation of water discharge in The Netherlands (rotterdam.nl)

The direction of the water flow is known as 'water catchment'. The water catchment of different water bodies forms the basis for the regional division of water systems. This way, most issues in the systems are controllable by the responsible waterboard. The water systems face two threats: draught and flooding. Draught is a problem due to the demand of fresh water. Fresh water is needed for agriculture and drinking water. In times of draught the supply of the fresh water decreases and the demand increases. The water that comes to the surface in lower regions is salt. During draught the discharge water bodies can become too salinized for the fresh water purposes. In order to flush out the salinized water, it is needed to supply fresh water from different regions. The water of the IJsselmeer and Markermeer is the main fresh water supply in The Netherlands.

The risk of flooding occurs during times of high levels of river water and extreme rainfall. High sea levels are less of a problem, since the sea level is accurately predictable, whilst the amount of rainfall or river levels are not. The discharge capacity of the regional systems is based on a flood risk of once in a certain amount of years. This network is calculated over the complete network, but can be locally exceeded. For this reason regional floods can take place during extreme river water levels and extreme rainfall.

In order to prevent salinization and floods from taking place, regional agreement are made between the water resource managers about a minimum and maximum water level.

Appendix C: Catchment and discharge of regional water systems

Hoogheemraadschap Hollands Noorderkwartier (HHNK)

HHNK is the regional water system that is located on the north side of the NZK. It is the orange coloured area in Figure 16. The system is completely bordered by water. On the western side by the North Sea, on the northern side by the Waddenzee, on the eastern side by the Ijsselmeer and Markermeer and on the southern side by the NZK Currently the region of HHNK had two main water catchment directions for its water. The south half of the region of HHNK is currently depended on the discharge of water in the NZK. The water is discharged with two pumping station, one at Zaandam and another at Kadoelen. Together these pumping stations have the capacity of 68 m^3/s. The north half of the region discharges its water in the Waddenzee at Den Helder. It is physically impossible to use the pumping station at Den Helder for the discharge of the southern half of the region due to the water catchment. For this reason, only the southern part of HHNK is considered in the analysis. For the Southern region two additional pumping stations are planned at the Monnikendam and Schardam that can discharge to the IJsselmeer, at the east border of the system. These pumping stations at the Markermeer are going to function as an alternative for the discharge in the NZK. The regional system has temporary water storage areas for peak loads of water. In the southern part of HHNK has no main historic city centres.

Hoogheemraadschap Rijnland (HRL)

HRL is the regional water system that is located south of the NZK and west of the ARK. It is the green coloured area Figure 16. The system is bordered by water in the west, the North Sea, and the north, the NZK. In the east HRL borders with the waterboards of HDSR and AGV and in the south with waterboards Schieland and Krimpenerwaard and Delfland. The regional water system can make use of three discharge directions. The system has a pumping station in the north at Spaarndam, that discharges the water into the NZK. The pumping capacity in this direction is 71 m^3/s. In the west HRL can discharge water directly into the North Sea with a pumping station at Katwijk. The pumping capacity in this direction is 100 m^3/s. However, this pumping station cannot be used at all times. This pumping station is part of primary coastal flood defence line and at extremely high sea levels the use of the pumping station is forbidden. The last discharge direction is towards the south-east with a pumping station at Gouda. This pumping station discharges the water with a capacity of 33 m^3/s into the Hollandse IJssel. It depends on the wind direction and local rainfall whether which direction the catchment of the regional system has. Therefore the favourable discharge direction is depended on the weather. The regional system has large areas of open water (± 5000 hectare), but the system has a water level margin. Within the region three average size cities with historical city centres are located: Haarlem, Leiden and Gouda.

Waterschap Amstel Gooi en Vecht

AGV is the regional water system that is located southern of the NZK, eastern of HRL and on both sides of the northern part of the ARK. It is the purple coloured area Figure 16. The ARK splits the regional system in half. The main discharge waters of the regional system are in open connection with the ARK. The west side of the regional system discharges in total 69 m^3/s into the ARK and the east side of system discharges in total 45 m^3/s into the ARK. Both discharge capacities are the sum of multiple local pumping stations. AVG only borders other discharge waters in the north, with the NZK and the Markermeer. AGV can discharge water into the Markermeer with a pumping station at Zeeburg, with the pumping capacity of 53 m^3/s. In winter, with a low water level at the Markermeer, it is possible for the north part of AGV to discharge water with gravity with though multiple small locks. This discharge capacity can add up to 59 m^3/s. An emergency storage for the regional system of 2,4 million m^3 of water is planned at De Hoep, also known as *"the airbag of Amsterdam".* As already mentioned, the regional system includes the city of Amsterdam and most of the facilities are built to prevent the city from high water levels. Amsterdam can be disconnected from the regional water system thought a series of locks. At that point the pumping station at Zeeburg functions as the drainage point of the city of Amsterdam.

Hoogheemraadschap De Stichtse Rijnlanden

HDSR is the regional water system that is located southern of AVG, eastern of HRL and on both sides of the southern part of the ARK. It is the yellow coloured area Figure 16. The main discharge waters of the regional system are in open connection with the ARK. The regional system discharges in total 78 m^3/s into the ARK. This discharge capacity is the sum of many local pumping stations. The southern border of HDSR is the river the Lek. The regional system has no discharge capacity in this direction, because there a no pumping stations and by gravity is impossible since it in the opposite direction of the water catchment. HDSR has an emergency discharge in the direction of the region of HRL, with the discharge capacity of 25 m^3/s. For the rest the regional system is depended on discharge of water through the ARK. Central in the region is the historical city of Utrecht.

Appendix D: Interview set-up of the case study

[*datum*] Interview [organisatie]

[*tijd, locatie aanwezige personen*]

Woorden vooraf (3 min)

- Interview is onderdeel van een exploratieve case studie en heeft als doel inzicht te verschaffen in de huidige gang van zaken binnen het Asset Management van Natte Kunstwerken en mogelijke implicaties van een nieuwe benadering
- Het onderzoek wordt uitgevoerd voor Deltares en de TU Delft. Conclusies van het onderzoek worden mogelijk gebruikt door 'ROBAMCI' en 'TO2, Natte Kunstwerken van de Toekomst'. Dit is afhankelijk van de project coördinatoren.
- De case is gekozen vanwege de bestaande informatie en zowel de object focus als de netwerk focus die toegepast is
- De geluidsopname dient alleen voor de interviewer om de antwoorden terug te luisteren en te documenteren. Alle informatie wordt vertrouwelijk behandeld en komen anoniem terug in de rapportage van het onderzoek. Na het onderzoek worden de opnamen verwijderd.

Introductie onderzoek (7 min)

Probleem diagnose

Gebrek aan een optimale aanpak binnen VONK. Grote natte kunstwerken zijn kostbaar en daarom een economisch probleem voor "BV Nederland".

Oorzaak:

- Lange termijn karakter infrastructuur vs. korte termijn onzekerheid
- Bestuurlijke scheiding netwerken met hoge mate van onafhankelijkheid vs. complexiteit opgave

Gevolg:

- Risico op lock-in situaties
- Risico op probleemverschuiving
- Gemiste kans op netwerk overschrijdende handelingsperspectieven
- Gemiste kans op meekoppelen
- Risico op onder- en overinvesteringen

Plan van aanpak

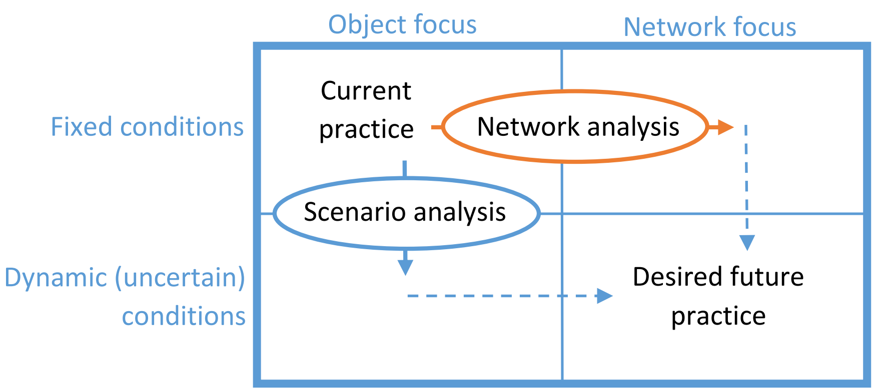


Figure 30 Scope of the suggested new solution approaches (own illustration)

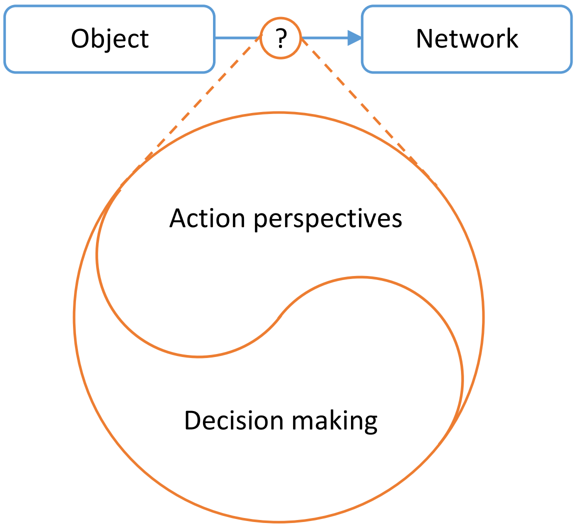


Figure 31 Graphical representation of the decomposition of the Research Approach (own illustration)

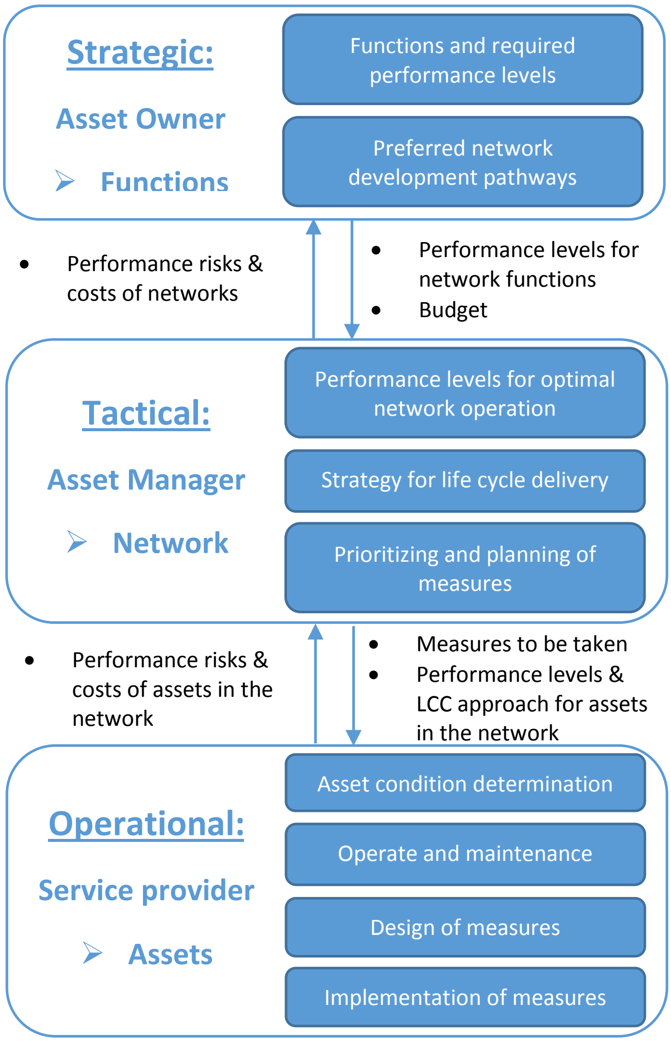


Figure 32 Roles and tasks within Asset Management (Den Heijer, 2015)

Interviewvragen (50 min)

1. Wat is jouw rol binnen deze casus?

2. Wat zijn de **componenten** die volgens jou het netwerk definiëren?

    a. Waar ligt de grens van het netwerk? (functioneel en fysiek)
    b. Wat zijn de behoeften voor het netwerk?
    c. Wat is de impact van de verschillende componenten?

3. Welke **actoren** spelen een rol in de netwerk?

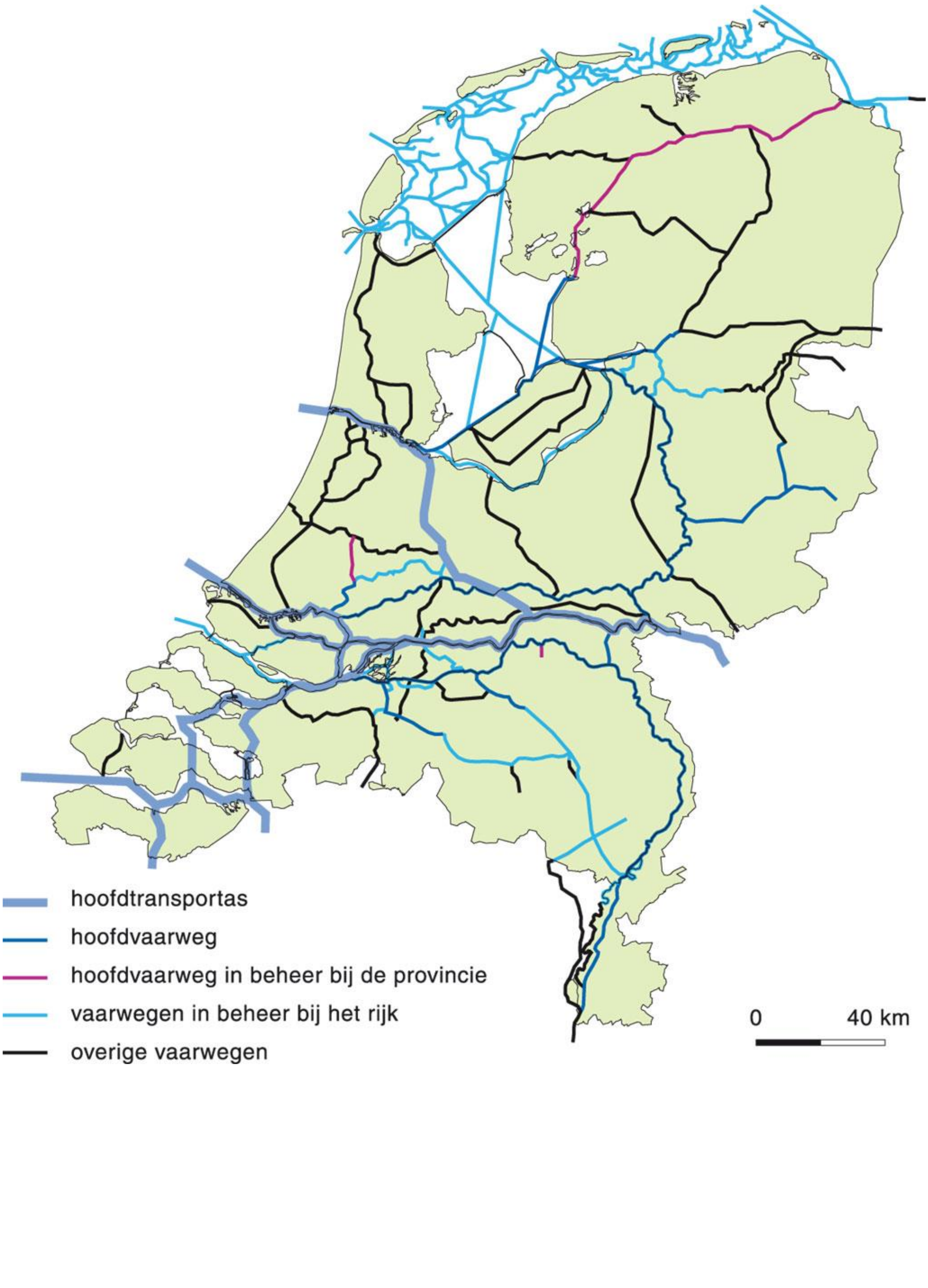
    a. Wat is hun rol?
    b. Hoe zijn de actoren onderling georganiseerd?
    c. Hoe verhouden ze zich tot elkaar binnen het netwerk?

4. Hoe worden de **handelingsperspectieven** bepaald in het geval van deze casus? (object en netwerk niveau)

    a. Wat zijn de handelingsperspectieven?
    b. Welke rol spelen de verschillende actoren hierin?
    c. Welke factoren staan hier aan de basis?
        i. Wat bepaalt deze factoren?
        ii. Wie bepaalt deze factoren?

5. Hoe komt de uiteindelijke **besluitvorming** tot stand?

    a. Is er al een besluit over de casus?
        i. Zo ja, wat is er uiteindelijk besloten?
    b. Op welk niveau wordt/werd dit besluit genomen?
        i. Welk organisatorisch niveau?
        ii. Op object niveau of netwerk niveau?
    c. Welke actoren spelen/speelden hier een rol in?
    d. Welke rol spelen/speelden (eerder benoemde) de handelingsperspectieven hierin?
        i. Wat zijn/waren de voornaamste afwegingen hiertussen de handelingsperspectieven?
        ii. Spelen/speelden object en netwerk oplossingen hier een andere rol in?
    e. Zijn/waren er andere (externe) factoren van invloed op deze besluitvorming?
        i. Zo ja, welke?


hoofdtransportas
hoofdvaarweg
hoofdvaarweg in beheer bij de provincie
vaarwegen in beheer bij het rijk
overige vaarwegen
0
40 km

Appendix E: Coding of the case study interviews

1. **Definitie netwerk**
   1.1. <u>Uiteenlopende termen/definities</u>
      1.1.1. RWS hanteert de term Hoofdwatersysteem voor hun netwerk
      1.1.2. Lokale netwerken beheert door waterschappen worden regionale systemen genoemd
      1.1.3. Belangrijk duidelijke definitie afspreken om verwarring te voorkomen
      1.1.4. Wateroverlast betekent dat het water uit de watergangen het land op loopt
   1.2. <u>Functionaliteiten</u>
      1.2.1. Waterveiligheid
         1.2.1.1. Primaire waterkering
            1.2.1.1.1. Juridisch vastgelegde normen
            1.2.1.1.2. Juridisch harde eisen aan overschrijdingskans
            1.2.1.1.3. Grijs gebied wat betreft de invloed van het peil beheer op de overschrijdingskans
         1.2.1.2. Grootste dreiging wateroverlast komt uit de Rijn en de Lek
      1.2.2. Waterbeheer
         1.2.2.1. Peilbeheer
               1.2.2.1.1.1. Wordt primair gekeken naar peil, andere factoren worden wel meegewogen
            1.2.2.1.2. Peilbesluit
               1.2.2.1.2.1. Komt voort uit te faciliteren functionaliteiten
               1.2.2.1.2.2. Kunstwerken worden hierop gedimensioneerd. Druk op het systeem wordt ingeschat
               1.2.2.1.2.3. Ervaring is grootste factor huidig peilbesluit
               1.2.2.1.2.4. Peilbesluit als middel om op te sturen
                  1.2.2.1.2.4.1. Peilbesluit is een middel om op te sturen
                  1.2.2.1.2.4.2. Er is geen overschrijdingsrisico verbonden aan peilbesluiten
                  1.2.2.1.2.4.3. Niet bruikbaar voor prestatiesturing, risicoloos sturen bestaat niet
               1.2.2.1.2.5. Wettelijk stuk uit 1992
            1.2.2.1.3. Waterakkoord
               1.2.2.1.3.1. Geen wettelijk document
               1.2.2.1.3.2. Afspraken kader hoe het waterbeheer wordt ingericht
               1.2.2.1.3.3. Gaat over wat te doen wanneer een grens wordt bereikt, niet over hoe te anticiperen/voorkomen dat de grens wordt bereikt
               1.2.2.1.3.4. Bij de grens van -0,30 gaan water beheer belangen voor scheepvaart belangen
               1.2.2.1.3.5. De regels houden geen rekening met verhang, mogelijk dat dit bij een nieuw waterakkoord wel meegenomen wordt
      1.2.3. Gebruik
         1.2.3.1. Scheepvaart
            1.2.3.1.1. Heeft geleid tot de aanleg van een nieuw sluizencomplex bij IJmuiden

1.2.3.1.1.1. Met name voor de cruiseschepen, aangelegd
1.2.3.1.1.2. Bij de bouw gefocust op economie, maar niet naar andere functies in het waternetwerk
1.2.3.1.2. Peilbeheer (zie 1.2.2.1.)
1.2.3.2. Industrie
1.2.3.2.1. Peilbeheer (zie 1.2.2.1.)
1.2.4. Waterkwaliteit
1.2.4.1. Verzilting/zoutindringing: altijd een belang bij zeesluizen
1.3. Grenzen
1.3.1. Het netwerk is het systeem van de objecten waar je mee kan spelen
1.3.2. Draaiknoppen zijn niet persé grenzen van het netwerk. Andere onderdelen kunnen ook grenzen vormen
1.3.3. De grenzen liggen waar er minder functionele samenhang optreed
1.3.3.1. Ingeval van VONK hangt heel het netwerk om het NZK/ARK heen
1.3.4. De grens bij Irenesluizen en IJsselmeer, zijn er om de opgave behapbaar gehouden, maar de fysieke samenhang houdt daar niet op
1.3.5. De functionele grens kan bij beter netwerk gericht gebruik nog een tijdje door, maar op termijn zal deze grens bereikt worden
1.4. Beheersgebieden
1.4.1. NZK
1.4.1.1. RWS West Nederland Noord
1.4.1.2. Peilnorm: tussen -0.55 en -0.30 NAP. Streefpeil -0.40
1.4.1.2.1. Geen overschrijdingsrisico aan verbonden
1.4.1.2.2. Heeft niks te maken met wateroverlast
1.4.1.2.3. Bepaald op basis van ervaring
1.4.1.2.4. Levert de minste problemen op voor de gebruikers
1.4.1.2.5. Wordt momenteel onderzoek gedaan om de effecten helder te krijgen
1.4.1.2.6. Veel in overleg met waterschappen en gebruikers
1.4.1.3. Wateroverlast vanaf NAP
1.4.1.3.1. 1/100 als overschrijdingsnorm is provinciaal beleid, dit is echter regionaal. Een norm voor NZK is er niet
1.4.1.3.2. Onduidelijkheid over wanneer er kades overlopen. De berichten variëren van NAP tot 1,25 boven NAP
1.4.1.3.3. RWS hanteert NAP voor kleine problemen, en dat er bij 0,25 zeer grote problemen optreden
1.4.1.4. Belangrijke kunstwerken (voor afwatering)
1.4.1.4.1. Spui-gemalen complex IJmuiden
1.4.1.4.1.1. Capaciteit klopt niet. Zit een foutmarge van 20% in wat erin en eruit gaat. Ongeveer 50 m3/s "houtje-touwtje"
1.4.1.4.1.2. Het verschil in capaciteit met verschillende waterstanden moet een keer goed geijkt worden, want dit kan verschillen. Als de hoogte-opvoer te hoog wordt, kunnen de pompen het niet meer. Oktober 2014 konden zowel de nieuw pompen als oude pompen het niet meer aan, dan ligt de volledige

afvoer stil. Het is goed gegaan omdat hier op geanticipeerd was

1.4.1.4.2. Sluizencomplex IJmuiden

1.4.1.4.3. Sluizencomplex Schellingwoude

1.4.1.5. In de zomer is er een zouttong in het NZK. Dit wordt verergerd door het uitbaggeren. Het is brak water

1.4.2. ARK

1.4.2.1. RWS Midden Nederland

1.4.2.2. Belangrijke kunstwerken

1.4.2.2.1. Beatrix sluis

1.4.2.2.2. Princes Irenesluis

1.4.3. Rijnland

1.4.3.1. Hoogheemraadschap van Rijnland

1.4.3.2. Belangrijke kunstwerken (voor afwatering)

1.4.3.2.1. Gemaal Alphen 32 m3/s

1.4.3.2.2. Gemaal Spaarndam 34 m3/s

1.4.3.2.3. Gemaal Gouda 40 m3/s

1.4.3.2.3.1. Afhankelijk van de wind of erop gepompt mag worden

1.4.3.2.4. Gemaal Katwijk 100 m3/s

1.4.3.2.4.1. Kan wegvallen bij hoge zeewater standen, aangezien het onderdeel is van de primaire waterkering

1.4.3.2.4.2. Recent vergroot met 46 kuub. Niet dat dit extra is, deze capaciteit is keihard nodig in het systeem

1.4.3.3. Met name wateroverlast en droogte zijn de problemen van het Rijnland

1.4.3.4. Inzet gemalen afhankelijk wind en regen. Stroomgebied is wisselend. Welk gemaal gebruikt dient te worden, wordt geautomatiseerd bepaald d.m.v. een BOS systeem

