A framework for the assessment of sustainability, functionality and stakeholders within multi-functional flood defence projects

Bachelor Thesis Final Report

Civil Engineering - University of Twente

Movares Nederland B.V.

By
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Figure on title page: Multi-functional flood defence project Afsluitdijk, collaboration on innovation and sustainability (Rijkswaterstaat, 2020a).

Colophon

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Preface

In front of you is my thesis 'A framework for the assessment of sustainability, functionality and stakeholders within multi-functional flood defence projects'. This product is the final assignment which is part of the third year of the bachelor program of Civil Engineering at University of Twente. In the past twelve weeks, I have been able to work on my research at Movares. Within the Hydraulic Engineering department, I have conducted research into multi-functional flood defences and the feasibility of topics like sustainability, functionality and stakeholders. Within Movares' innovation and water departments, this subject is currently underexposed and requires more depth and perspective from important stakeholders. With this research I hope to contribute to the further understanding of this. The first phase of the research consisted of a literature study and the second phase of the research consisted of interviews and an analysis of the knowledge obtained from phase one.

I would like to thank my external supervisor Thom Olsthoorn for his supervision and support throughout the entire graduation period. He was always open to questions and feedback and was very enthusiastic in his guidance and interest in the subject. From the University of Twente I would like to thank Johan Damveld for his guidance as well. Besides helpful tips and feedback, Johan has kept me on track to finish all deadlines in time and with his scientific background he took my research to a higher level.

In addition to my two supervisors, I would like to thank Movares for their persistence and aid in these difficult Corona times and, in particular, my colleagues in the Hydraulic Engineering department for their help, friendliness and interest. Although I was working from home constantly, I had a very pleasant experience with Movares, where the working atmosphere was always good and everyone