1.4.3.4.1. 3 van de 4 gemalen is geautomatiseerd, de ander wordt met de hand bedient. Die gebruik je het liefst overdag

1.4.3.4.2. Rekent 24 uur vooruit en komt met waterpeil, wij zien dit liever over een langer termijn en met risico-benadering

1.4.3.5. In de zomer wordt er met name bemaald tegen verzilting vanuit dieptepolders (Haarlemmermeer). Dit water moet zo snel mogelijk het systeem uit

1.4.3.5.1. Droogmakerijen pompen jaarlijks 200.000 kilo zout naar boven. Erg slecht voor natuur, landbouw en hoge concentraties ook veeteelt

1.4.3.6. Weinig flexibel peil door grachten in Leiden en Haarlem. Van -0,65 tot -0,62, -0,50 is uiterste grens

1.4.3.6.1. Het systeem kan 15mm-17mm buien weerstaan

1.4.3.6.2. Een risico-afweging met kosten berekening zit niet aan deze limiet

1.4.3.6.3. Uit ervaring blijkt dat de oude afwegingen vaak wel deugen, al weten we niet precies de destijdse afweging

1.4.3.6.4. Te kleine marge om te wachten met lozen op het NZK tot de waterstand gezakt is

1.4.3.6.5. Peil wordt gemeten aan de hand van 20 locaties: representatief boezempeil. Peil bij een draaiend gemaal is niet representatief

1.4.3.7. Systeem met 5000 hectare aan open water, maar kan relatief weinig bergen door kleine marges

1.4.3.8. Het systeem is er ontworpen dat er niet meer dan 1/100 jaar wateroverlast optreedt, naar eis van de Provincie

1.4.3.9. Er worden momenteel extra piekbergingen gerealiseerd

1.4.3.10. Bij een 1/100 incident, kunnen we geen capaciteit van NZK overnemen, omdat we dan ons gehele systeem voor onszelf moeten benutten. als we zo een bij niet aankunnen hebben we een aansprakelijkheidsprobleem. Buien daarbuiten niet

1.4.3.10.1. 1/100 klinkt heel veilig, maar dat is een kan van meer dan 50% dat je dit meemaakt in je mensenleven

1.4.4. Hollands Noorderkwartier

1.4.4.1. Hoog heemraadschap Hollands Noorderkwartier

1.4.4.2. Belangrijke kunstwerken

1.4.4.2.1. Gemaal Zaandam

1.4.4.2.2. Gemaal Den Helder

1.4.4.2.2.1. Gemaal Den Helder heeft overcapaciteit, maar geen hydraulische problemen, aangezien de aanvoerroute 80km is, en het hoogste punt van het watersysteem in het midden ligt en dus naar 2 kanten afwatert. Daarnaast heeft het beheersysteem kleine marges

1.4.4.2.3. In de toekomst komt er ook een gemaal bij Spardam en Monnikendam richting het Markermeer. Gemaal dat 2 kanten op kan pompen

1.4.4.2.3.1. De planning van het nieuwe gemaal loopt al 30 jaar, dus het is direct een lange termijn investering. Kan tegen verschillende scenario's van waterstanden op het IJsselmeer

1.4.4.2.3.2. Om gemaal Zaandam, en dus ook IJmuiden te ontlasten, is er de mogelijkheid om het gemaal groter uit te voeren

1.4.4.3. Boezemstand is -0,40 NAP

1.4.4.4. Het systeem tijdelijke bergingsgebieden, die hebben direct effect, want afvoer heeft altijd een vertragende werking

1.4.5. Amstel, Gooi en Vecht

1.4.5.1. Waternet

1.4.5.2. Belangrijke kunstwerken

1.4.5.2.1. Gemaal Zeeburg, siffon van 57 m3/s. Functie is met name Amsterdam droog houden. Momenteel krijgt dit kunstwerk een standaard renovatie

1.4.5.3. Onderdeel van het hoofdsysteem, omdat de boezemwateren, de Amstel en de Vecht er mee in open verbinding staan

1.4.5.4. Bij laagwater, meestal gedurende winter, kan er onder vrij verval afgewaterd worden op het IJmeer

1.4.5.5. Amsterdam kan met Amsterdam West Boezem losgekoppeld worden van het netwerk, aan de hand van het sluiten van een aan sluizen. Zeeburg kan dit dan afwateren

1.4.5.6. Bij 0 NAP krijgen wij overlast, dan overstromen kaders, dus we hebben 40 cm speling. Dit kan minder zijn afhankelijk van de wind. Het risico is dat op zo'n moment de dijken verzadigd raken en wegspoelen

1.4.5.7. Rond de Hoep is er een calamiteiten berging: 2,4 miljoen kuub

1.4.5.7.1. "airbag van Amsterdam"

1.4.5.7.2. Ter voorkoming Watergraafsmeer onderwater loopt: 5m onder zeespiegel en vestiging van grote delen van de ICT sector van west Europa

1.4.5.7.3. Zorgt voor veel discussie met bewoners van de Hoep, en de faciliteiten worden geblokkeerd. Er wordt momenteel een inrichtingsplan gemaakt, met inlaatwerk en maatregelen voor bescherming. Er zijn geen burger in gevaar, discussie gaat om schade. De vraag is of al deze investeringen het waard zijn voor een 1/100 event

1.4.5.8. Vanwege Natura 2000 is het van belang dat het water hoog genoeg staat, zodat de Vechtplassen genoeg zoetwater hebben

1.4.6. Stichtse Rijnlanden

1.4.6.1. In extreme situaties kan Stichtse Rijnlanden tot 25m3/s afvoeren naar Rijnland

1.4.7. Markermeer/IJsselmeer

1.4.7.1. RWS Midden Nederland

1.4.7.2. Verziet ongeveer 10 waterschappen van zoet water. Als het NZK 20% meer zoet water nodig heeft door een nieuwe sluis, kan 2/5 van NL hier last van hebben

1.4.7.3. Alternatieve afvoerroute voor IJmuiden is via het IJmeer, naar het Markermeer, via de Houtripdijk naar het IJsselmeer en via de afsluitdijk naar de Waddenzee. Momenteel gaar er 95-99% via IJmuiden

1.4.7.3.1. Er kan op verschillende manieren naar het IJmeer afgewaterd worden: via het gemaal bij Zeebrug

1.5. <u>Kwetsbaarheid</u>

1.5.1. Netwerk erg gevoelig voor coïncidenties

1.5.1.1. Bij het falen van IJmuiden en een maalstop bij Katwijk, ontstaan er zeer grote problemen

1.5.2. Grote angst bij de beheerders dat een keer NZK wegvalt met zware regenval. Gebrek aan realisatie bij het grote publiek hoe kwetsbaar het is. Als Gemaal-IJmuiden met extreem weer uitvalt, kan er in een uur 10cm peilstijging optreden. Het heeft een cruciale functie voor een heel groot gebied. Je moet zorgen dan hier topcapaciteit is, en zo nodig upgraden.

1.5.3. Beschikbaarheid en betrouwbaarheid Gemaal-IJmuiden is een kritische factor voor heel het netwerk

1.5.3.1. Jaarlijks is er op 1 tot 2 hoogwaters niet de maximale capaciteit beschikbaar

1.5.4. Niemand weet de precieze kwetsbaarheid, omdat er nooit een grondige faalkansanalyse van het netwerk uitgevoerd is.

1.5.4.1. Dit gaan wij uitvoeren binnen SWM

1.5.5. Er is geen absolute veiligheid
1.5.6. Als door uitstel vervanging gemaal IJmuiden minder gaat functioneren, heeft uiteindelijk iedereen er last van
1.5.7. Bij een zeespiegelstijging kan de opvoerhoogte van de pompen te hoog worden, waardoor ze niet meer kunnen functioneren. Dan ligt de afvoer stil
  1.5.7.1. In oktober 2014 kwam dit voor bij springtij. Doordat er van te voren op geanticipeerd was, werd het geen crisis situatie
1.5.8. De veiligheid van het netwerk zal op termijn afnemen door zeespiegelstijging, meer neerslag, meet afvoer, meer stedelijk gebied. Dit zorgt dat er eerder maalstops komen. Dit is wat niemand wilt, want dan lopen letterlijk de polders onder water, waar hele woonwijken staan.
  1.5.8.1. Voor gemaal IJmuiden betekent extremere situaties meer onderhoud. De vraag is hoe hier in de toekomst mee om te gaan
1.5.9. Lokaal vallen er wel eens buien die de statistieken te boven gaan (juli 2014, 140 mm). Hier kan niet tegen gedimensioneerd worden. Er kan lokaal dan overlast optreden, maar dit nivelleert in het systeem. Als zo'n bui over heel het netwerk valt, heb je een heel groot probleem
1.5.10. Door de buien met extreme piekniveau 's die lokaal veel overlast veroorzaken, wordt er veel onderzoek gedaan het gedrag van water op microniveau
1.5.11. Stroomstoringen kunnen ook vervelend zijn. De hoofdkantoren hebben vaak wel noodstroom, maar de kleine pompen en locaties niet. Als deze communicatie wegvalt, ben je afhankelijk van de persoon die daar op dan moment aanwezig is
1.5.12. Het netwerk is nog teveel afhankelijk van personen. In crisissituaties bellen de praktijkmensen elkaar, maar dat gaat niet aan de hand van protocollen. Zij kunnen met ziekte, vakantie of reorganisaties hun kennis meenemen. Daarnaast kan dit discussies veroorzaken. Dit komt deels doordat akkoorden en de protocollen niet alles meenemen. SWM moet dit veranderen
  1.5.12.1. Voorbeeld was onenigheid van het inzetten van Noordersluis om preventief te spuien. Deze werd nog voor scheepvaart gebruikt, omdat deze functie nog voorrang had

2. Actoren in het netwerk

2.1. <u>Uitvoerende organisaties (beheerders)</u>
2.1.1. RWS: Uitvoeringsorganisatie van het I&M
  2.1.1.1. RWS regio West Nederland Noord
    2.1.1.1.1. Beheer en onderhoud NZK incl. sluizen en gemaal bij IJmuiden en sluizen bij Schellingwoude
    2.1.1.1.2. Trekkersrol voor van nieuwe initiatieven gaat voornamelijk via de beheerder. Ook landelijke programma's doen dit vaak via de beheerder
    2.1.1.1.3. Belang: Kosten energie verbruik gemaal speelt een belangrijke rol
      2.1.1.1.3.1. Alles wordt gestuurd op zoveel mogelijk spuien, bemalen is bijna uit den boze
    2.1.1.1.4. Het is in het belang van RWS om een alternatieve oplossing/uitstel voor vervanging gemaal IJmuiden te vinden
    2.1.1.1.5. Neemt soms contact op met AGV of gemaal Zeeburg aan kan

2.1.1.1.6. Direct contact met scheepvaart en drinkwaterbedrijven, maar minder met de burger. Op deze manier speelt energie beperking een grotere rol dan schade beperken in hun afweging

2.1.1.2. RWS regio Midden Nederland

2.1.1.2.1. Beheer en onderhoud ARK incl. sluizen en gemalen bij de rivieren, en Markermeer en IJsselmeer

2.1.2. Waterschappen: Regionale uitvoerders en deel beleidsontwikkeling vanwege inhoudelijke kennis

2.1.2.1.1. Bestuur waterschap bestaat uit de Verenigde Vergadering, met wethouders, een dijkgraaf en hoogheemraden. Hier zijn ook de agrariërs in vertegenwoordigd.

2.1.2.2. Hoogheemraadschap van Rijnland

2.1.2.2.1. Belangrijkste factor zijn faalrisico's, in kosten schade en slachtoffers

2.1.2.2.2. Belang: beperken van verzilting. Zowel door zoutindringing als door verzilting vanuit dieptepolders

2.1.2.2.3. Afhankelijkheid van lozing op het NZK groeit bij extreme weersomstandigheden, dan zijn de uitslagpunten naar NZK heel hard nodig (zie 1.4.3.)

2.1.2.2.4. Belang bij tegengaan wateroverlast, grote schade treed op door hoogwaardige teelt (3 greenports)

2.1.2.2.4.1. In 1998 200 miljoen schade in Delfland

2.1.2.2.4.2. Maalbeperkingen zijn erg vervelend, al hebben ze nog niet tot rampen geleid

2.1.2.2.5. Speelt geen energie issue

2.1.2.2.6. Heel direct contact met de burger. Schade raakt mensen, ondernemingen kunnen failliet gaan

2.1.2.2.7. Beheergrens overschrijdend werk moet te verantwoorden zijn (wat levert het ons op?)

2.1.2.2.8. Door verkiezingsbeloften hebben we minder geld te besteden, en moeten we doelmatiger te werk gaan

2.1.2.3. Hoogheemraadschap Hollands Noorderkwartier

2.1.2.3.1. Niet afhankelijk van NZK voor water aanvoer, gaat via IJsselmeer en Markermeer. NZK is te zout

2.1.2.3.2. Gedeeltelijk afhankelijk voor afvoer naar NZK, alleen voor het beperkt gedeelte van het systeem. Belang bij een goed werkend gemaal IJmuiden

2.1.2.3.3. Met de aanleg van een extra gemaal, is het systeem in balans en om de opgave zo klein mogelijk te houden. Het wegvallen van Zaandam verstoord deze balans, zo kan de opgave heel groot worden

2.1.2.4. Waternet

2.1.2.4.1. Uitvoerende organisatie van AGV: veiligheid, waterbeheer, afvalwater, etc.. Waternet neemt ook taken van gemeente Amsterdam waar: Riolering, grondwater, heemwater, drinkwater, het hele vaarwegbeheer, delta, vissen

2.1.2.4.2. AGV zelf bestaat nog enkel uit het bestuur. Amsterdam heeft een verantwoordelijk wethouder, maar in de praktijk delegeert hij een hoop taken naar de directeur van Waternet
2.1.2.4.3. Verschillende belangen binnen het eigen systeem
2.1.2.4.3.1. Het gebeurt wel eens dat belangen van AGV en Amsterdam tegenstrijdig zijn, binnen Waternet zijn er daarom weinig tot geen mensen die in een spagaat van functies zitten. Bij moeilijke zaken beslissen de wethouder en bestuur
2.1.2.4.3.2. Normaal is er zoetwater nodig, maar in sommige situaties wil je het kwijt. Er is altijd genoeg water, alleen is de vraag of er in droge situaties genoeg water is van goeie kwaliteit
2.1.2.4.4. Zit direct aangesloten op het ARK. Meest afhankelijk van IJmuiden. Wat bij IJmuiden geloosd wordt staat niet in verhouding met wat Zeeburg aan kan. Grote aanjager om de situatie beter te krijgen
2.1.2.4.5. Kan volledig afgesloten worden van ARK, maar dan hebben ze nog een kleine afvoer richting het IJmeer
2.1.2.4.6. In geval van nood kan het gemaal bij Zeeburg aan
2.1.2.4.6.1. Hoge kosten voor energie
2.1.2.4.6.2. Gebeurde in 2013, toen NZK/ARM te hoog lag
2.1.2.4.7. Kan voor AGV veel winst worden behaalt bij HHNK en Rijnland, omdat zij NZK kunnen ontlasten door ergens anders te lozen.
2.1.2.4.8. Deel afhankelijk van het peil van het IJmeer, aangezien AGV onder vrij verval water kan lozen bij laag water. Een pomp daar neerzetten is een hele grote investering
2.1.2.4.9. Veel problemen met de bewoners van de Hoep over het inzet van het gebied als calamiteiten berging. Zij verzetten zich ertegen, omdat er een risico is dat zei materiële schade leiden: vee of dure auto's in de kelder. Maatregelen zijn erg kostbaar en er is een risico tot rechtszaken
2.1.2.4.10. Problemen met bewoners van de Horstermeer polder, die hebben zich zelf al eens uitgeroepen tot onafhankelijke republiek. Er wonen daarnaast mensen van de media die op die manier actie afdwingen
2.1.2.5. Hoogheemraadschap De Stichtse Rijnlanden
2.1.2.5.1. Zit direct aangesloten op het ARK. Sterke afhankelijkheid.
2.1.2.5.2. In extreme situaties afhankelijk van afvoer naar Rijnland
2.2. <u>Controlerende organisaties</u>
2.2.1. Ministerie I&M
2.2.1.1. Stelt normeringen HWS en HVS
2.2.1.2. Gaat over zaken buiten vastgestelde beleidskaders (toedienen van extra budgetten)
2.2.2. Provincies
2.2.2.1. Stelt normeringen, maar vanwege gebrekkige expertise gebeurt dit in nauwe samenwerking met de uitvoerder.

2.2.2.1.1. Verordening definieert naar landgebruik: 1/10 bij weiland, 25 bij akkerbouw, 1/100 bij stedelijk

2.2.2.2. Belang: goed vestigingsklimaat voor burgers en organisaties. Een gebied dat telkens onder water staat is economisch niet aantrekkelijk en voelen mensen zich niet veilig

2.2.2.3. Toezicht op regionale keringen

2.2.2.4. Beslist uiteindelijk over de inzet van calamiteitenberging: commissaris van de Koning

2.2.2.5. Noord-Holland, Zuid-Holland, Utrecht

2.2.2.5.1. Soms meerdere provincies per waterschap, dit is wel goed verdeelt, zodat er altijd maar 1 penvoerder is

2.3. Invloedrijke stakeholders

2.3.1. Beroepsvaart

2.3.1.1. Belangen worden deels door RWS behartigt, met het hoofdvaarwegennet

2.3.2. Gemeentes

2.3.2.1. Beginnen zich vaak te roeren als er cameraploegen in hun gebied staan

2.3.3. Gemeente Amsterdam

2.3.3.1. Belang bij laag water, kan paal-rot voorkomen. Onbekend hoe snel dit gaat

2.3.3.2. Riolering is aangesloten op het waterpeil. Is nu (nog) geen probleem. Bij -0,15 overstroomd het riool

2.3.3.3. Zeer veel invloed gehad op de komst van de nieuwe zeesluis

2.3.3.4. Gemeente Amsterdam zit samen met AGV in Waternet, zij kunnen Amsterdam afkoppelen van het NZK/ARK bij hoog water. Waternet regelt voor gemeente Amsterdam: Riolering, grondwater, heemwater, drinkwater, het hele vaarwegbeheer, delta, vissen

2.3.4. Industrie

2.3.4.1. Laag belang wat betreft water inlaat

2.3.4.2. Grote bandbreedte wat betreft peil

2.3.4.3. Grote delen buitendijks, kunnen last krijgen van overstromingen

2.3.4.3.1. Westpoort industriegebied

2.3.5. Landbouw

2.3.5.1. Directe invloed van te natte of te droge gewassen

2.3.5.2. Greenports in Rijnlanden die zeer gevoelig zijn voor wateroverlast. Hoogwaardige landbouw zit voor een groot gedeelten, gaat om honderden miljoenen omzet

2.3.5.3. Omdat ze direct belang hebben, kunnen ze de pers inschakelen

2.3.6. Natuur en milieuorganisaties

2.3.6.1. Zijn instaat projecten ernstig te vertragen

2.3.6.2. Zijn heel scherp op waterkwaliteit

2.3.7. Burgers

2.3.7.1. Belang bij kunstwerken is vaak laag. Bij dijkversterkingen komen ze eerder in actie en vormen ze belangengroepen

2.3.7.2. Als democratisch gekozen organisatie zijn “ingelanden” van groot belang voor waterschappen, RWS staat minder dicht op de burger

2.3.7.3. In de Hoep (AGV) blokkeren de bewoners faciliteiten om het gebied als calamiteitenberging in te zetten

2.3.8. Media

2.3.8.1. Rampen die in de media komen zorgen voor irrationele beslissingen. (zie 4.6.1.)

2.3.8.2. Als de media er bovenop springt wordt je bijna gedwongen tot beslissingen die inhoudelijk niet moet doen. Ze zijn instaat een beslissing teweeg te brengen

2.4. Minder invloedrijke stakeholders

2.4.1. Bij veel stakeholders staat water niet op de agenda omdat het goed geregeld is. We wonen in een veilig land, er is altijd water en we hoeven ons niet druk te maken als er een stormpje komt. Water is niet echt een onderwerp

2.4.2. Rondvaart sector Amsterdam

2.4.2.1. Grote afhankelijkheid van het waterpeil

2.4.2.2. Kunnen bij hoog water nauwelijks varen

2.4.3. Bij crisis situaties spelen veiligheidsregio's een rol: politie, ambulance en brandweer

3. Handelingsperspectief

3.1. Object gericht

3.1.1. Vervanging kunstwerk

3.1.2. Renoveren

3.1.2.1. Het is van belang te blijven investeren in je kunstwerken, met name de kunstwerken die enkel ik crisissituaties nodig zijn. Het gevaar is dat de aandacht verslapt en kennis en ervaring wegzakt

3.1.3. Uitbreiden

3.1.3.1. Mogelijk andere kunstwerken ontlasten

3.1.4. Achteruitgang accepteren

3.1.5. Goede faalkans analyse

3.1.5.1. Om de robuustheid van je kunstwerken te vergroten

3.2. Netwerk gericht

3.2.1. Beter afstemming van onderling beheer

3.2.1.1. "Laaghangend fruit"

3.2.1.2. Door betere afstemming tussen de verschillende beheerders kan je het netwerk een stuk kan verbeteren. Zonder grote ingreep kan je al grote stappen nemen

3.2.1.3. Wateroverlast kan in sommige gevallen verholpen worden door betere onderlinge afstemming

3.2.1.4. Voorbeeld is SWM

3.2.1.5. Valt winst te behalen bij anticiperend peilbeheer

3.2.1.5.1. Meeste winst in het geval IJmuiden, zit bij AGV en HDSR, minder bij Rijnland

3.2.1.5.2. Kost meer aan energie voor extra pompen, maar het vergroot de robuustheid van het netwerk

3.2.1.6. Verschillende afwegingen spelen een rol bij verschillende organisaties: kosten energie, of kosten schade accepteren

3.2.2. Draaiknoppen

3.2.2.1. Door begrip van de onderlinge samenhang, kan je zien met wel je ingreep je het netwerk kan optimaliseren

3.2.2.2. Draaiknoppen zijn niet persé grenzen van het netwerk

3.2.2.3. Mogelijkheid tot draaiknoppen toevoegen

3.2.2.3.1. Oranjesluizen kunnen alleen spuien, mogelijk een pomp erbij plaatsen

3.2.2.4. Aan de hand van een functie-eis kunnen knelpunten in het netwerk duidelijk worden, en waar je met zo min mogelijk moeite de prestatie van verbeteren

3.2.2.5. Meer afvoer richting IJmeer. Dit hangt alleen samen met de beslissing rond de Houtripdijk.

3.2.2.6. Afwateren tegen het systeem in richting de Lek. Alleen een serieuze optie als je er een mega-gemaal neerzet

3.2.2.7. Gemaal Zaandam ontlasten, door Monnikendam groter uit te voeren

3.2.3. Herzien peilnormering NZK/ARK (in peilbesluit)

3.2.3.1. Effect: Handelingsperspectief vergroten

3.2.3.2. Bespreekbare optie bij andere partijen

3.2.3.3. Komt voort uit gevoeligheidstest

3.2.3.4. Wordt bepaald door functionele einde levensduur

3.2.3.5. Met huidige interpretatie van de normering is de functionele levensduur ten einde

3.2.3.6. KBA & effecten analyse van verschillende normeringen

3.2.3.6.1. Iedere norm heeft zijn prijskaartje

3.2.3.6.2. “Regret” minimaliseren

3.2.4. Risico (faalkans en impact) reduceren

3.2.4.1. Als Waternet betere sluizen bij Amsterdam aanlegt, treden er al minder snel problemen op bij hoogwater

3.2.4.2. Dijken ophogen is geen optie, het is zaak binnen de bestaande marges te blijven. Een onderzoek wat een beveiliging van +0.10 de kosten voor dijkverstevigingen in de honderden miljoenen zou lopen, die snel zakken, omdat er meer gewicht op komt

3.2.4.3. Meerlaagse veiligheid

3.2.4.3.1. Actief met bedrijven praten over de risico’s van hun locatie en hoe maatregelen de impact kunnen verkleinen. Bijvoorbeeld dat het noodapparatuur niet in de kelder, maar op het dak staat. Vaak hebben ze geen idee dat ze buiten bedijkt gebied zitten

4. Besluitvormingsproces

4.1. <u>Belangrijke factoren voor aanstichting besluitvormingsproces</u>

4.1.1. Waterbeheer gebeurt aan de hand van kunstwerken

4.1.2. Eindelevens van kunstwerken komt inzicht, dan ga je kijken naar mogelijke handelingsperspectief

4.1.2.1. Goed startpunt vanwege de hoge investeringskosten. Het gaat voornamelijk om geld

4.1.2.2. Beton falen is één van de voornaamste oorzaken technische einde levensduur van een nat kunstwerk

4.1.3. (Landelijke) Programma’s voor een andere ruimtelijke ordening netwerk met budget kunnen veranderen buiten de vaste beheerbudgetten

- 4.1.3.1. Voorbeeld: nieuwe sluis bij Maaslandkering, die te bouwen vanwege nijpende situatie Dordrecht
- 4.1.3.2. Voorbeeld: Slim Watermanagement als onderdeel van het Deltaprogramma
- 4.1.3.3. Voorbeeld: nieuwe zoetwater aanvoer Goude (zie 4.3.3.)

4.1.4. Je moet ervoor blijven zorgen dat al je kunstwerken het netwerk aan zijn functie-eisen kunnen handhaven

4.2. Huidige gang van zaken

4.2.1. Technische einde levensduur voornaamste reden vervanging
- 4.2.1.1. Weinig vanuit functionaliteit geredeneerd

4.2.2. (Vaak) Te laat met ingrijpen
- 4.2.2.1. Spoedreparaties
- 4.2.2.2. Geen tijd voor alternatieven

4.2.3. Functionaliteit huidig netwerk wordt gebruikt als randvoorwaarde voor nieuwe interventies
- 4.2.3.1. Kan leiden tot Lock-ins
- 4.2.3.2. Terwijl eerste de nieuwe functionaliteit de randvoorwaarde vormde

4.2.4. Verschillende uitvoerders bepalen hun eigen handelingsperspectief. Niet altijd in samenspraak met andere beheerders
- 4.2.4.1. Het is niet geïnstitutionaliseerd dan verschillende beheerders met elkaar praten
- 4.2.4.2. Het is niet dat iedereen langs elkaar heen werkt, maar de integratie mag wel sterker
- 4.2.4.3. Beheerders weten vaak niet goed hoe het netwerk van hun buren werkt. Zowel in dagelijks beheer, als in crisis situaties. Dit gaat alleen via protocollen
- 4.2.4.4. Besluitvormingsproces is voornamelijk intern op de organisatie gericht
- 4.2.4.5. RWS stuurt op beperking energie, waterschappen op beperking schade, dit conflicteert nog wel eens
- 4.2.4.6. “Nederland kan heel goed polderen, maar Nederland kan ook geel goed niet polderen”

4.2.5. Strikte functiescheiding in projecten: met name in het verleden werden opdrachten sectoraal aangepakt.
- 4.2.5.1. Fysieke grens is niet het probleem van het netwerk, maar de grote variëteit aan functies, en soms wegen de belangen van de een zwaarder dan de ander
- 4.2.5.2. Sluis wordt gebouwd voor scheepvaart proces gebouwd, maar blijkt achteraf ook impact te hebben in het waterbeheer
- 4.2.5.3. Bij de besluitvorming rond het sluizencomplex in IJmuiden is er geen rekening gehouden mee gehouden dat de sluis onderdeel is van een groter netwerk
- 4.2.5.4. Moet altijd een milieu effecten rapportage gemaakt worden, maar er zijn grote twijfels over de effectiviteit van de maatregelen om zoutindringing te voorkomen bij het nieuwe sluizencomplex bij IJmuiden
- 4.2.5.5. Uitbaggeren van de sluizen, blijkt een negatieve invloed te hebben op de zoutindringing
  - 4.2.5.5.1. Uitbaggeren van de Rotterdamse havens is een voorbeeld

4.2.5.6. Ongewenste effecten komen steeds minder voor, omdat de waterschappen tegenwoordig qua grote zijn ingedeeld op stromingsgebied

4.2.5.7. Verwijderden van een drempel in het ARK bleek onverwacht negatieve invloed te hebben op de zoutindringing, vanwege snellere stroomsnelheid

4.2.6. Handelingsperspectief is met name objectgericht

4.2.6.1. Risico dat je bijvoorbeeld een gemaal onder dimensioneert, omdat je de groei van andere regio's niet mee hebt genomen

4.2.6.2. Als wij een groot gemaal bouwen zit iedereen eraan vast

4.2.6.3. Per kunstwerk is er vaak een protocol en instandhoudingsplan, deze is niet afgestemd met andere kunstwerken, terwijl hier een meerwaarde te halen is. Voorbeeld van een serie sluizen

4.2.7. Kennis zit beperkte hoeveelheid personen. Door het (tijdelijk) uitvallen van deze personen kunnen er verkeerde keuzes gemaakt worden

4.2.8. Onderling wordt het veel informeel opgelost, een draaiboek zegt weinig

4.2.8.1. Typisch is wanneer iemand weggaat z'n vervanger dan aan de hand van het draaiboek gaat doen

4.3. <u>Netwerk benadering</u>

4.3.1. Belangrijke redenen voor een netwerk benadering

4.3.1.1. Grote onderlinge verwevenheid netwerk

4.3.1.2. Meenemen functionele context netwerk

4.3.1.2.1. Negatieve bijeffecten voorkomen

4.3.1.3. Meekoppelen belangen en investeringen van derden

4.3.1.3.1. Zitten vooral op uitvoeringprojecten op object niveau. Op strategisch niveau komt dit niet voor

4.3.1.3.2. Soms schieten de plannen te ver door, zoals de aanleg van jachthavens koppelen, dit vertraagd dan alleen maar en gaat te ver af van het probleem

4.3.1.4. Investering in één regio, heeft mogelijk een andere beheerder baat bij

4.3.1.5. Druk voor maatschappelijk optimale investeringen

4.3.1.6. Meerwaarde om budgetten te klusteren lijkt evident

4.3.1.7. Vergemakkelijkt: niet constant bij elke ingreep uit hoeven te zoeken hoe het netwerk samenhangt

4.3.1.8. Een netwerk kan je nooit op de schop nemen door telkens object gericht aanpassingen te doen (zie 4.2.4.)

4.3.1.9. Overlast is vaak lokaal, dit kan het netwerk mogelijk elders opvangen. Een bui valt niet overal

4.3.1.10. Verminderen afhankelijkheid van personen, die met ziekte of reorganisaties hun kennis meenemen

4.3.1.11. Infrastructuur is een harde randvoorwaarde, omdat de levensduur 50 tot 100 jaar is, en uitvoering als gauw 4-5 jaar duurt, met alle overlast. Je wilt dus goed scherp hebben waarvoor je het maakt

4.3.2. Belangrijke factoren voor succes

4.3.2.1. Gedegen actuele kennis areaal

4.3.2.1.1. Stap 1 is kennis uitwisselen

4.3.2.1.2. Duidelijke (specifieke) normstelling

4.3.2.1.2.1. Kan door betere kennis prestaties objecten

4.3.2.1.2.2. Belangrijk voor prestatiesturing

4.3.2.1.2.3. Voor het vaststellen van knelpunten en draaiknoppen

4.3.2.1.3. Kennis van de systemen van je buren en hun handelen

4.3.2.1.3.1. Organisaties moeten hun data openstellen

4.3.2.1.3.2. Soms is data, bijvoorbeeld faalkansmechanismen, moeilijk in beeld te krijgen

4.3.2.1.3.3. Het volstaat niet alleen met kennis uitwisselen, maar ook met lijfelijk contact. Op die manier kan je elkaar tips geven

4.3.2.1.4. Faalkansenboom op systeemniveau, voor de knelpunten

4.3.2.1.5. Alle actoren moeten een meerwaarde zien

4.3.2.2. Tijdig voorzien van problemen

4.3.2.2.1. Falende objecten dwingen je tot ongeplande ingrepen

4.3.2.2.2. Voorkomen dat de grenzen bereikt worden, niet alleen handelen als het al fout gaat.

4.3.2.3. Gezamenlijk toekomstbeeld opstellen, mogelijk met scenario's

4.3.2.3.1. Dit kan vergemakkelijkt worden wanneer er een faalkans analyse op netwerk niveau uitgevoerd wordt. Hier komt een getal uit als 1/60 of 1/100. Vervolgens moet de partijen onderling akkoord gaan met dit veiligheidsniveau.

4.3.2.3.2. Een goede faalkans analyse staat of valt bij de aanpak. Het moet niet te uitgebreid worden dat je verzuipt in de data. Goed is om eerste te brainstormen met experts

4.3.2.4. Gezamenlijk handelingsperspectief opstellen, ook met budgettering, anders val je alsnog terug op het object

4.3.2.4.1. Operationele afwegingen over bestuur grenzen heen doen. Dit is niet alleen een technisch verhaal

4.3.2.4.2. De vraag is of bij de netwerkbenadering ten behoeve van de uitstel van de vervanging van gemaal IJmuiden, heel het netwerk gebaat is, of alleen RWS

4.3.2.5. Op de hoogte zijn van reeds geplande veranderingen

4.3.2.5.1. Goede koppeling tussen korte termijn en lange termijn is nodig

4.3.2.6. Alle bestuurslagen moeten betrokken zijn, want in iedere laag kan er belemmerd worden. Daarnaast heeft iedereen een deel van de puzzel. Als je operationeel beheer niet meeneemt, bouw je een papieren werkelijkheid

4.3.3. Haalbaarheid

4.3.3.1. Visie van een klein aantal mensen van RWS en waterschappen, de uitdaging is om de hele organisatie erin mee te krijgen. Als het bestuur er niks in ziet, kunnen we net zo goed stoppen

4.3.3.2. Belangrijkste uitdaging is het coördineren van het besluitvormingsproces. Het vraagt organisaties om soms over hun eigen belang heen te stappen

4.3.3.3. Er zijn genoeg projecten in NL die met meerdere stakeholders opgezet worden, het is wat dat betreft haalbaar

4.3.3.3.1. Nieuwe zoetwater inlaat bij Gouda is een goed voorbeeld. Regionaal probleem gesteund door een landelijk programma met een financieringsstructuur (vanuit Deltaprogramma)

4.3.3.4. Uitkijken dat je als organisatie niet je pad te buiten gaat, daar kunnen mensen chagrijnig van worden. Binnen VONK was iedereen hier eigenlijk heel positief over

4.3.3.5. Het is een hele uitdaging om op tactisch niveau afspraken te maken tussen de verschillende organisaties

4.3.3.6. Droom is geen waterakkoorden meer, maar 1 grote gezamenlijke sturing waarin we regelen hoe we water verdelen in periodes van nat, droog en alles er tussen in. Deze droom gaan we waarmaken

4.3.3.7. Bij een netwerk aanpak in het netwerk, kan het zo zijn dat een waterschap lokaal mensen dupeert ter voorkomen van een groter probleem. Dit moet op zo'n moment wel ter plaatsen kunnen verantwoorden

4.3.4. Initiatieven

4.3.4.1. Slim Watermanagement is een voorbeeld van netwerk benadering

4.3.4.1.1. Met name nog een papieren exercitie

4.3.4.1.2. Het opnieuw bevragen het eigen voorzieningen niveau en deze afstemmen op andere organisaties hun voorzieningen niveau, zit niet in SWM. Dit is om het behapbaar te houden

4.3.4.1.3. Geslaagd voorbeeld van SWM is in Brabant. Daar zijn verschillende organisaties met elkaar een kanaal ook als boezem gaan gebruiken. Is bottom-up geboren. Zo merk je dat je netwerken beter kan benutten

4.3.4.1.4. Manier om zo goed en zo lang mogelijk het netwerk te benutten

4.3.4.1.5. Een van de doelen is het netwerk minder afhankelijk te maken van personen

4.3.4.1.6. Voor SWM wordt de faalkans analyse uitgevoerd

4.3.4.2. Open-boezem-open-data is een proef wat betreft informatie uitwisselen

4.3.4.3. Aan de hand van gezamenlijke beheerdersscenario's worden nu gezamenlijk protocollen gemaakt hoe netwerk breed geanticipeerd wordt

4.4. <u>Bestuurlijke dilemma's</u>

4.4.1. Investering in één regio, heeft mogelijk een andere beheerder baat bij

4.4.1.1. Mogelijke financiële verevening is moeilijk ergens op de baseren, aangezien niet alles monetair is

4.4.1.2. Als een partij mee investeert in een andere regio, wilt deze wel deels zeggenschap over het beheer

4.4.1.3. Het is lastig een organisatie te vragen om schade te accepteren voor de kansen van een andere organisatie

4.4.1.4. Wordt erg makkelijk gepraat over dat andere partijen wel schade kunnen accepteren, zodat de ander zijn kosten kan drukken. "Dan zet je toch wat polders blank"

4.4.1.5. Bij vergroten van het gemaal van Monnikendam wilt HHNK deze wel betaalt zien door partijen die daarvan profiteren

4.4.2. Institutionele scheiding

4.4.2.1. Eigen beleidsopdrachten

4.4.2.2. Eigen politiek mandaat

4.4.2.3. Eigen besturen

4.4.2.4. Eigen geld

4.4.2.5. Eigen cultuur
4.4.2.5.1. Kosten energie vs. voorkomen van schade. Verschillende aansturingsmechanismen van beslissingen
4.4.3. Verschillende belangen
4.4.3.1. Belangen cruiseschepen zijn groter dat het zout dat binnen komt
4.4.3.2. Soms in het ene belang groter dan de ander. “Nederland kan heel goed polderen, maar Nederland kan ook geel goed niet polderen”
4.4.3.3. Bij de bouw van het nieuwe sluizencomplex is er gefocust op economie, maar niet naar andere functies in het waternetwerk
4.4.4. Bestaansrecht van organisaties
4.4.4.1. Politiek bestuurlijke organisaties bestaan bij de gratie dat ze verantwoordelijkheid hebben. Om die reden zouden ze centralisatie tegen kunnen werken
4.4.4.2. Jaren geleden waren Waterschappen Calimero en Rijkswaterstaat groot. Nu zijn waterschappen groter geworden en gezamenlijke gesprekspartners.
4.4.5. Onderlinge afhankelijkheid
4.4.5.1. Regionale beheerders zijn afhankelijk van het functioneren van het hoofdwatersysteem
4.4.5.1.1. De belangrijkste draaiknop van AGV, gemaal IJmuiden, kunnen zij zelf niet bedienen
4.4.5.2. RWS is voor alternatieve oplossingen afhankelijk van regionale beheerders
4.4.5.3. Regionale beheerders zijn afhankelijk van elkaar wanneer er ergens geconcentreerd een bui valt. Als de een minder loost, kan de ander verlicht worden
4.4.6. Optimale functies sluiten elkaar uit
4.4.6.1. Betere doorvoer door snellere schuttingen en uitgediepte kanalen, zorgt voor een grote zoutindringing. Economische ingrepen in het systeem, verzwaren de zoutbelasting. Om 1 druppel zout weg te werken heb je 10 miljoen druppels zoetwater nodig. Dit moet ergens vandaan komen. Dit komt met name omdat ze een oude sluis neerleggen
4.4.6.2. Preventief spuien met sluizen maakt scheepvaart onmogelijk
4.4.6.3. Groot gedeelte van de tijd gaan de functies prima samen
4.4.7. Wantrouwen
4.4.7.1. Sommige organisaties willen hebben moeite met informatie delen vanwege angst dat de burger of organisaties dit kunnen misbruiken, bijvoorbeeld rechtszaken starten
4.4.7.2. Curieus als een organisatie die zijn eigen netwerk niet goed kent, heel gemakkelijk doet als een ander schade accepteert
4.4.7.3. Soms zie ik collega’s een sommetje uitgevoerd door RWS overdoen
4.4.7.4. In het verleden zijn er vaak dingen besloten met onvoldoende aandacht daar de context, waarvan achteraf wordt afgevraagd of het de juiste beslissing was. Maatregels worden daarom tegenwoordig met argwaan bekeken. Er wordt bijvoorbeeld heel scherp gekeken naar de nieuwe zeesluis

4.4.7.5. De vraag is of de onderlinge afspraken tussen waterschappen nog nageleefd worden wanneer de media zich ermee bemoeien. Als je de commotie ziet bij overlast, dan worden waterschappen soms afgeslacht.

4.5. <u>Externe factoren</u>

4.5.1. Politieke besluiten

4.5.1.1. Leidend voor uitvoerende organisaties

4.5.1.2. Mogelijk eerdere ingrijpen dan technisch noodzakelijk

4.5.1.2.1. Nieuwe sluizen IJmuiden

4.5.1.3. Lange termijn investeringen/programma's zijn leidend

4.5.1.4. Keuzen op basis van emotionele overwegingen wanneer er iets misgaat (irrationeel)

4.5.1.4.1. Kockengen worden nu achterlijke ingrepen gedaan door media aandacht bij zandzakken leggen

4.5.1.4.2. Aanleg gemaal in provincie Groningen, die niet nodig is, maar vanwege een kleine evacuatie er toch kom

4.5.1.5. Economisch gedreven besluiten, zoals het aanleg van een sluis of uitdiepen van een kanaal, kunnen negatieve gevolgen hebben op het netwerk. In geval van IJmuiden, met name omdat ze een ouderwetse sluis neerleggen, en niet een state-of-the-art sluis die zout buiten laat

4.5.1.6. Gemeente kan een bestemmingsplan voor bijvoorbeeld het vergroten van een gemaal afkeuren

4.5.2. Investeringen externe partijen

4.5.2.1. Marktpartijen

4.5.2.2. Europese fondsen

4.5.3. Tijd (timing)

4.5.3.1. Procedureel is tijd een factor binnen een politieke doelstelling. Deze is mogelijk lastiger te behalen met een netwerkaanpak. Dit is een risico

4.5.3.2. Niet tijdig zien van falende objecten dwingt je tot a la minuut oplossingen. Tijd is een harde randvoorwaarde

4.5.4. Economische ontwikkelingen

4.5.4.1. Crisis zijn van grote invloed op de infrasector

4.5.5. Media

4.5.5.1. Hoogwaardige agrarische sector zoekt nog wel eens de pers op om invloed uit te oefenen op waterschappen

4.5.5.2. Rampen die in de media komen zorgen voor irrationele beslissingen. (zie 4.6.1.)

4.5.5.3. Als de media er bovenop springt wordt je bijna gedwongen tot beslissingen die inhoudelijk niet moet doen. Vooral de verantwoordelijke ter plekke, hij kan dan moeilijk rationeel uitleggen waarom je dingen wel of niet doet. Niemand kent het systeem en echt bereid om te luisteren zijn ze niet. Soms moet je op een plek mensen duperen, om elders een groter probleem te voorkomen, om dit publiekelijk te verdedigen moet je stevig in je schoenen staan

4.5.5.3.1. Voorbeeld Horstermeer polder: In juli 2014 stond in AGV hoogwater. . In Hostermeer was de toestand minder kritiek dan andere gebieden, maar door aanwezigheid van media (toevallige bewoners) die veel heisa maakte, voelde het waterschap zich gedwongen er noodpompen neer te leggen.

Dat terwijl zo'n pomp nauwelijks zoden aan de dijk zet, het is enkel om te laten zien dat er wordt ingegrepen en om mensen gerust te stellen.

4.5.5.3.2. Bij de problemen bij Kockengen werd het waterschap in de media afgeslacht. Deze problemen hadden verzacht of voorkomen kunnen worden door RWS. In plaats daarvan worden nu onnodige maatregelen lokaal genomen

4.5.5.3.3. Groningen heeft door een kleine evacuatie in 2012 een nieuw gemaal aangelegd. Een twijfelachtig besluit

Appendix F: Complete empirical analysis of the case study

Most references in this chapter are a numeral code. This code refers to the discussed subject of statement made in the interview, which corresponds with the code in Appendix E: Coding of the case study interviews. To make a distinction between the comments that follow from the interviews and the interpretation in this research, the comments of the interviewees are written in *italic*. Since the interviews were confidential the comments are anonymous. Only when relevant, it will be mentioned if the comment was given by an interviewee of one of the waterboards or RWS. At the start of every paragraph the fragment of the theoretical framework which will be discussed will be shown, in order to clarify which part of the theoretical framework the paragraph is about.

Scope & understanding

Network definition

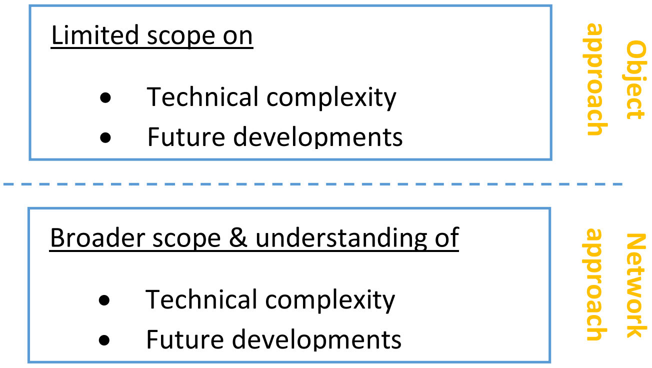


Figure 33 Theoretical framework: scope & understanding (own illustration)

All actors that are interviewed determined that the *borders of the functional network are from the Afsluitdijk, to the Princes Ireneluis and the Princes Beatrixsluis and to the pumping station complex at IJmuiden (1.3.4.; 1.3.3.)*. By the means of a map of the main waterways in The Netherlands, the interviewees pointed out what the network of the case situation was. The map that is used can be seen in the interview set-up in Appendix D: Interview set-up of the case study. The determination of the network of all interviewees corresponded. It can be state that, within the different organisations, people have the same scope of the network border of the case situation. It is widely known by which different regional HCS the regions are interconnected. This unilateral definition of the network probably originates from the Waterakkoord agreed upon in the case network. The Waterakkoord of 2013 already describes the functional cohesion of the network (Beuse, 2013).

Technical complexity

All interviewees show a basic understanding of the technical complexity of the network. Nonetheless, the interviewees do not comprehend the technical complexity of the network in-depth. Within none of the interviewed organisations it is even known what the exact impact is of the wicked effects in their own region. In both the Main Water System, as well as in the regional systems, water management is performed by anticipating measures on the water level. *The ability to control the targeted water level, is leading for the dimensioning of the HCS (1.2.2.1.2.2.). There is no flood risk involved in the Peilbesluit (1.2.2.1.3.4.3.), because a complete risk analysis of the network has never been performed.* None of the interviewees knows *the exact vulnerability and potential damages in their system (1.5.4.; 1.4.3.6.2.).* The water level can rise above the targeted level, without causing any problems. The moment on which damages will occur, is disputed. All actors are willing to take and perform an *in-depth risk analysis of the network (1.5.4)*.

Both at RWS and the waterboards, it is not known how the current water levels are established. *The exact consideration on which the water levels are decided upon is not clear, but it is believed to be mainly based on expertise (1.4.1.2.4.).* This course of events is defended with the remark that *often after calculation, the old estimations turn out to be not far off (1.4.3.6.3.)*. So, the water level is maintained, but the reason why it has to be this specific water level is unknown. This makes operation rather meaningless. As one of the interviewees puts it: *"There is no such thing as performance management, without knowing the risk"* (1.2.2.1.2.4.3.).

Not only is the risk unclear, *the exact performance of the pumping station at IJmuiden is also unknown. The pumping station does not meet its designed performance of 260 m^3/s. Network calculations show that there is a margin of error of 20% on the water that under normal situations enters and leaves the system. About 50 m^3/s of water "disappears" from the network (1.4.1.4.1.1.).* It is believed capacity of the pumping station is overestimated. Additionally, *with higher elevations the capacity of the pumping station supposedly decreases. The exact impact of different water levels on the pumping capacity is also unknown (1.4.1.4.1.2.).* This is the responsibility of RWS. So, in this way the water level is the only controlling mechanism that RWS has to operate their pumping station. The waterboards are not amused by lack of understanding. One interviewee called it "cobbled-together work".

Misunderstandings

This basic understanding of the complexity of the network, does not go further than the knowledge on how the different regions are connected to each other. *The different managers in the network do not know how the regional system of their neighbour works (4.2.4.3.).* As a consequence, there are misunderstandings between RWS and the waterboards. When talking about the risks of water level rise in the NZK/ARK, the interviewees of RWS talk about the impact on the areas adjacent to the NZK/ARK *(1.4.1.3.2.)*. One interviewee of RWS for instance mentions that *the NZK/ARK can handle a lot more water when AVG installs better locks to close of Amsterdam (3.2.4.1.).* Waterboards on the other hand hardly mention the risk of the flooding of the NZK/ARK area. They mainly talk about the effects of discharge limitations and stops for their own region. They are unanimous about how drastically this impacts their regional system. Discharge stops have never taken place, but limitations have. Discharged limitation are seen as *annoying and unwanted, but most of the time the waterboards are able to prevent flooding (2.1.3.3.4.2.). In July 2014 it went wrong for HDSR, the region of Kockengen flooded, causing a lot of damages (4.5.5.3.2.). The waterboards fear that in the future more discharge limitations and even discharge stops might take place. They foresee that this can cause many regional floods (1.5.2./1.5.8.).*

Consideration of complexity in the operational layer

In the operational layer, there are agreements and protocols in the Waterakkoord between all water managers in the network, on how they should act it in certain situations. The impact of the flood in Kockengen could have been limited if anticipating measures were taken elsewhere within the network. However, RWS followed the protocols and these *do not include anticipating measures (1.2.2.1.3.3.). This leaves a grey area in the decision making (1.2.1.1.3.). The different water managers have different principles (4.4.2.5.1.). There are different opinions between RWS and the waterboards about preventative discharge through locks (1.5.12.1). RWS opposes this, because preventative discharge through locks limits shipping transport, while the waterboards want it (4.4.6.2.).* According to them, *too often the response to problems is too late (4.2.2.). It is important to act before the performance boundary is reached (4.3.2.2.).* The interviewees from the waterboards seem irate about the *easy talk about accepting floods in regional systems (4.4.1.4.)* by RWS. One interviewee cynically mentions, "an easy *demand for an organisation that does not know how its own system works" (4.4.7.2.).* However, one interviewee of a waterboard does acknowledge that RWS was not the only actor who could have helped Kockengen in 2014, but that the other *waterboards could also have helped (4.4.5.3.). Every waterboard has its own protocol, but these protocols of the different systems are not aligned (4.3.4.3.).*

It must be stated that *most of the times the different functions work perfectly next to each other in the network (4.4.6.3.)*. Issues only occur during critical times, but also then the impact has been limited. *The network is vulnerable for coincidental events. The failure of IJmuiden and a discharge stop at*

Katwijk in combination with extreme rain events can have huge negative consequences (1.5.1.). Fortunately, this has never occurred and the probability of that two critical events coincide is extremely low.

In addition, it has to be stated, that the water managers *do not work past each other, but the integration can be improved (4.2.4.2).* In the operational layer, *the managers of the different organisation have a lot of informal contact beyond the protocol procedures (1.5.12.)* For instance; the operational manager of *RWS sometimes contacts the operational manager of Waternet with the request to turn on their pumping station at Zeeburg at high water levels in the NZK/ARK (2.1.1.1.5.).* This has as a consequence that the scope of the complexity of the network is depended on which operational manager is present. *Since all kind of agreements between the managers of the different systems are not formalized, problems can occur when these people are not there (4.2.7/4.2.8.).*

Consideration of complexity in the other layers

In the operational layer there is alignment between the organisations in the network, based on the HCS connecting the network. The organisations are actively improving the mutual coordination. They lack in-depth understanding of the network complexity, but the organisations are aware of this and are working on improving it (4.3.4.). In a tactical or strategic layer however, there are no signs of a network scope. *The decision making about interventions is primarily focussed on internal goals (4.2.4.4./2.1.2.3.3.).* Recently a new pumping station was built at Katwijk for the region of HRL and another pumping station is planned to be completed in 2015 at Schardam for the region of HHNK. In both instances *the extra pumping station was dimensioned in order to get the regional system in balance.* In this decision however, possible discharge limitations at IJmuiden are not taken into account. *During critical situations with high water levels, the regions are still depended on the discharge to NZK (2.1.2.3.3./1.4.3.2.4.2.)*. This is despite the fact that both of the new pumping stations provide the regional system with alternative discharge routes by discharging directly in the North Sea or IJsselmeer. Also it is mentioned, that the waterboards are still not able to unburden the NZK during critical times, which could be of help to other regional systems. With a bigger capacity at the new pumping stations, the regions might have become less depended on the discharge via the NZK and could have had more possibilities to help the other regions.

It remains unclear whether the network interdependencies were deliberately or unconsciously not considered. One remark of an interviewee suggests that it is possibly deliberate: *"The Netherlands is great at poldering, but also great at not poldering." (4.2.4.6.)* (**poldering** is a Dutch expression for working together and making compromises). However, through the project of VONK, negotiations take place between HHNK, RWS and other regional managers to make a larger design of another planned pumping station at Monnikendam (3.2.2.7.). This shows that also in a tactical layer there in an increasing understanding of the technical complexity of the network.

Future developments

For all interviewees, there is a high uncertainty about the impact of future developments on the network. They know *the risk of network failure will increase due to sea level rise, increase of rainfall, increasing water discharge, growth of urban areas and more discharge limitations (1.5.8.)* There are scenarios of changes that can take place in the future, only the exact impact of the different scenarios is not known. Furthermore, on the basis of the fact that none of the other organisations was aware of the construction plans of the other organisations until project VONK, it can be stated that the organisations have little knowledge of the future developing plans of the other organisations.

Action perspective

Problem shifting

The limited scope of the technical complexity has its impact on the action perspective. Both RWS and the waterboards admit that *in the past, most of the problems in the case situation were addressed function specific (4.2.5).* One interviewee mentions that *multiple times in the first instance, they believed to know all the effects of an intervention, but in hindsight the decision at that time proved doubtful, due to negative consequences. Accordingly, insufficient attention was spend on the functional context of the intervention (4.4.7.4.).* This is because, the limited perspective has caused the negative effects of problem shifting in the past. The waterboards name multiple examples of problem shifting that occurred after interventions in the case area. These examples are all about salinization, and therefore not part network definition of this case. In spite of this fact, these examples will be discussed in this paragraph, because they provide a proper image of how problem shifting takes place in practice.

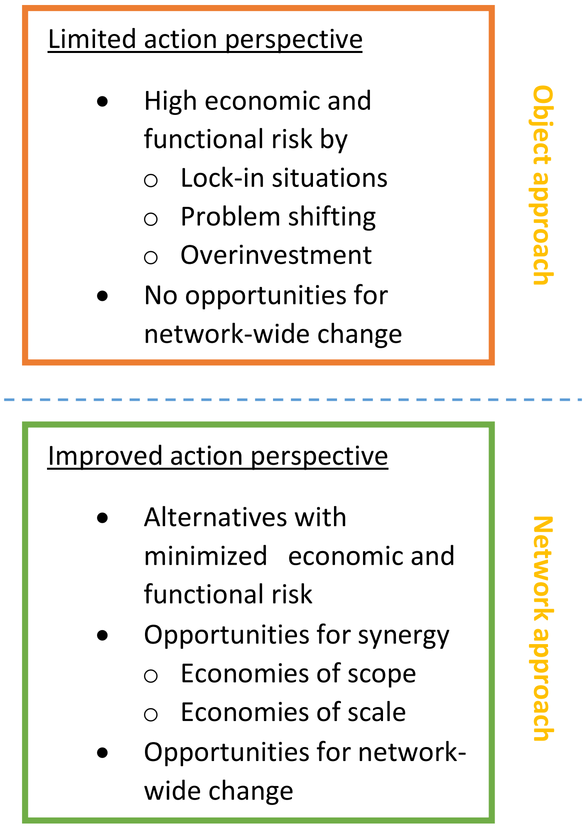


Figure 34 Theoretical framework: action perspective (own illustration)

In times of draught, salinization is the primary issue in the water resource management in coastal regions (see Appendix B: Introduction to water resource management). *Salt water is bad for the ecology, agriculture and in very high concentrations of salinization also life stock is affected (1.4.3.5.1.).* Especially interventions that are focussed on the improvement the shipping transport function, have had negative impacts on this salinization. *Dredging of the (sea) locks and canals (4.2.5.5.)* is one of these interventions. The dredging ensures that the ships can pass thought the canal without obstacles. However, in addition to the ships, the obstacles disappear for the salt wedge as well. The will reach further upstream, with all its consequences. This shows that an intervention that solves problems for one function, can create problems for another. Very clear was the negative *impact from the removal of lock fundaments in the ARK. Due to this intervention the water flow at the bottom increased, causing the salt wedge to reach further upstream (4.2.5.7.)*. This effect was not foreseen at the time that the decision was made.

According to the waterboards, *new interventions are viewed with suspicion, due to the mistakes that were made the past (4.4.7.4.).* There are for instance suspicions about the effects of the planned new sea lock at IJmuiden by RWS, because, according to an interviewee, *the planning of the new sea lock at IJmuiden is only done on the basis of economic considerations for the city and port of Amsterdam (1.2.3.1.1.2./2.3.3.3.).* Also the interviewees from RWS acknowledge that some interventions are still function specific. *Locks are built for the shipping process, but afterwards turn out to have impact on water resource management (4.2.5.2.).* Sea locks have a great impact on the salt intrusion. The planned new sea lock in IJmuiden is going the become the biggest lock in the world. Large amounts of fresh water might be needed to flush out the additional salt water. *If the NZK needs 20% more fresh water from the Ijsselmeer due to the new sea lock, 2/5 of The Netherlands that is depended on the same fresh water can feel the consequences (1.4.7.2.) It is not taken into account that the lock is part of a bigger network (4.2.5.3.)* RWS is responsible to limit the salt intrusion, but the lock design is criticized on this aspect. One interviewee of a waterboard states that *he does not understand why RWS chooses to design an old fashioned lock and not a state-of-the-art new lock, that can stop salt water intrusion (4.5.1.5.).* Another interviewee of a waterboard mentions that the design passed *the environmental impact assessment, but there are doubts about the effectivity of the activities that are supposed to reduce salinization (3.2.5.4.).*

Even though there are suspicions about the newly planned sea lock, the interviewees see problem shifting as a thing of the past. For instance, about the alignments of interventions between different waterboard, one interviewee states that *negative impacts are a declining phenomenon since waterboards have become larger and are segregated on the basis of the regional water catchment (4.2.5.6.).* Both an interviewee of RWS and a waterboard mention that with *a network scope negative effects can be prevented (4.3.1.2.1.)* With an increasing understanding of complexity of the effects, the probability on problem shifting will decline. Nonetheless, it can be a deliberate decision not to consider all complex effects, as the "poldering" remark of the Scope & understanding paragraph suggests.

Lock-in situation and missed opportunities in the tactical layer

Not only does problem shifting take place in the case situation, there are also signs of an increasing risk of a lock-in situation in the case. The increase of the risk of a lock-in situation is not explicitly discussed by the interviewees, but is based on an analysis of action perspectives discussed in the case and documentation research.

One of the outputs of the VONK study was an overview of the action perspective of the case situation. This overview is illustrated as FIGURE XX. The action perspective focusses on the alternatives to unburden or increase discharge capacity of the NZK/ARK. These possible actions were explorative, based on a pair of expert meetings and were only qualitatively substantiated. The different solutions vary from temporary regional water storage to alternative regional discharge routes (Tosserams, 2014). Within the study of TO2, the different alternatives were analysed and calculated on their feasibility. This study shows that temporary regional storage and most of the alternative regional discharge routes are technically not feasible. Just a few alternatives remain. What stand out is, that replacement of the regional pumping station at Katwijk is discussed as an alternative in the VONK study, but is found infeasible in the TO2 study. Not because extra discharge is technically infeasible, but because it is infeasible on institutional grounds. The pumping station and the canal are recently upgraded and it is not possible to upgrade the pumping station again, so shortly after a construction. This would be too big of an investment and cause again a lot of nuisance to the environment of the pumping station (Klerk, 2015).

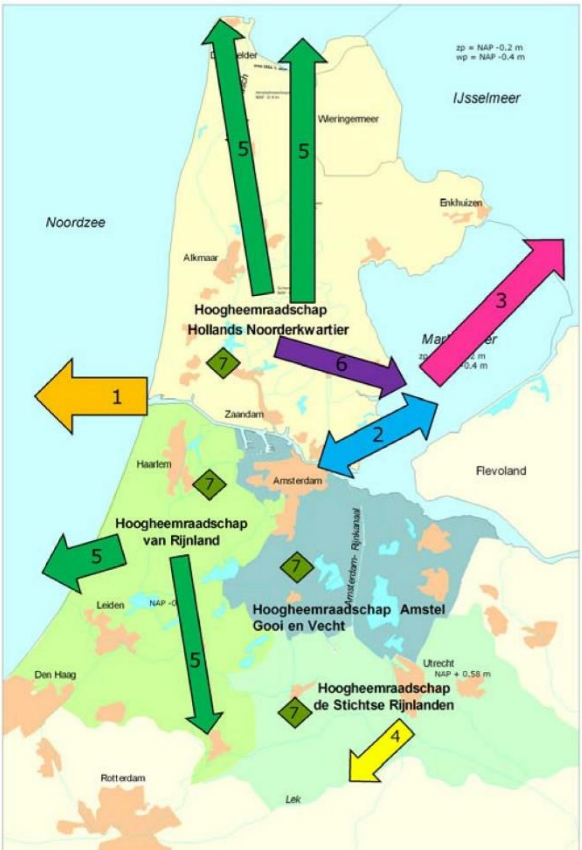


Figure 35 Action perspective according to VONK (Tosserams, 2014)

As already stated in the previous paragraph, an interviewee explained that *the capacity increase at Katwijk was needed as additional capacity for their own region and is not meant as extra capacity unburden to the NZK/ARK (1.4.3.10.).* It is not clear whether an increase of discharge limitations imposed by RWS was included in the design of the pumping capacity. *The interviewees of HRL mention that discharge limitations are unwanted, but have not let to problems in their region (2.1.2.2.4.2.).* Apart from this, the question arises whether the recent upgrade of the pumping station at Katwijk could have been designed with greater capacity? It seems that with additional capacity at Katwijk, HRL would have been less depended on the discharge at the NZK and the waterboard would have had the possibility to help other regions during critical situations. But, this opportunity is not utilized and is therefore lost. Be that as is may, Katwijk can never be an alternative discharge route for IJmuiden, because it *cannot be used when dealing with extreme high sea levels. With the loss of Katwijk as a discharge point, the discharge at the NZK is essential (2.1.2.2.3.).*

The planned pumping stations at Schardam and Monnikendam are briefly mentioned in the VONK study as alternative discharge routes for regional systems. For these pumping stations the same goes as for the pumping station at Katwijk. *The design of the discharge of Schardam and Monnikendam was focussed on the own region (1.4.4.2.3.).* Again, it is questionable whether the influence of discharge restrictions is taken into account in the design of these pumping stations. *The construction of an extra pumping station was undertaken in order to get the regional system into balance. A stop at Zaandam can really disrupt this balance (2.1.2.3.3.).* For HHNK the question also arises whether the construction of the pumping station at Schardam could have been designed with a greater capacity? It seems that with additional capacity at Schardam and Monnikendam, HHNK would have been less depended on the discharge at the NZK and the waterboard would have had the possibility to help other regions during critical situations. But, this opportunity is not utilized and is therefore lost, in case of the pumping station at Schardam. *There is still the possibility of enlarging the design of the pumping station capacity at Monnikendam (1.4.4.2.3.2.).* An advantage of these alternatives, relative to the replacement of the pumping station at Katwijk, is that the pumping stations do not discharge into the North Sea, but into the Markermeer. Therefore the pumping station continues functioning during extreme sea levels.

It can be stated that the regional interventions of the waterboard did not consider the whole network. As an result the action perspective has decreased and the risk on a lock-in situation has increased. There is no evidence of overinvestment in the case situation. Contrary, as one interviewee of RWS mentions, *there is a risk of under dimensioning a pumping station, when you do not account for the growth of the other regions (4.2.6.1.)*. It can be argued that the replacement of the pumping station at Katwijk and the construction of the pumping station at Schardam are an underinvestment in the context of the complete network.

There are additional alternatives for interventions in the case network. *A pumping station at the Oranjesluizen can create another alternative route for the water discharge of the NZK/ARK (3.2.2.3.).* Disadvantage of this alternative is, that there is little room for the construction of a pumping station at this location. *A pumping station at the Prinses Beatrix Sluis can also create another alternative route for the water discharge of the NZK/ARK. This alternative is only feasible with the realisation of a huge pumping station, since it has to pump against the water catchment (3.2.2.6.).* An important question to ask, is whether these alternatives outweigh the need of replacing of the pumping station complex at IJmuiden. One interviewee from a waterboard doubts this. *If a decreasing performance is the consequence of postponing the replacement of the pumping station complex at IJmuiden, it entails that all organisations responsible for the water resource management in the network, suffer from the consequences. It is questionable if the network profits from postponing the replacement of the pumping* *station complex (1.5.6./4.3.2.4.2.).* If the replacement of the pumping station complex at IJmuiden turns out the be too crucial to postpone, it can be argued that the case situation is already a lock-in situation. An interviewee of RWS confirms this by stating, "*when we build a giant pumping station, everybody is stuck to it" (4.2.6.2.).*

Opportunities for synergy

According to an interviewee the key of the problem, is that the *functionality of the current network is used as condition for new interventions, instead of changing the functionality itself (4.2.3.).* A network situation will eventually become a lock-in, when it is addressed as a fixed condition that needs to be contained. Another interviewee notices that *it is never possible to make major changes in a network when there only regional interventions (4.3.1.8.).* These interviewees, both from RWS, acknowledge the fact that the current approach is not tenable and add that *there is an increasing societal pressure to optimally invest (4.3.1.5.).* According to them it is *an evident added value to cluster the budgets of different organisations, because can it can be beneficial to invest in another region (4.3.1.4./4.3.1.6.).* Clustering budgets has synergy effects, when the budget of one organisation delivers more value if it is invested in the region of another organisation. This is the reason why currently negotiations take place, to enlarge the designed capacity of the planned pumping station at Monnikendam.

Remarkably, the alternative of clustering budgets in order to replace the pumping station at IJmuiden, is not mentioned once by any interviewee. According to this research, this option is worth considering. By not suggesting it, it seems that RWS waits for the waterboard to take the initiative on investing elsewhere in the network. On the other hand waterboards are waiting for RWS to take the initiative to replace the pumping station at IJmuiden. Both RWS and the waterboards look at each other for a solution of the network problems, but forget to consider taking the initiative themselves and ask for a contribution to their plans.

Opportunities in the operational layer

Until this point, all the discussed alternative solutions focus on the reduction of the water load in the NZK/ARK. The reason for this is that, reduction of the flood probability *by strengthening the dykes, is not an option. The network area is too large and consequently this alternative is too big of an investment (3.2.4.2.).* Risk reduction of floods is only possible on the basis of reduction of the impact. Waterboards are involved in impact reduction, through the allocation of *emergency flood areas (1.4.3.9./1.4.5.7.)* and through *the application of the program "Multi-Layer Safety". Multi-layer safety includes actively advising companies and inhabitants on how to limit their damages in cases of floods (3.2.4.3.1.).* Both alternatives focus on limiting the flood impact, so it is not a solution to the flood problems. Additionally, the waterboards have limited authority over the hinterland, so they cannot enforce these alternatives.

The above examples all discuss the action perspective in the tactical layer. There are additional opportunities beyond this layer. As most interviewees endorse, *the water load on the NZK/ARK can be reduced through better alignment of operations between the different operators without major intervention. Floods occur often local due to rain, the network can help absorb the water (4.3.1.9.). When one region discharges less, the other can be unburdened (4.4.5.3.).* Especially, *HHNK and HRL can help AGV with discharging into directions different than the NZK (2.1.2.4.7.).* Operational alignment of water resource management operations *worked out well in Brabant (4.3.4.1.3.).* Since it is supposedly not much effort, one interviewee calls this opportunity, *"Low-hanging fruit" (3.2.1).* Not only during crisis times, but also before it *anticipating measures, like lowing the water level in the NZK/ARK, can preventing network failure. Preventative measures costs more energy, but it enlarges the robustness of the network (3.2.1.5.).* The interviewees agree that through alignment of operations, *the functional limits of the network can be stretched and it can perform adequately as long as possible* *in its current condition (4.3.4.1.4.). However, ultimately circumstances will change too much and interventions will be needed (1.3.5.).*

Opportunities in the strategic layer

The interviewees agree on the fact that, in the strategic layer the *water levels norms need to be revised and coupled to a failure risk of the complete network (3.2.3.). Possible a cost/benefit analysis can be executed for the different norms. Every norm has its risk and every risk has its price. (3.2.3.6.).* By drafting a more quantified water level norm in the strategic layer, a better estimation can be made on when the network fails. Through this it can better estimated when functional end of service life of the HCS is reached and what actions should be taken. New norms need to be accepted by all involved organisations. Consequently, this in only possible in a network approach.

Governance structure

Institutional collaboration

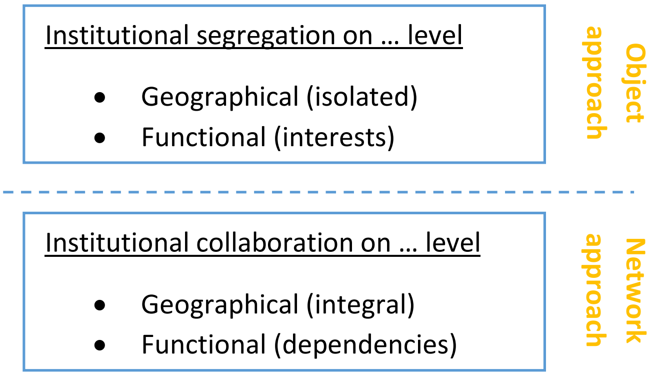


Figure 36 Theoretical framework: Institutional structure (own illustration)

The geographical segregation on geographical level is already discussed in paragraph 3.2.2., since this is formalized in documents. According to most interviewees, *collaboration is not formalized. There is no formal policy of communication between the different organizations (4.2.4.1.). This does not mean that everybody works past each other, but the integration between the different organisations can be improved (4.2.4.2.). Most of the collaboration between the different organizations is on the basis of informal contact (4.2.8.).* According to an interviewee *the problems in the water network are not caused by the physical borders, but due to the great diversity of functions, and the fact that sometimes one function outweighs another in priority (4.2.5.1.)* This case study focusses on the function of water discharge. There are however more functions present in the waters of the case. The utilisation of these other functions can be a driving force in the interest of an organisations.

Interests of the organisations

RWS controls the main water transport lines in The Netherlands and therefore looks after interests of the shipping industry (2.3.1.1.). The impact of this industry is noticeable in all institutional layers. In the strategic layer, the different interests are established in the water level norms. *The water level norms are decided upon, while considering the shipping industry (1.4.1.2.6.).* Between the targeted water levels of -0,55 NAP and -0,30 NAP of the NZK/ARK, *the interests of the shipping transport outweighs the interest of the water management. This changes when the water levels rise above at -0,30 NAP (1.2.2.1.3.4.).* The influence of the shipping industry on the policy of RWS, becomes really clear in the tactical layer. According to the interviewees of the waterboards, *organisations depended on the shipping industry, like the port and municipality of Amsterdam, are the driving force behind the planning of the new sea lock in IJmuiden (1.2.3.1.1/2.3.3.3.). The primary focus is on the economic prospects of this industry and the interests of the different functions of the water network were not considered in the decision making (4.4.3.3.).* An interviewee cynically adds that the *interest of cruise ships outweighs the interest of salinization (4.3.3.1.).* The influence of the shipping industry also plays a role on the operational layer. RWS is *reticent to perform additional preventative discharge at low sea tides through the locks, since this blocks the shipping transport (4.4.6.3.).*

According to interviewees of the waterboards, RWS values the interests of the inhabitants of the hinterland less than the they do. *RWS has contacts with the shipping industry, but not directly with the inhabitants (2.1.1.1.6.)*. This supposedly also influences the decisions by RWS in the operational layer. For preventative discharge costs, the use of the pumping station at IJmuiden, plays an important role. *Since discharge by gravity is free, the RWS focusses on maximising the discharge by gravity, and diminishes the use of the pumping station. "It seems like usage of the pumping station is 'not done'" (2.1.1.1.3./-1.).* It is also suggested that *postponing the replacement of the pumping station complex at IJmuiden is only based on the economic interest of RWS (4.3.2.4.2.).*

The waterboards have a different interest than RWS. Waterboards are democratically elected, so to them *the voters are of high importance (2.3.7.2.)*. *Political promises for elections can influence the policies and budget of waterboards (2.1.2.2.8.).* The executive board of the waterboard is called is the "Verenigde Vergadering". *In this board, the agriculture sector is also present (2.1.2.1.1.).* Therefore, the agricultural sector is of great influence to the policies of the waterboard. According to the interviewees from the waterboards, *they are in direct contact with the inhabitants, in contrast to RWS (2.1.2.2.6.).* Normally, the policy focusses on the *need for fresh water, but in some situations you need to get rid of it (2.1.2.4.3.2.)* In these situations, *failure impact, expressed in potential cost and casualties, is the most important factor in the decision making process of waterboards. Damages affect people and businesses can go bankrupt as a result (2.1.2.2.4.1.).* The waterboard interviewees substantiate this by giving numerous examples of damages. For instance, the *200 million damages in 1998 in Delfland* are mentioned *(2.1.2.2.4.1.).*

Every regional water system the situation is different. Consequently, there are differences in the interests of the waterboard. For the waterboard HRL the water level is of great importance, since *there are small margins in their regional water levels, due to the canals in the historic cities of Leiden and Haarlem (1.4.3.6.).* Despite of this, the interviewee of HRL mentions, that *discharge limitation never caused problems at HRL (2.1.2.2.4.2.).* The strongest stakeholders in the system of HRL are the **Greenports**. *These are high quality and sensitive agriculture fields, like flower bulbs (2.1.2.2.4.). The Greenports are very sensitive to superfluous water. Damages can cost hundreds of millions of euros (2.3.5.1./2.3.5.3.).*

The interviewee from HHNK does not define any specific influential stakeholder in their region. There is however an important comment about the influence of municipalities on the waterboards. It is mentioned that *for the construction of a pumping station, licences need to be permitted by the municipality. The municipality needs to adjust the land use plan. For this reason, the planning of a pumping station can take really long, and adjustment in later stadium can be problematic (1.4.4.2.3.1./4.5.1.6.).*

The waterboard of AGV is differently as most waterboards. *Waternet is the executive organisation of AVG and performs the water related tasks of the municipality of Amsterdam (2.1.2.4.1.). The waterboard itself only exists as an executive board. Amsterdam has a responsible alderman. However, in practice much of his tasks are delegated to the director of Waternet (2.1.2.4.2.).* Due to this structure, the municipality of Amsterdam is the most important stakeholder of AGV. The system of AGV is mainly focussed on preventing the flooding of the capital city. *The only water outlet, apart from the outlets to the NZK/ARK, is the pumping station of Zeeburg. Amsterdam can be closed off from the NZK/ARK. Zeeburg than manages the drainage of Amsterdam (1.4.5.2.1./1.4.5.5.).* In addition, *Amsterdam has an emergency discharge at "De Hoep". This area functions as the "airbag of Amsterdam" (1.4.5.7.1.).* AGV has problems with inhabitants of De Hoep. *These citizens protest to the use of De Hoep as an emergency reservoir. Even though the inhabitants are never in danger, they are afraid that they suffer damages (1.4.5.7.3.). To avoid a conflict of interest, the province decides about of the emergency* *discharge waters (2.2.2.4.).* Another important stakeholders of AGV are the industries around Amsterdam. *They are mainly located in the areas outside of the dyke protection, like Watergraafsmeer and the Westpoort. Most of the IT of Western Europe is located in these areas. This industry is vulnerable, but it does not seem to be aware of its vulnerability.* A remarkable thing is, the example the interviewee gives for this ignorance. It is stated that *the "VU Medical Centre" functions like a bath tub, nonetheless most critical installations are located in the basement (3.2.4.3.1.).* That the VU Medical Centre is vulnerable was proven two months after the interview, when the building flooded and the damages are estimated at tens of millions of euros (NOS, 2015).

Interdependencies between the organisations

In a collaboration it is important that the organisations focus on the interdependencies instead of their own interest. In the operational layer, RWS is little depended on the waterboard in regular occasions. *During critical times of high water levels its happens that they contact Waternet in order to turn on the pumping station at Zeeburg, in addition to IJmuiden (2.1.1.1.5.).* Contrary, in the tactical layer *RWS is depended on regional operators for alternative solutions for the functioning of the main water system, in order to postpone great interventions at IJmuiden (4.4.5.2.).*

The waterboards are a lot more depended on RWS. *Everyone depends on a properly functioning pumping station at IJmuiden, whilst only RWS operates it. They are the only organisation that can anticipate heavy weather by lowering the water level in the NZK/ARK (1.5.6./3.2.1.5./4.4.5.1.). 95-99% of the discharge of the NZK/ARK goes through IJmuiden (1.4.7.3.1.).* All waterboards are afraid of the impact of *discharge stops. RWS has the authority to enforce these in extreme water levels. Discharge stops have as effect, that the polders flood (1.5.8.).* The regional operators are depended on each other in extreme weather conditions. *Extreme rain peaks are often only experienced locally. The different waterboards can unburden the heavily affected regions (4.4.5.3.).*

The regional systems are HDSR and AGV are most depended on other organisations. Both systems are *physically part of the main water system, since its discharge waters are open connection with the NZK/ARK (1.4.5.3.). In extreme situations, HDSR has the opportunity to discharge a certain amount of water the HRL (1.4.6.1./2.1.2.5.2.). Waternet can use Zeeburg. Nonetheless, according to an interviewee, both alternative discharge routes are not in proportion to IJmuiden (2.1.2.4.4.). HHNK and HRL are less depended on the discharge to the NZK, since both waterboards have alternative discharge routes (2.1.2.3.2.).* However, interviewees of both waterboards state that *they still are depended on a properly working IJmuiden. For both regions discharge limitations to the NZK disrupt the functional balance in their region (2.1.2.3.3.).* This especially accounts for HRL, *when the pumping station at Katwijk discharges water directly into the North Sea, due to a high sea level (2.1.2.2.3.)*

Decision making process

Simple decision making process

As discussed in the Governance structure paragraph, the organisations that perform water resource management in the case situation, all have different stakeholders demanding a certain level of performance of them. This can cause troublesome situations, but in general, no great problems occur. The interviewees agree on the fact that *the general public is most of the time ignorant to water resource management. There is no realisation about how vulnerable the network is if the pumping station at IJmuiden does not work (1.5.2.).* Little awareness amongst the general public is good signal according to an interviewee. It shows that *in general the water resource management is well organised in The Netherlands (2.4.1.).* Attention for the activities at HCS is also very low. *Inhabitants have little connection with HCS. In contrast to dyke reinforcement. These can provoke heavy protests from interest groups (2.3.7.1.)* .

Asymmetric information division

Institutional segregation entails, that organisations have different *policy tasks, mandates, boards, budgets and cultures (4.4.2.).* It is not the technical complexity of the network, but these aspects, that make a network approach complex. An interviewee indicates that the *technical failure of an object is the main trigger to discuss rehabilitation or replacement of HCS. There is little functional reasoning involved in the determining the end of service life (4.2.1./-1.). It is important to know when the functional boundaries of the network are reached. In this way it is possible to prevent failure from happening (4.3.2.2.2.). Not foreseeing network failure, forces organisations to preform unplanned actions on HCS (4.3.2.2.1.).* However, it proves to be difficult to determine a shared perspective on the technical complexity of the network and to centralize this information. As already mentioned in Scope & understanding paragraph, *organisations often have no idea how the neighbouring system works. This accounts for the daily operations and for the crisis situations (4.2.4.3.).* Therefore, *the exact impact of different water levels in NZK is not known (1.4.1.2.1.).* Additionally, the *availability of information is depended on persons (4.3.3.1.5.).*

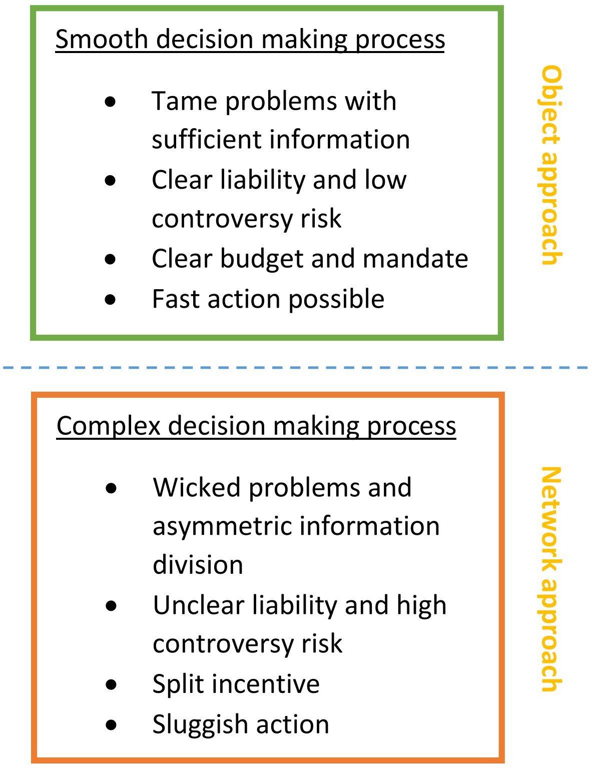


Figure 37 Theoretical framework: Decision making process (own illustration)

According to most interviewees, *sharing information and knowledge is the first important step towards a network approach (4.3.2.1.1.). Knowledge of the systems of the neighbouring organisations is very important for performance management and it is a good way to see the critical points in the network (4.3.2.1.).* The decision making process would be a lot simpler, *if a failure risk of the network decided is upon, between the organisations (4.3.2.3.1.).* This has to include a *shared view in future developments, like scenario's, so possible issues in the future can be foreseen (4.3.2.3.).* On the basis of this all, *clear and shared norms can be established (4.3.2.1.2.).* Furthermore, it is stated as important *to know from the different organisations, what their planned interventions are. There needs to be a good connection between the short term plans and the long term developments (4.3.2.5./-1).*

This alignment of information and knowledge does not come naturally. Firstly, *the technical complexity of the network is not always easily translated to data (4.3.2.1.3.2.).* It is stated as an risk, that the *risk analysis becomes too extensive. To prevent the organisations from drowning in the data, the right level of detail needs to be decided upon. With too little detail, the data does not project a proper view of the future (4.3.2.3.2.).* Secondly, the *sharing of information alone does not solve the problems, personal contact between the different organisations is also important (4.3.2.1.3.3.). Organisations have to make their data available to others, but are not very willing to share their information. Organisations are afraid of misuse of their sensitive information (4.3.2.1.3.1./4.4.7.1.).* This can be considered a lack of trust. This is also noticeable in the willingness of organisations to accept information of another organisation. The lack of trust was mainly expressed in the attitude waterboards have towards information provided by RWS. One interviewee mentions that he *sometimes sees a colleague redo a calculation performed by RWS (4.4.7.3).* Another interviewee states that, *in the past wrong estimations have been made, for this reason nowadays all interventions of RWS are watched more closely (4.4.7.4.).*

Multiple interviewees of waterboards are astonished that *the estimated capacity of the pumping stations in IJmuiden are not correct (1.4.1.4.1.1.).* It is likely that these things harm the trust.

There are already some initiatives in order the align the information between different organisations. One pilot project is mainly focussed on data exchange and is called is *open-boezem-open-data (4.3.4.2.)* (boezem = discharge water). Another initiative is *Slim Water Management* (SWM) (English: Smart Water Resource Management). *SWM is a interregional alignment of operations, in order to make good use of the network functionality (4.3.4.1.4.).* SWM is part of the Delta Program and *has proved to be successful in Brabant. This was a collaboration between the different waterboards, that decided about functional changes in the network. SWM was initiated top-down, but the content of the plan was established and implemented bottom-up. It was a good example, showing that utilisation of the network can be improved (4.3.4.1.3.).* In the context of SWM, *a shared failure risk analyses is performed in the case situation (4.3.4.1.6.).* However, one interviewee adds that *it is still namely a plan on paper, with no concrete results yet (4.3.4.1.1.).*

Liability and controversy

According to an interviewee, an important reason why organisations are not very willing to share their information, *is the risk that stakeholders can abuse the information and start legal procedures against them (4.4.7.1.).* Organisations are *liable for failure within their own system. Therefore, limiting discharges to unburden the NZK/ARK, is not without risk (1.4.3.10.).* Issues like this occur in the *area of De Hoep. The inhabitants oppose the emergency discharge, because they fear damages to their properties. In order to diminish the risk of legal procedures, expensive preventative measures are needed (2.1.2.4.9.).*

Additional to legal claims, stakeholders make use of the media to enforce actions. For instance, *the agricultural sector and environmental organisations know the responsibilities of the waterboard. In their use of the media, these stakeholders take advantage of this knowledge. By creating controversy they try to delay projects or enforce actions by the waterboards (2.3.5.3./2.3.6.1./4.5.5.1.).* As an interviewee explains, *the media has the tendency to "butcher" the waterboard when something goes wrong (4.4.7.5.). During critical high water level situations, negative media can put a local responsible manager in a very difficult situation. When floods are broadcasted, rational explanations about how the waterboard could not have done more, will not be heard or accepted. The manager has to be very confident, not be influenced by the negative consensus the media creates (4.5.5.3.).*

Negative images cause a lot of reactions. For instance, *Waternet has troubles with inhabitants of the Holstermeerpolder. These inhabitants actively oppose the waterboard. It is an wealthy area located close to the city of Hilversum, with a lot of journalists living there. This makes the area sensitive to controversy. In their opposition to the policy of Waternet, the inhabitants declared themselves as an independent republic (2.1.2.4.10.). When the general public gets involved they are able to slow down policies and even block them as pressure groups (2.3.7.3.)*. In addition to the public, *municipalities have the tendency to interfere when media are active in their region (2.3.2.1.). Due to the public and political pressure, controversy in the media can lead to irrational decision making (2.3.8.1.).* For instance, *during a period of heavy weather, media made a big fuzz on the television about floods in the Horstermeerpolder. Waternet was forced to react, whilst it was not the most heavily affected area in their region. Even though it did not make any difference, emergency pumps were placed in the area. This was done in order to create a positive image in the media (4.5.5.3.1.).* Other examples where, according to multiple interviewees, *disputable decisions were made, are the area of Kockengen (4.5.5.3.2.) and in the province of Groningen (4.5.5.3.3.). In the area Kockengen "idiotic" interventions were executed after there were some images of sandbags on the television (4.5.1.4.1.). In Groningen an unnecessary new pumping station was realised because of a minor evacuation (4.5.1.4.2.).* One interviewee openly questions *whether waterboards will stick to mutual agreements, whenever the media gets involved (4.4.7.5.).* Again, this can be considered a lack of trust between the organisations.

It has to be noted that, the issues of stakeholders pressuring their organisation, were extensively discussed by the different waterboards interviewees, but were not mentioned in the interviews with RWS. This research interprets this fact as; that liability issues play a less significant role in the decision making process of RWS.

Interests and incentive

Liability issues and the fear of controversy cause organisations to act in their own interest, or in the interest of the organisations they represent. As an interviewee of a waterboard mentions, *cross border operation needs to be justifiable. At 1/100 year incidents HRL cannot unburden the NZK, because than it needs its full capacity. The system is dimensioned on this capacity. Taking over capacity of NZK can cause liability issues (1.4.3.10.)* Most interviewees agree that the question that always needs to be answered is*: "what is in it for us?" (2.1.2.2.7.). All organisations need to see added value in the collaboration, otherwise it will not work out (4.3.2.1.5.).* As a result, *in determining their action perspective, the organisations often do not comply with the other organisations (4.2.4.).* As already mentioned: *Organisations are good at poldering, when it does them good (4.2.4.6.).*

Organisations merely reason out of their own interest, whilst there is a lot of profit to be made from collaboration. As discussed in the Action perspective paragraph, a network approach can be profitable for every institutional layer. However, all interviewees agree on the fact that it is *a major challenge to make decisions in a network (4.3.3.5.).* Especially, since is it is for employees already difficult to get their plans accepted in their own organisation. As one interviewee mentions, *"if we cannot get the board enthusiastic, we can better end our efforts" (4.3.3.1.). In the decision making process it is important to involve all institutional layers in the decision making process. In every layer the process can be blocked and every level adds a piece to the puzzle. For instance, when the operational level is not involved, a paper reality is created (4.3.2.6.).*

Organisations are willing the collaborate when there is a payoff. An example of this is the pumping station at Monnikendam. The interviewee of HHNK states that, *they are willing to enlarge the design of the pumping at IJmuiden, but in return this has to be financed by the organisations that profit (4.4.1.5.).* An interviewee of RWS states that, *they are willing to invest in the new pumping station.* However, it is difficult to determine how much they will benefit from the enlargement of the pumping station. *Firstly, because it is difficult to express the benefits in monetary terms (4.4.1.1.). Secondly, because they cannot control the use of the pumping station. In return for their investment, RWS wants to have some control over this use (4.4.1.2.).* This is when split incentives occurs. One organisation has the authority, but not the direct interest. The other organisation has the direct interest, but not the authority. In addition, both organisations have demands, which carries risk that in the end, both organisations stick to their object approach.

As most interviewees admit, *a major challenge of the decision making process in a network approach, is the fact that organisations sometimes have set their own interests aside (4.3.3.2.).* In the most extreme situation, *it can happen in a network approach, that one organisation needs to let some of its region down. In order to prevent a bigger problem elsewhere (4.3.3.7.).* As one interviewee of a waterboards stated, *it is difficult for an organisation to accept damage to allow for the opportunities of another organisation (4.4.1.3.).* Another interviewee indicates that, *organisations need to be cautious with having demands. When these conflict with their responsibilities or values of other parties, it can frustrate the collaboration (4.3.3.4.).* Especially differences in culture can play a role in this. As an example for this, priorities in the operational management of the case situation are given. *RWS* *primary focusses on limiting their energy consumption and limiting disruption of the shipping transport. Whilst, the waterboards see this as insignificant in comparison to the risk of floods. For the waterboards floods are more than just damaging costs, but it personally impact their voters.* As one interviewee states, *businesses can go bankrupt due to a flood. Therefore they primarily focus on the diminishing of flood risk (2.1.2.2.6./3.2.1.6./4.4.2.).* As a result, waterboards on the one hand, *demand from RWS to preventative lowering of the water level, in order to diminish the risk of floods.* RWS on the other hand*, demands from the waterboard that they limit their discharge, in order to save pumping costs and to limit the disruption of the shipping transport (3.2.1.5.).*

These conflicting interests harm the trust in the collaboration. That there is a lack of trust in this case situation can be understood by looking at the accusing remarks of interviewees from both RWS and the waterboards. Two interviewees of waterboard are offended by the *easy talk from RWS, stating that they have to accept damages of flooding in the polders (4.4.1.4.).* An interviewee of RWS suggests that *waterboards might oppose collaboration, because they fear for their right to exist. Political organisations thank their existence to possession of certain responsibilities. If these responsibilities are being centralized, they might fear for their existence (4.4.4.1.).* The right to exist, can be interpreted as the ultimate form of self-interest, since this should not be a goal of itself. That this might play a role in the attitude of waterboards is not a crazy idea, since an interviewee of a waterboard confirms that they have been struggling with their role in the network. "*As a waterboard, for a long period we felt like Calimero against RWS, but since we have grown in size, we have become more equal counterparts" (4.4.4.2).*

Sluggish action

Incorporating local plans, policy tasks, mandates, budgets and cultures in the decision making process, *often slows it down and diverges it from the actual problems (4.3.1.3.2.).* It is believed by the interviewees that *time can be a limiting factor for collaboration. Especially when something breaks down and needs to be fixed on a short term, the network is not considered (4.5.3.2).* Time also influences the decision making process as *a political factor. Political deadlines are harder to reach in a network collaboration (4.5.3.1.).* However, one interviewee suggest that *once a network alignment is established, an easy decision making process is possible. Because, not every time cohesion in the system needs to be researched. (4.3.1.7.).* So a network approach does not necessarily harm the speed of the decision making process.

Confidence in the network approach

Despite all threats that a network approach has on the decision making process, all interviewees look back satisfied on their collaboration in VONK study. Even though the goal of VONK was never to come to concrete results in the case situation, the interviewees see possibilities for network collaborations in the future. An interviewee of RWS mentions that these initiatives are still *in a state of infancy and is still just an ideal of a limited amount of people*. However, the interviewee is hopeful about collaboration, because *otherwise we would not have done the VONK project (4.3.2.6.).* An interviewee of a waterboard goes as far as stating: *"My dream is that through collaboration, in the future no more waterakkoorden need to be reached, but that there is one comprehensive shared agreement, in which we manage how we distribute the water in periods of wet, dry and everything in between. We are going to fulfil this dream" (4.3.3.6.).*

Appendix G: Complete management Game Design process

For the design of the game four feedback rounds have taken place.

Respondents	Duration	Goal session(s)	Feedback
Gaming experts, Deltares and TU Delft (3 respondents)	2x 1 hour	Feedback on game ideas	Minimize the variables. Focus on one layer: water resource management. Do not use RWS as a role in the game. It differs too much from the other roles.
MSc. Students, Various TU Delft (8 respondents)	2x 1,5 hour	Testing game set-up and scenarios	There is no incentive to perform strategic behaviour. The scenario with the greatest differences along players proves most promising.
Professionals, Various (8 respondents)	2x 1 hour	Testing pilot version including presentation	Rules where not clear and confusing at the start. The monetarisation of the problems are too easily negotiable.
MSc. Students, Technology Policy Management TUD (4 respondents)	2 hours	Testing of the game with an additional controversy factor	Controversy factor makes the game work good. Incorporate tactical layer by means of a big map with investment possibilities.

Table 1 Overview of feedback rounds

Round 1

Setting

This round took place in two sessions of an hour. The first session took place at the office of Deltares, together with two game design experts of Deltares. The second session was at Delft University of Technology, with a PhD. candidate who designed and used a management game for his research. The objective of the session was the let experts have a first look on and judge the management game ideas.

Product presented at the round

The first game that was designed for this research, was a water network with a water resource management problem. This set-up was played by four participants. Three of them were waterboards and one of them a regional department of RWS. The game consisted of multiple rounds and every round a random scenario would take place that impacted the network. Examples of these rounds are:

- Big storm at sea, which causes the sea level to rise and central pumping station towards the sea to lose capacity.
- A fire at one of the pumping stations, causing a 100% function failure of a random pumping station on the board.
- Large water loads upstream the canal, causing the large quantities of water in the main canal.
- Extreme regional rainfall, causing large quantities of water in a random regional system.

Every turn a water load would be divided over the game board. This board is illustrated in Figure 38. All information would be openly visible for all participants. The regional managers would have to decide what to do with the water on their system. The participant who plays RWS gets to decide whether he preventatively discharges water before the revealing of the scenario. Between each round the participants get the chance to invest in their of region. They can buy additional pumping capacity or regional storages.

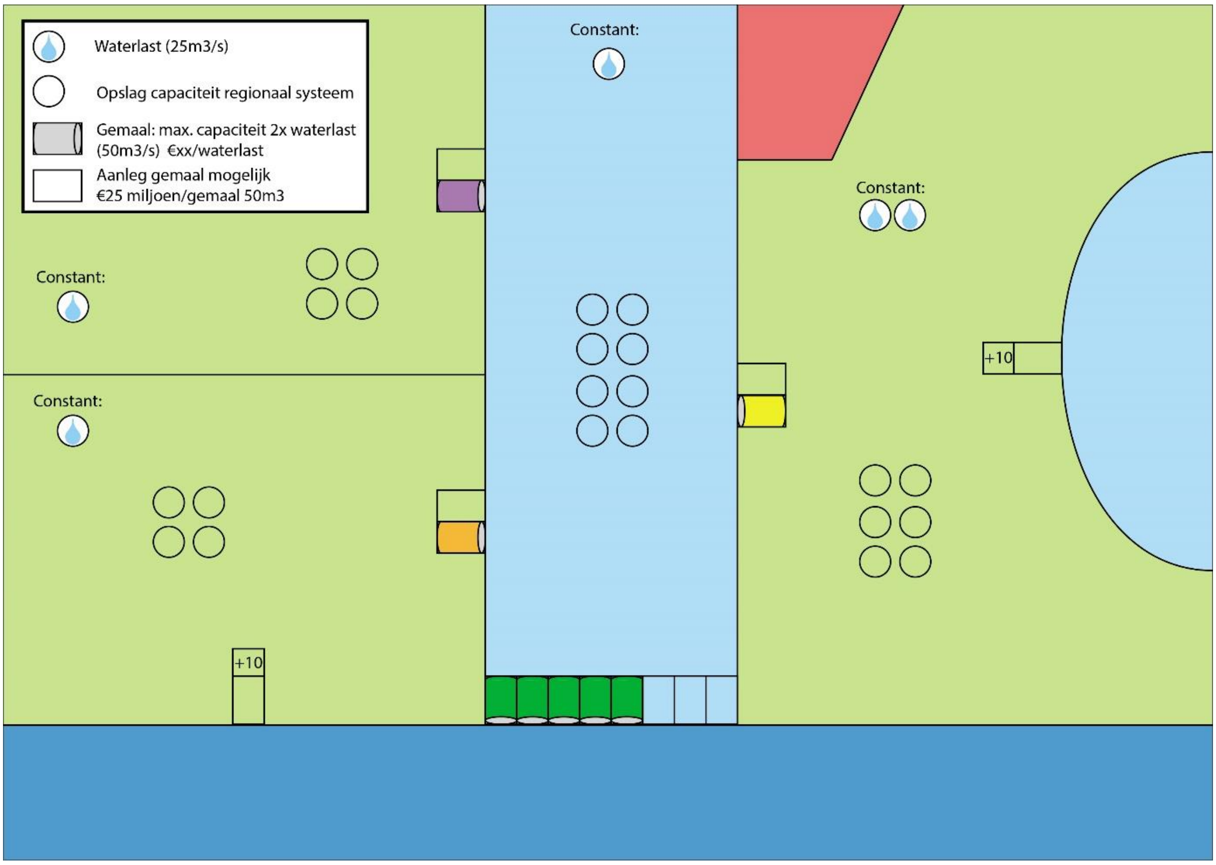


Figure 38 First game design board

Remarkable insights of the round

- Very difficult to gain research data from a game that is analogue, has random factors and is only played several times. It is advised that at least one of these three characteristics is changed.
- The role of RWS is not a nice playable in the game as it is now. The role is more like and supporting role, that does not really participate in the game and has no incentive to cooperate. It is suggested as a better option not to include the role of RWS in the game.
- Limit the amount of variables. Having too much variables in the game has multiple disadvantages. More variables often means more rules. This can be confusing for the participants. Many variables are more difficult to analyse and gain data from it. Is is difficult to determine with variable has the most impact. Many variables also have as an effect that the learning objective of the game will not be understood. It is suggested to make a decision about whether the game should be a game that is about rehabilitation or replacement of HCS, or about a water resource management problem.
- Most important of a serious game, is the lesson that you want to convey to the participants. The lesson of this game version is not clear. The game is now more like a solvable puzzle. It is suggested to focus on the problems that also take place in real-life. One of the most important problems is the tension between individual interests vs. the added value of working together. The self-interest part is totally lacking in this game setting.
- Think about the amount of players. Is a fixed amount of players desirable, or is it possible to have make it flexible? It is suggested that is best played with about four participants. With four

participants, the game outcome is not fixed, and there is a lot of discussion possible between the different participants. This is possible without creating too much data, like when the game is played with more participants.

Round 2

Setting

This round took place in two sessions of one and a half hour. Both sessions took place at the home of Maarten Vissers and where with students from the Delft University of Technology. The objective of the sessions was to check if the new game set-up worked as a management game by conveying learning objectives on the participants, and what set-up the variables that worked best for playing the game.

Product presented at the round

On the basis of the suggestion of the game design experts, the new game setup got less variables. Therefore, it only focussed on water resource management. The choice for water resource management was made, since it was expected that the dilemmas in this context would be more easily understandable. This could help the participants in learning the game objectives. In addition to this, it was decided that information of the participants should be private. For this reason, all players received a private monitor, which could change screens. This is illustrated in Figure 39. The common board was not part of the game anymore. This way it became possible to create tension between individual interest and the added value of working together. It was decided not to include RWS in this setting and also the randomised scenarios were let go. For this feedback round no different types of rounds were tested, since it mainly focussed on the tuning of the variables.

The game was only based on a few variations: The water quantity per region, the cost of the first storage area and exponential function of the total cost. An excel documents was programmed that could easily calculate all possible outcomes of different variables. Different types of variation were tested during this feedback round:

- All participants have the same average figures.
- One participant has high initial cost, but a low exponential function behind the cost. One participant has low initial cost, but a high exponential function. Two participants have the same average figures, only one has more rain as the other participants.
- This set-up had the same cost setting as the previous, however these was a great variety of rain in the different regions.
- There was a great variety in cost, with a great imbalance between the different participants. All participants got the same rain quantities.

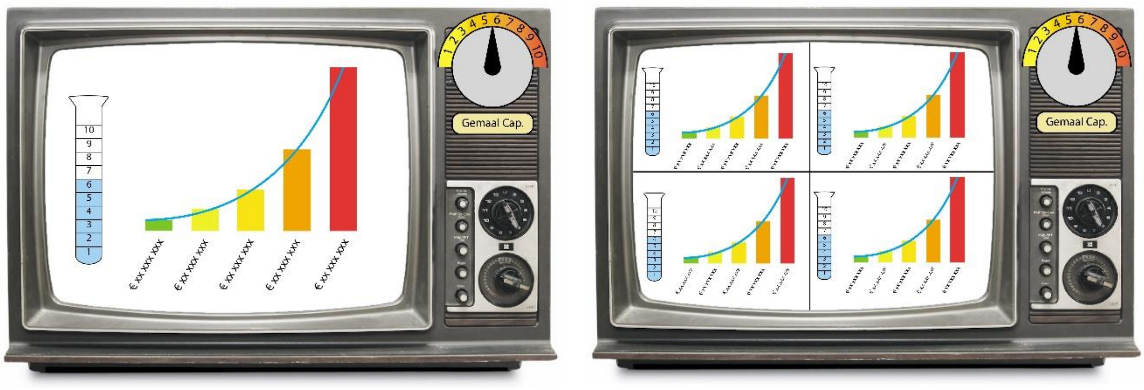


Figure 39 Game monitors in the second and third round

Remarkable insights of the round

- The game was nicely playable. The personal monitors were perceived asset to the gameplay.
- Without a general map, the game setting was initially was not clear for the participants. An explanation was needed about how water resource management happened in The Netherlands and how the different regions were connected.
- With variable setting proved to give the most interesting gaming experience, was the last. The imbalance between the different participants evoked most discussion. The rain capacity variation did not provide any interesting effects. The test sessions also showed that it was best to have only one favourable outcome, since this take the players most time to figure out.
- Even though the monitors were personal and the participants were told to focus on personal gains rather that the group results, all participants started the negotiate immediately. There was no incentive to perform strategic behaviour. This was a problem, since this was key in conveying the learning objectives on the participants.

Round 3

Setting

This round took place in two sessions of one hour. Both sessions took place at the final conference of the TO2 project at Deltares. During the conference two gaming sessions were organised and participants of the conference were free to join in. The participants were experts from different types of institutions. There were participants from governance institutions, educational institutions, research institutions and companies. This was the first real test of the game. The objective of the sessions was check if the new game set-up was a good product that could be used for this research. The version was therefore presented as a Beta version.

Product presented at the round

The design of the game did not change after the previous feedback round. In addition this round, the management game got a presentation that introduced water resource management in general and how the different participants were connected. The game set-up was based on the most promising set-up that the last test round provided. This set-up was further improved. Another addition in this round was the introduction of different types of gaming rounds. Gaming session consisted of four gaming rounds:

- A round with private information, a self-interest for the participants and no negotiation allowed.
- A round with private information, a self-interest for the participants and negotiation allowed.
- A round with shared information, a self-interest for the participants and negotiation allowed.
- A round with shared information, a common interest for the participants and negotiation allowed.

Through the different set-up of the rounds, strategic behaviour should emerge in the first round and disappear in the last round, showing that the results in collaboration are an improvement. The self-interest was caused by punishing the actor with the most cost. The shared information was created by having a screen in the monitor with two sides. In the third round the participants got the instruction the turn this screen around. The shared information screen in the second screen showed in Figure 39.

Remarkable insights of the round

- The explanation at the start was not clear enough. There was a great misunderstanding of the difference in water storage and water discharge.

- There was no strategic behaviour by the participants. In the second round the participants already started honest negotiation on compensating each other. They already found the best result in this round.
- Suggested to express the storage not only in monetary terms, but make the losses more personal. Monetary terms prove to be too easily negotiable. Factors like the death of inhabitants is not. In addition, strategic behaviour mainly emerges when actors have to do something that goes against their core principles.
- The exponential function proved to make the calculation on the best result very easy.
- The game was valued as fun to play by all participants. One participant, working for an educational institute, even wanted to buy the game for educational purposes.

Round 4

Setting

This round took place in one session of two hours. This session took place at the faculty of Technology, Policy and Management (TPM) and the Delft University of Technology. The participants were TPM students with sufficient knowledge on water management. Since the beta version did not provide the results that were intended, this round was used to test a new aspect of the game that should create self-interest and strategic behaviour. In addition the session is two hours, in order to extensively discuss how the game could be further improved, and how the rehabilitation or replacement of HCS could be addressed in the water resource management setting.

Product presented at the round

With the premonition that personalizing damages, like adding a death toll to the regions, would make the game unrealistic, it was decided to use something else to create self-interest. In the case study the

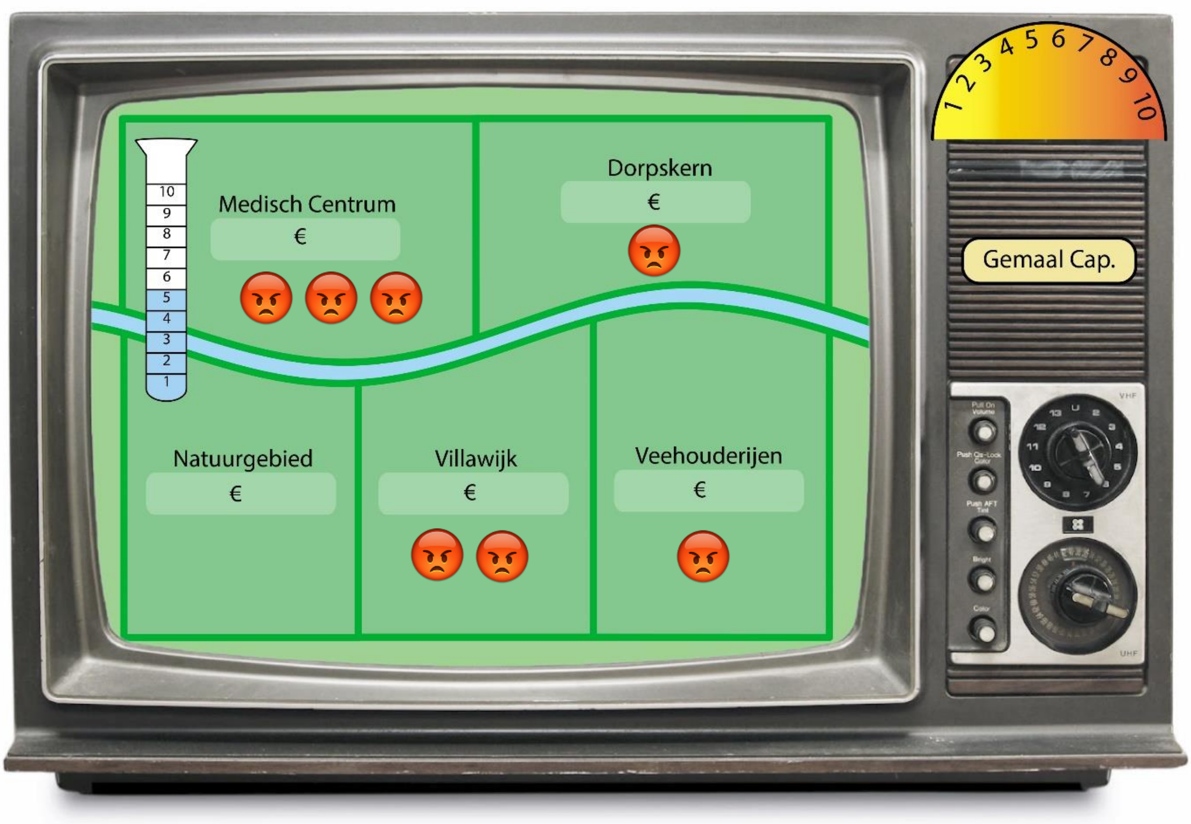


Figure 40 Personal monitor of round 4

waterboard proved to be very much bothers by negative media attention. This fact was used as a factor to create self-interest. The negative media attention was illustrated by angry looking emojis, as illustrated in Figure 40. In addition, the exponential function in the screen changed into a map of the region. All regions looked the same, but the figures were different per participant. Not the added costs, but the costs per region were shown in the screen. This way the game set-up and rules are easier to understand. In addition, the calculation and discussion could take more time and would become more interesting.

In order to make a good connection to the research topic of rehabilitation or replacement of HCS, it was very important to incorporate this in the game. This last feedback round was planned to be extra-long, so it could be used to come up with suggestions to do this.

Remarkable insights of the round

- These negative media attention has the desired effects. In the previous round the negotiations were finished within 5 minutes. In every gaming round in this last feedback round the negotiations took about 20 minutes. In addition, the players perform strategic behaviour. The extra variable proved to be the missing element. Media attention proved to have such a positive effect, since it is not exchangeable and not expressible in monetary terms. The water resource management game is finished.
- The last problem that this feedback round needs the tackle, is how to include the rehabilitation or replacement of HCS in the game. As an idea it is suggested to add investment decisions. These decisions can be illustrated in a common map. The participants need to make long term investment decisions to improve the network and prevent the problems of the water resource management from taking place. The short term water resource management decision are this way coupled to the long term investment decisions of the rehabilitation or replacement of HCS.

Appendix H: Management Game Elements

Components

Game board

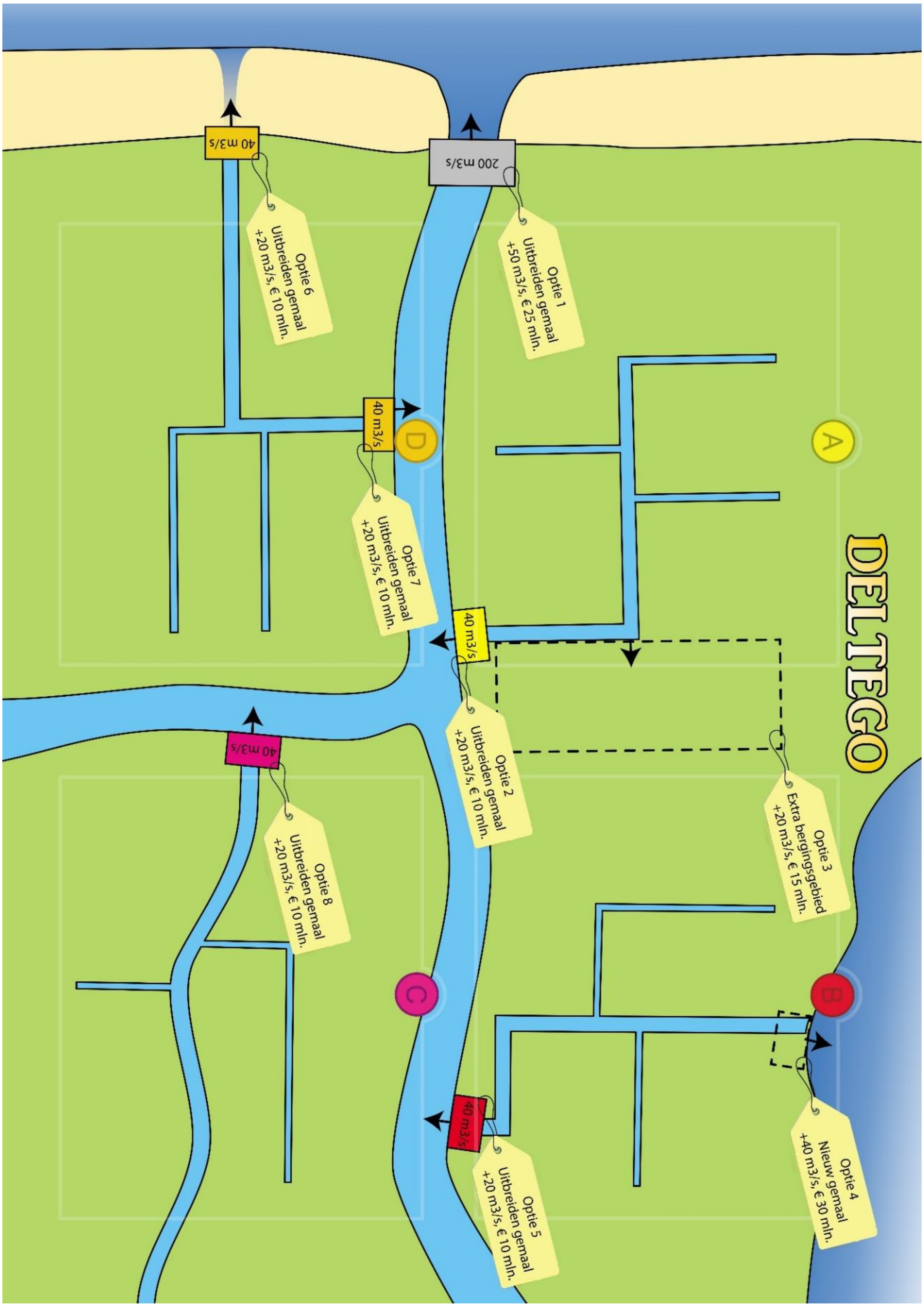


Figure 41 Deltego: Game board (own illustration)

Monitor

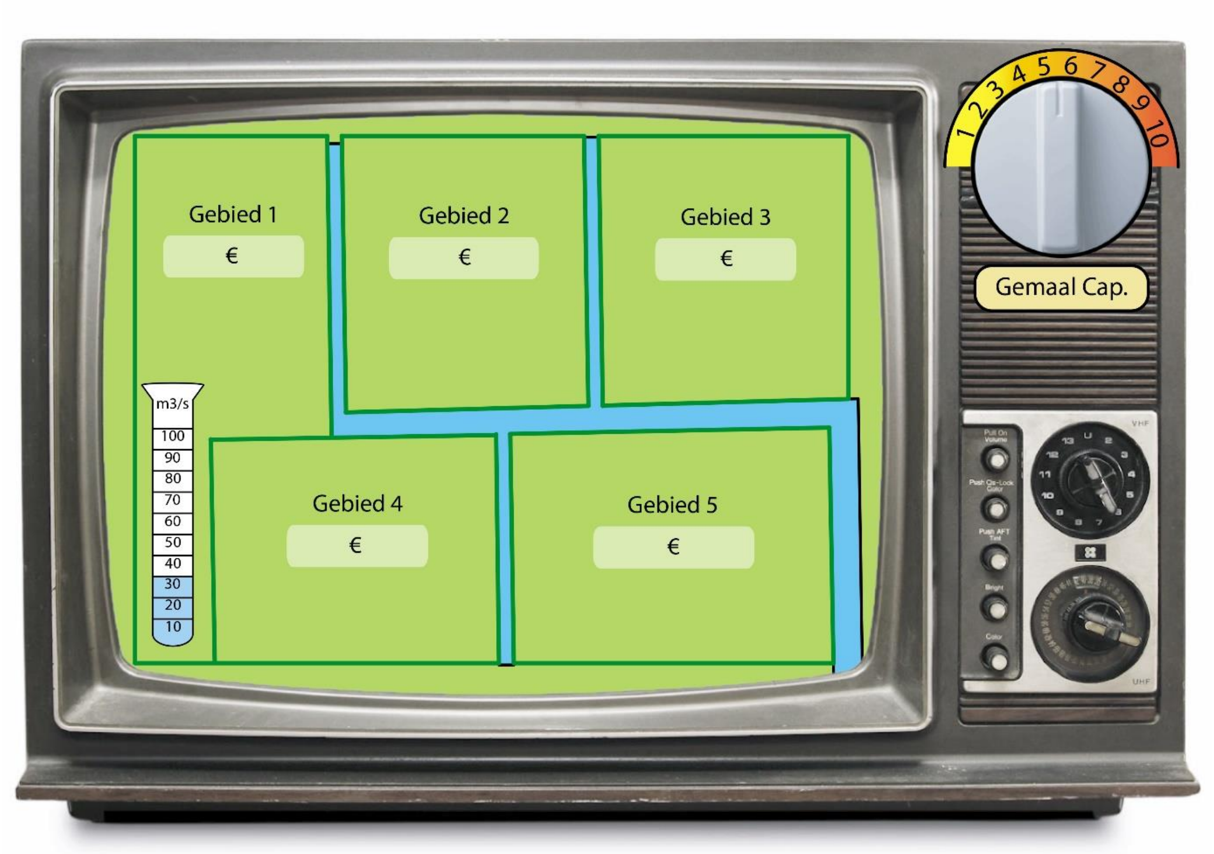


Figure 42 Deltego: Playing Monitor (own illustration)

Personal water system cards

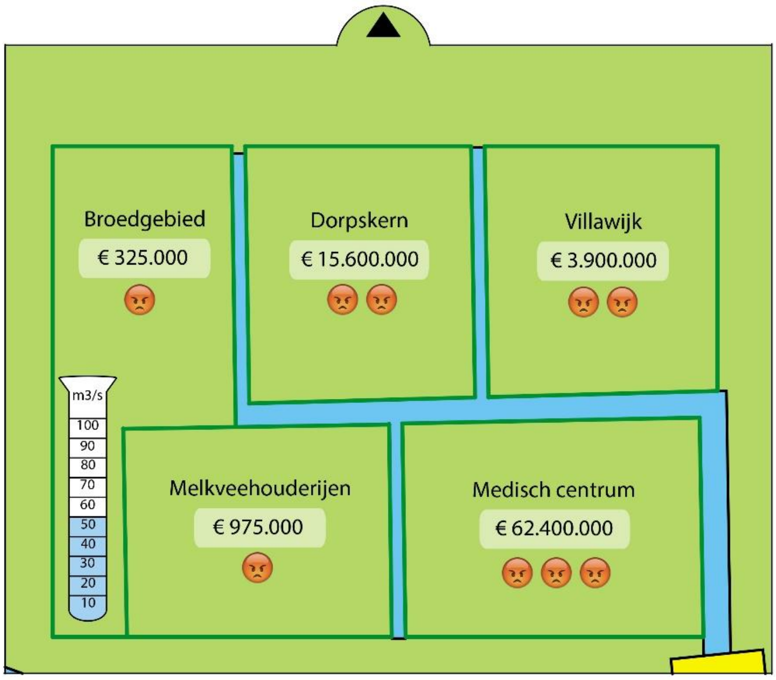


Figure 43 Deltego: Personal water system card Player A

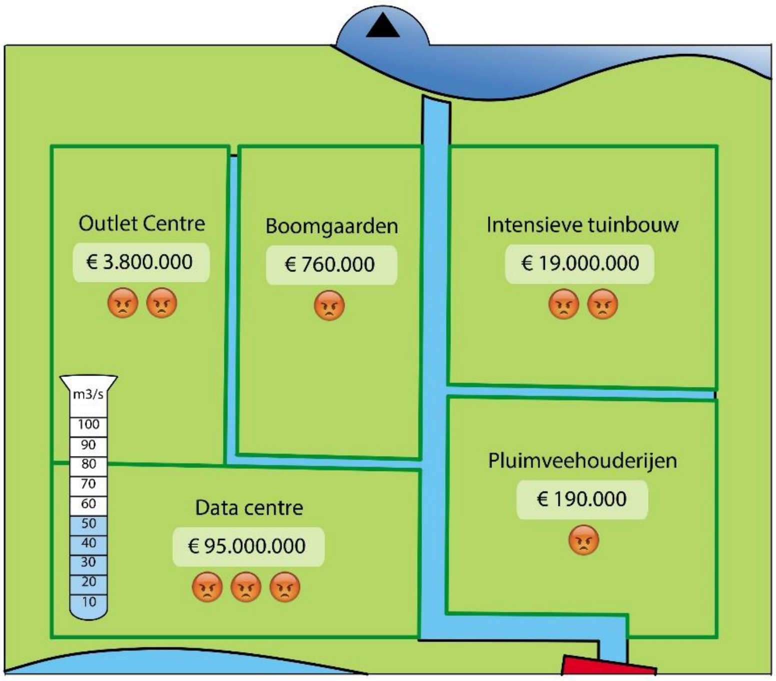


Figure 44 Deltego: Personal water system card Player B

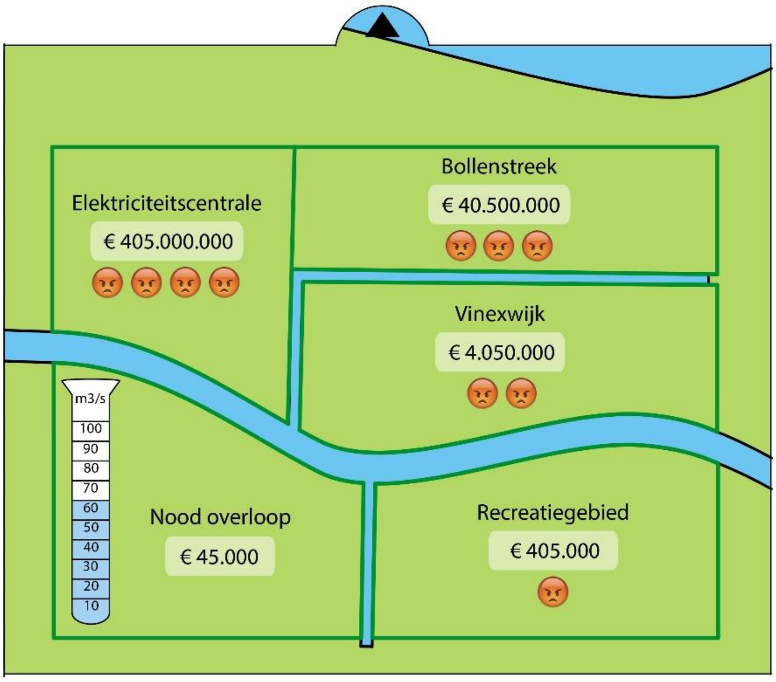


Figure 45 Deltego: Personal water system card Player C

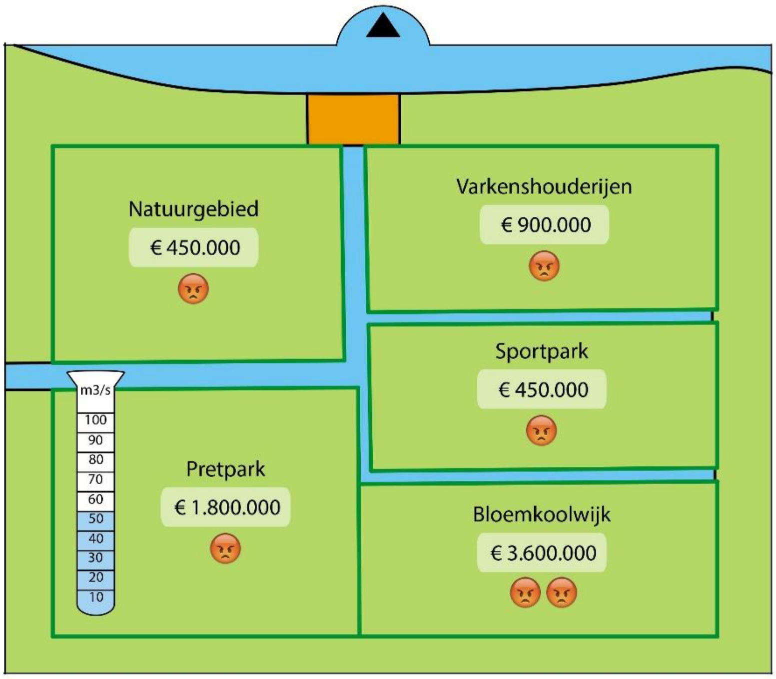


Figure 46 Deltego: Personal water system card Player C

Information

Game presentation slides

Figure 47 Deltego presentation: Slide 1

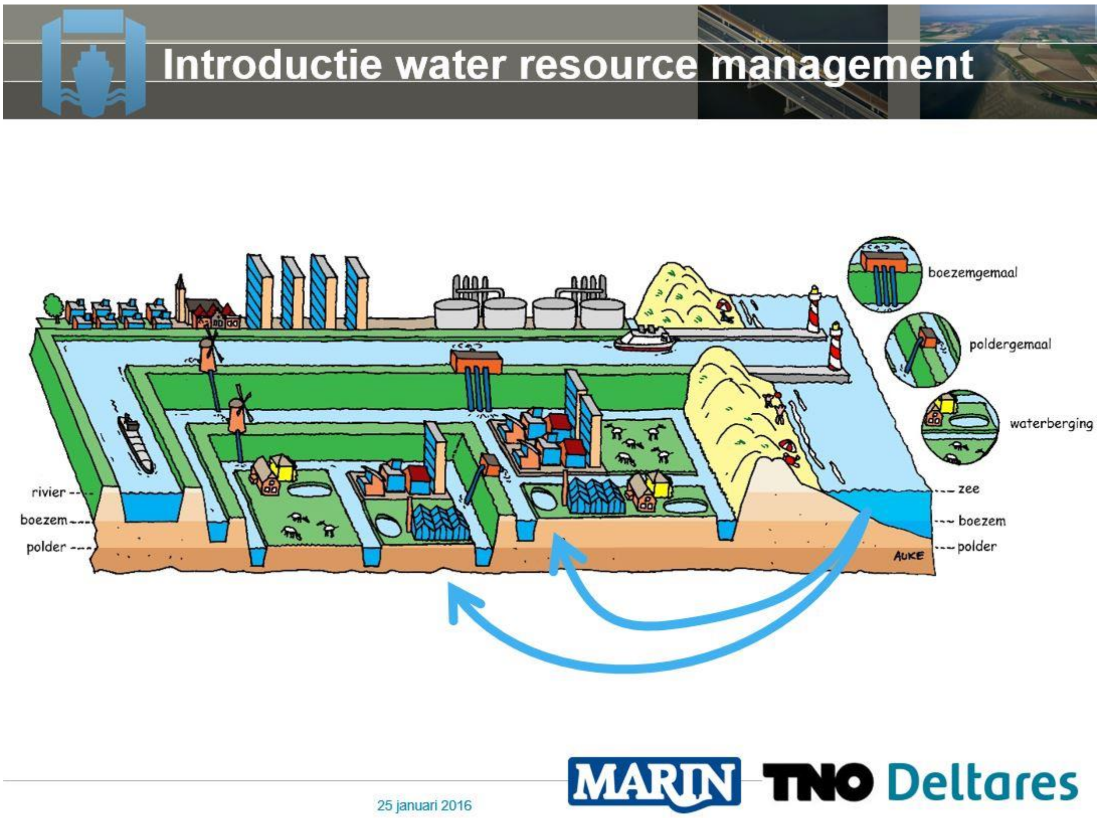


Figure 48 Deltego presentation: Slide 2

Figure 49 Deltego presentation: Slide 3

Figure 50 Deltego presentation: Slide 4

Figure 51 Deltego presentation: Slide 5

Figure 52 Deltego presentation: Slide 6

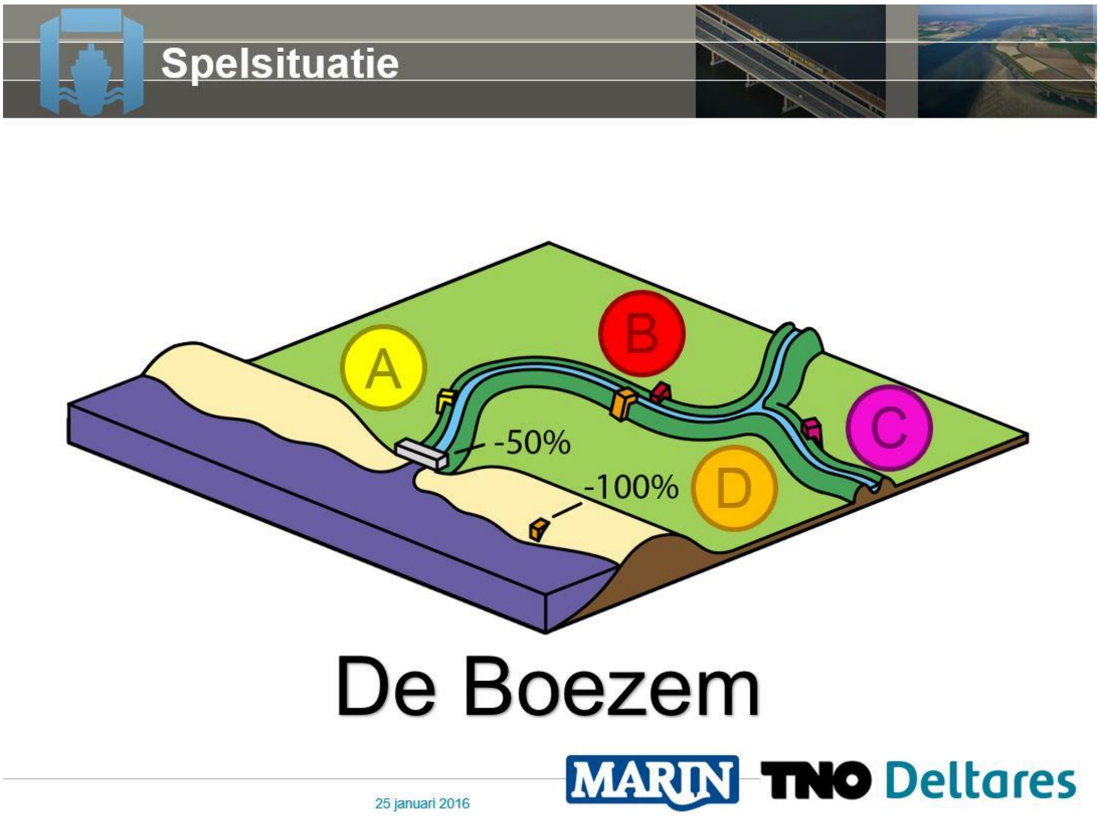


Figure 53 Deltego presentation: Slide 7

Figure 54 Deltego presentation: Slide 8

Figure 55 Deltego presentation: Slide 9

Figure 56 Deltego presentation: Slide 10

Figure 57 Deltego presentation: Slide 11

Figure 58 Deltego presentation: Slide 12

Figure 59 Deltego presentation: Slide 13

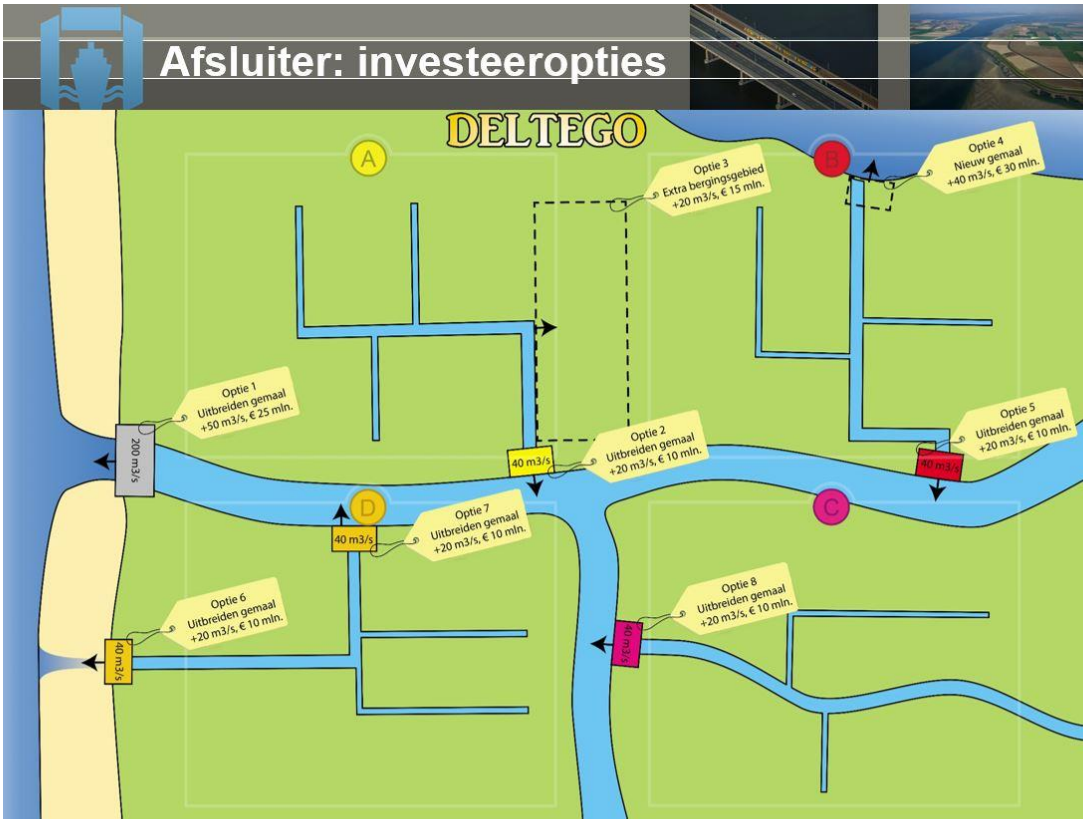


Figure 60 Deltego presentation: Slide 14

Figure 61 Deltego presentation: Slide 15

Figure 62 Deltego presentation: Slide 16

Figure 63 Deltego presentation: Slide 17

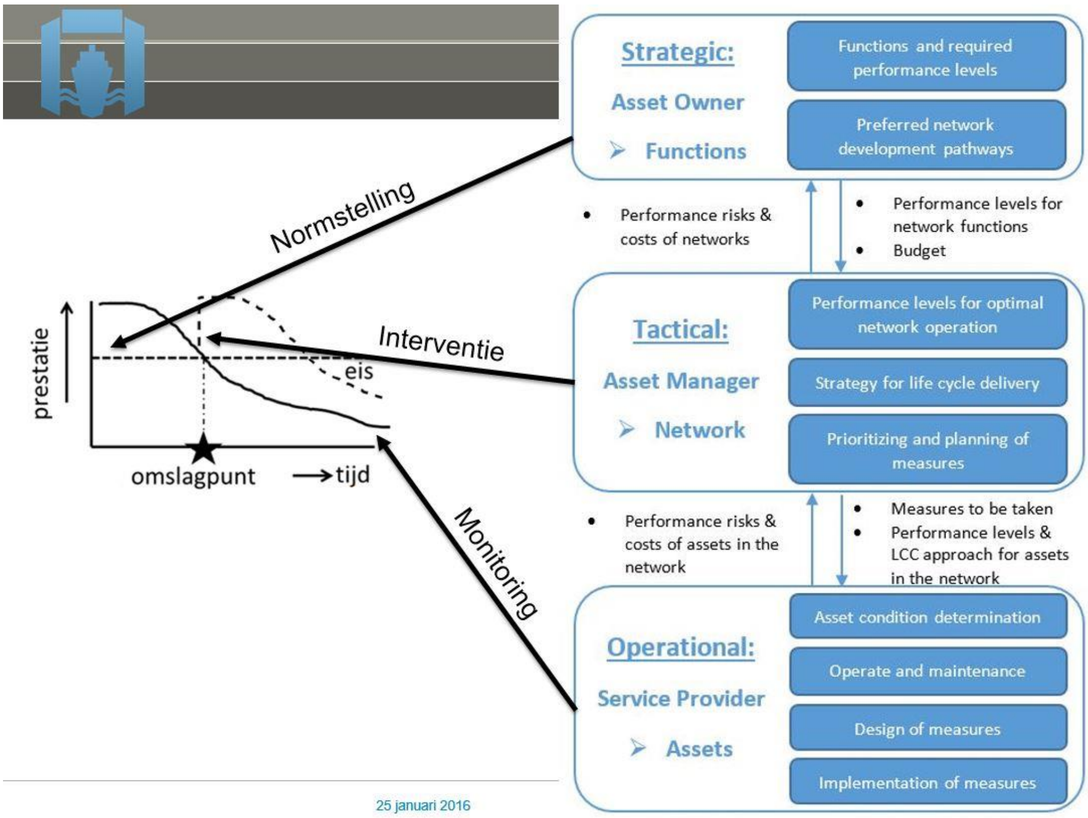


Figure 64 Deltego presentation: Slide 18

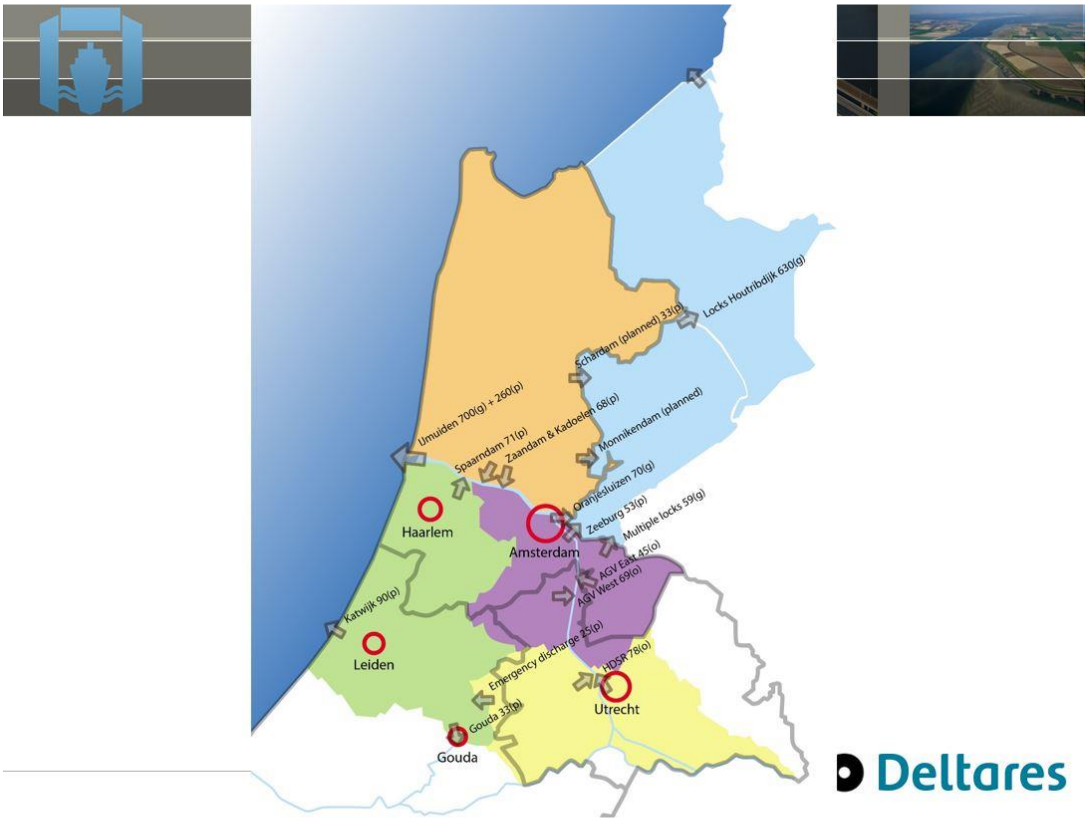


Figure 65 Deltego presentation: Slide 19

Game rules

Spelregels

Iedere speler heeft via een monitor zicht op zijn waterschap. Deze monitor verschaft alle nuttige systeeminformatie in crisissituaties.

Linksonder in het scherm staat de gevallen waterlast van het gebied weergeven. Deze waterlast kan worden **geloosd** op de boezem. Lozen op de boezem is kosteloos en kan in hoeveelheden van 10 m^3/s. Echter zit er een maximale capaciteit aan wat je kunt lozen.

- Ten eerste kan je poldergemaal maximaal 40 m^3/s lozen
- Ten tweede kan de totale boezem door de hoge waterstand nog maar 100 m^3/s aan

Als de boezem capaciteit overschreden wordt, **overstroomt** de boezem. Per 10 m^3/s die teveel geloosd is, lijden alle spelers samen €40 mln. Schade.

In plaats van lozen, kan water ook tijdelijk **bergen** eigen gebied. In ieder gebied kan 10 m^3/s geborgen worden. Per gebied verschillend, zijn kosten verbonden aan het bergen. Daarnaast zorgt bergen voor negatieve publiciteit in de media.

Je wilt eigen kosten zoveel mogelijk beperken en negatieve publiciteit mijden. Het is nu aan jou om voor je systeem te bepalen wat je met de waterlast gaat doen: **Hoeveel van de waterlast ga je lozen en hoeveel ga je bergen?**

Figure 66 Deltego: Game rules handout

Feedback

Investment decision form

Speler: ☐

Investeer beslissing:

Bepaal welke investering voor jouw gebied het meest gewenst is om de functionaliteit te verbeteren..
Rangschik de opties van meest gewenste investering (1), naar meest ongewenste (8). Motiveer de keuze.

Opties	Motivering
1.	....
2.	....
3.	....
4.	....
5.	....
6.	....
7.	....
8.	....

Figure 67 Deltego: Form investment decision rounds

Feedback formulier "Deltego"

Personalia

Functie ....

Organisatie ....

Algemene indruk

Maak voor de vragen in deze sectie keuze uit de onderstaande mogelijkheden

1: Slecht 2: Matig 3: Prima 4: Goed 5: Uitstekend

Wat is uw beoordeling van het spel in zijn geheel?: ☐

Wat is uw beoordeling van de locatie waar het spel gehouden is?: ☐

Wat is uw beoordeling van de informatie verstrekking van te voren?: ☐

Waren de regels in het spel duidelijk?: **Ja/Nee**, want ....

....

Wat is uw beoordeling van het tempo/duur in het spel?: ☐

Wat is uw beoordeling van de faciliteiten in het spel?: ☐

Wat is uw beoordeling van de informatie verstrekking achteraf?: ☐

Realiteit en concretisering

Maak voor de vragen in deze sectie keuze uit de onderstaande mogelijkheden

1: Slecht 2: Matig 3: Prima 4: Goed 5: Uitstekend

In hoeverre komt het spel realistisch over?: ☐

Wat is uw beoordeling van de bruikbaarheid van het spel in de praktijk?: ☐

In hoeverre heeft het spel aan uw verwachtingen heeft voldaan?: ☐

Spelervaring

Maak voor de vragen in deze sectie keuze uit de onderstaande mogelijkheden

1: Zeer weinig 2: Weinig 3: Gemiddeld 4: Veel 5: Zeer veel

Met hoeveel plezier u het spel speelde?: ☐

In hoeverre sloot het spel aan op uw kennisniveau?: ☐

Reflectie

Maak voor de vragen in deze sectie keuze uit de onderstaande mogelijkheden

1: Slecht 2: Matig 3: Prima 4: Goed 5: Uitstekend

Wat is uw beoordeling van het nut van het spel? ☐

In hoeverre is het spel erin geslaagd nieuwe u nieuwe inzichten te geven? ☐

Benoem welke inzichten u door de game gekregen heeft:

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

Wat is uw beoordeling de mate waarin het spel aanzet tot het maken van andere keuzes? ☐

Speltechnische feedback

Welk onderdeel van het spel werkte goed?

…………………………………………………………………………

Welk onderdeel van het spel werkte niet?

…………………………………………………………………………

Ziet u nog andere verbeterpunten? **Ja/Nee** Zo ja, welke?

…………………………………………………………………………

Overige opmerkingen

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

Figure 68 Deltego: Feedback form

Game mechanics

Score form

Spelsituatie ☐ **Speler** ☐

Hoeveelheid bemalen ☐

Hoeveelheid bergen ☐

Negatieve publiciteit door bergen ☐

Kosten bergen € ______

Compensatie -/+ € ______

Boezem overstroomt? Ja/Nee

Totale kosten € ______

Figure 69 Deltego: Score form

Excel programming

Game			Aantal uitkomsten < 10.000.000
Regionale waterlast	5		1
Kosten schade maalstop	€ -40.000.000,00		
Capaciteit boezem	10		
Actor A			
Kosten 1 berging	€ -325.000,00		
Groei factor bergingkosten	4		
Extra waterlast	0		
Actor B			
Kosten 1 berging	€ -190.000,00		
Groei factor bergingkosten	5		
Extra waterlast	0		
Actor C			
Kosten 1 berging Actor 3	€ -45.000,00		
Groei factor bergingkosten	10		
Extra waterlast	1		
Actor D			
Kosten 1 berging Actor 4	€ -450.000,00		
Groei factor bergingkosten	2		
Extra waterlast	0		

Figure 70 Deltego excel: Game input

J8 =ALS(B8>0;Input!$B$8^(B8-1)*Input!$B$7;0)+ALS(A8=0;0;ALS(I8<0;I8*Input!$B$3*-1/(ALS(A8>0;1)+ALS(C8>0;1)+ALS(E8>0;1)+ALS(G8>0;1))))

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Handelingen								Maalstop	Kosten				
2	Actor 1		Actor 2		Actor 3		Actor 4			Actor 1	Actor 2	Actor 3	Actor 4	Totaal kosten bui
3	Pompen	Bergen	Pompen	Bergen	Pompen	Bergen	Pompen	Bergen						
4	5	0	5	0	5	1	5	0	-10	€ -100.000.000,00	€ -100.000.000,00	€ -100.045.000,00	€ -100.000.000,00	€ -400.045.000,00
5	5	0	5	0	5	1	4	1	-9	€ -90.000.000,00	€ -90.000.000,00	€ -90.045.000,00	€ -90.450.000,00	€ -360.495.000,00
6	5	0	5	0	5	1	3	2	-8	€ -80.000.000,00	€ -80.000.000,00	€ -80.045.000,00	€ -80.900.000,00	€ -320.945.000,00
7	5	0	5	0	5	1	2	3	-7	€ -70.000.000,00	€ -70.000.000,00	€ -70.045.000,00	€ -71.800.000,00	€ -281.845.000,00
8	5	0	5	0	5	1	1	4	-6	€ -60.000.000,00	€ -60.000.000,00	€ -60.045.000,00	€ -63.600.000,00	€ -243.645.000,00
9	5	0	5	0	5	1	0	5	-5	€ -66.666.666,67	€ -66.666.666,67	€ -66.711.666,67	€ -7.200.000,00	€ -207.245.000,00
10	5	0	5	0	4	2	5	0	-9	€ -90.000.000,00	€ -90.000.000,00	€ -90.450.000,00	€ -90.000.000,00	€ -360.450.000,00
11	5	0	5	0	4	2	4	1	-8	€ -80.000.000,00	€ -80.000.000,00	€ -80.450.000,00	€ -80.450.000,00	€ -320.900.000,00
12	5	0	5	0	4	2	3	2	-7	€ -70.000.000,00	€ -70.000.000,00	€ -70.450.000,00	€ -70.900.000,00	€ -281.350.000,00
13	5	0	5	0	4	2	2	3	-6	€ -60.000.000,00	€ -60.000.000,00	€ -60.450.000,00	€ -61.800.000,00	€ -242.250.000,00
14	5	0	5	0	4	2	1	4	-5	€ -50.000.000,00	€ -50.000.000,00	€ -50.450.000,00	€ -53.600.000,00	€ -204.050.000,00
15	5	0	5	0	4	2	0	5	-4	€ -53.333.333,33	€ -53.333.333,33	€ -53.783.333,33	€ -7.200.000,00	€ -167.650.000,00
16	5	0	5	0	3	3	5	0	-8	€ -80.000.000,00	€ -80.000.000,00	€ -84.500.000,00	€ -80.000.000,00	€ -324.500.000,00
17	5	0	5	0	3	3	4	1	-7	€ -70.000.000,00	€ -70.000.000,00	€ -74.500.000,00	€ -70.450.000,00	€ -284.950.000,00
18	5	0	5	0	3	3	3	2	-6	€ -60.000.000,00	€ -60.000.000,00	€ -64.500.000,00	€ -60.900.000,00	€ -245.400.000,00
19	5	0	5	0	3	3	2	3	-5	€ -50.000.000,00	€ -50.000.000,00	€ -54.500.000,00	€ -51.800.000,00	€ -206.300.000,00
20	5	0	5	0	3	3	1	4	-4	€ -40.000.000,00	€ -40.000.000,00	€ -44.500.000,00	€ -43.600.000,00	€ -168.100.000,00
21	5	0	5	0	3	3	0	5	-3	€ -40.000.000,00	€ -40.000.000,00	€ -44.500.000,00	€ -7.200.000,00	€ -131.700.000,00
22	5	0	5	0	2	4	5	0	-7	€ -70.000.000,00	€ -70.000.000,00	€ -115.000.000,00	€ -70.000.000,00	€ -325.000.000,00
23	5	0	5	0	2	4	4	1	-6	€ -60.000.000,00	€ -60.000.000,00	€ -105.000.000,00	€ -60.450.000,00	€ -285.450.000,00
24	5	0	5	0	2	4	3	2	-5	€ -50.000.000,00	€ -50.000.000,00	€ -95.000.000,00	€ -50.900.000,00	€ -245.900.000,00
25	5	0	5	0	2	4	2	3	-4	€ -40.000.000,00	€ -40.000.000,00	€ -85.000.000,00	€ -41.800.000,00	€ -206.800.000,00
26	5	0	5	0	2	4	1	4	-3	€ -30.000.000,00	€ -30.000.000,00	€ -75.000.000,00	€ -33.600.000,00	€ -168.600.000,00

Figure 71 Deltego excel: Simulation overview of possible scenarios

Kosten berging				
Actor A	Kosten totaal	Kosten p.l.	Type gebied	Boosheid
1	€ -325.000,00	€ -325.000,00	Broedgebied	1
2	€ -1.300.000,00	€ -975.000,00	Melkveehouderijen	1
3	€ -5.200.000,00	€ -3.900.000,00	Villawijk	2
4	€ -20.800.000,00	€ -15.600.000,00	Dorpskern	2
5	€ -83.200.000,00	€ -62.400.000,00	Medisch Centrum	3
6	€ -332.800.000,00	€ -249.600.000,00		

Figure 72 Deltego excel: Cost storage actor A

Actor B	Kosten totaal	Kosten p.l.	Type gebied	Boosheid
1	€ -190.000,00	€ -190.000,00	Pluimveehouderijen	1
2	€ -950.000,00	€ -760.000,00	Boomgaarden	1
3	€ -4.750.000,00	€ -3.800.000,00	Outlet Centre	2
4	€ -23.750.000,00	€ -19.000.000,00	Intensieve tuimbouv	2
5	€ -118.750.000,00	€ -95.000.000,00	Data Centre	3
6	€ -593.750.000,00	€ -475.000.000,00		

Figure 73 Deltego excel: Cost storage actor B

Actor C	Kosten totaal	Kosten p.l.	Type gebied	Boosheid
1	€ -45.000,00	€ -45.000,00	Noodoverloop	0
2	€ -450.000,00	€ -405.000,00	Recreatiegebied	1
3	€ -4.500.000,00	€ -4.050.000,00	Vinexwijk	2
4	€ -45.000.000,00	€ -40.500.000,00	Bollenstreek	3
5	€ -450.000.000,00	€ -405.000.000,00	Elektriciteitscentrale	4
6	€ -4.500.000.000,00	€ -4.050.000.000,00		

Figure 74 Deltego excel: Cost storage actor C

Actor D	Kosten totaal	Kosten p.l.	Type gebied	Boosheid
1	€ -450.000,00	€ -450.000,00	Sportpark	1
2	€ -900.000,00	€ -450.000,00	Natuurgebied	1
3	€ -1.800.000,00	€ -900.000,00	Broedgebied	1
4	€ -3.600.000,00	€ -1.800.000,00	Tuinbouw	1
5	€ -7.200.000,00	€ -3.600.000,00	Pretpark	2
6	€ -14.400.000,00	€ -7.200.000,00		

Figure 75 Deltego excel: Cost storage actor D

Appendix I: Game session results

Game Session 1

Kosten						
Rondes	Speler A	Speler B	Speler C	Speler D	Totaal	Std
1	€ 41.400.000,00	€ 40.950.000,00	€ 40.450.000,00	€ 40.450.000,00	€ 163.250.000,00	€ 457.119,61
2	€ 1.300.000,00	€ 950.000,00	€ 4.500.000,00	€ 3.600.000,00	€ 10.350.000,00	€ 1.734.154,45
3	€ 11.875.000,00	€ 13.275.000,00	€ 12.575.000,00	€ 8.575.000,00	€ 46.300.000,00	€ 2.080.064,10
4	€ 1.300.000,00	€ 950.000,00	€ 450.000,00	€ 7.200.000,00	€ 9.900.000,00	€ 3.169.253,33

Investeer beslissing: gewenst - ongewenst	Speler A		Speler B		Speler C		Speler D	
	Voor	Na	Voor	Na	Voor	Na	Voor	Na
1	2	1	5	1	8	1	3	1
2	3	3	4	4	1	8	8	8
3	1	4	1	3	3	6	5	3
4	6	6	3	6	4	3	4	4
5	4	2	2	5	6	4	7	7
6	8	8	7	7	2	5	1	2
7	7	5	8	2	7	2	2	5
8	5	7	6	8	5	7	6	6

	Opties in eigen systeem
xx	Opties die systeem verder belasten
xx	Opties die systeem ontlasten

Figure 76 Deltego: Player input score and investment decision form, session 1

Game Session 2

Kosten						
Rondes	Speler A	Speler B	Speler C	Speler D	Totaal	Std
1	€ 40.325.000,00	€ 40.190.000,00	€ 40.450.000,00	€ 40.450.000,00	€ 161.415.000,00	€ 124.054,76
2	€ 3.200.000,00	€ 2.950.000,00	€ 6.500.000,00	€ -200.000,00	€ 12.450.000,00	€ 2.737.509,51
3	€ 4.300.000,00	€ 950.000,00	€ 1.450.000,00	€ 4.200.000,00	€ 10.900.000,00	€ 1.773.179,82
4	€ 1.300.000,00	€ 950.000,00	€ 450.000,00	€ 7.200.000,00	€ 9.900.000,00	€ 3.169.253,33

Investeer beslissing: gewenst - ongewenst	Speler A		Speler B		Speler C		Speler D	
	Voor	Na	Voor	Na	Voor	Na	Voor	Na
1	1	4	4	4	8	1	6	4
2	2	1	5	3	1	3	7	1
3	3	3	3	7	6	3	1	3
4	-	2	2	8	3	8	4	7
5	-	-	1	2	4	-	2	6
6	-	-	6	5	2	-	8	2
7	-	-	7	1	5	-	5	5
8	-	-	8	6	7	-	3	8

	Opties in eigen systeem
xx	Opties die systeem verder belasten
xx	Opties die systeem ontlasten

Figure 77 Deltego: Player input score and investment decision form, session 2

Game Session 3

Kosten						
Rondes	Speler A	Speler B	Speler C	Speler D	Totaal	Std
1	€ 40.325.000,00	€ 40.950.000,00	€ 40.805.000,00	€ 40.900.000,00	€ 162.980.000,00	€ 286.385,52
2	€ 3.100.000,00	€ 3.750.000,00	€ 3.200.000,00	€ 3.100.000,00	€ 13.150.000,00	€ 311.916,12
3	€ 3.100.000,00	€ 3.400.000,00	€ 3.100.000,00	€ 3.100.000,00	€ 12.700.000,00	€ 150.000,00
4	€ 1.300.000,00	€ 950.000,00	€ 450.000,00	€ 7.200.000,00	€ 9.900.000,00	€ 3.169.253,33

Investeer beslissing: gewenst - ongewenst	Speler A		Speler B		Speler C		Speler D	
	Voor	Na	Voor	Na	Voor	Na	Voor	Na
1	2	1	5	5	8	8	1	6
2	1	4	4	4	1	1	6	1
3	6	6	1	1	7	3	7	4
4	4	2	6	6	6	2	4	3
5	5	3	7	7	5	6	2	7
6	7	5	8	2	4	7	5	8
7	8	7	2	8	2	5	8	2
8	3	8	3	3	3	4	3	5

	Opties in eigen systeem
xx	Opties die systeem verder belasten
xx	Opties die systeem ontlasten

Figure 78 Deltego: Player input score and investment decision form, session 3

Feedback form rating

	Rating from 1 - 5, 1 is bad, 5 is excellent													Gem	StD			
General impression	Session 1				Session 2					Session 3								
General rating of the game	5	4	4	4	4	5	4	4	4	5	4	4	5	4,31	0,48		Students	4,1261261
Rating of the game location	3	5	3	4	5	5	5	4		4	5	4	4	4,25	0,75		Deltares	4,2463768
Rating of the information about the game before hand	4	2	3	3	4	5	4	4	3	4	3	2	4	3,46	0,88			
Were the rules clear? Yes/No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes					
Rating of the game tempo and duration	4	4	4	4	5	5	4	4	4	5	3	4	4	4,15	0,55			
Rating of the game facilities	4	4	4	5	4	5	4	5	5	5	4	3	5	4,38	0,65			
Rating of the information about the game afterwards	5	5	5	5	5	4	4	4	5	4	5	4	5	4,62	0,51			
Realism and concretising																		
Rating of the realism of the game	5	4	3	5	4	4	3	4	4	4	3	4	5	4,00	0,71			
Rating of the practical use	5	4	4	4	4	4	5	4	4	5	4	4	5	4,31	0,48			
Rating of the the extend to which the game the expectations	4	4	4	4	4	5	4	4	4		4	3	5	4,08	0,51			
User experience																		
Rating of the entertainment	5	4	4	4	4	5	4	5	4	5	4	3	5	4,31	0,63			
Rating of the comprehensiveness	4	5	5	3	4	5	4	4	3	4	3	4	4	4,00	0,71			
Reflection																		
Rating of the added value of the game	4	4	4	5	5	5	5	4	5	5	4	4	5	4,54	0,52			
Rating of the ability to create new insights	5	5	4	5	4	5	4	3	3	4	3	4	5	4,15	0,80			
Rating of the extend the game stimulate different decisions	5	4	3	5	4	5	4	4	3	4	3	2	4	3,85	0,90			

Figure 79 Deltego: Player input feedback form, all sessions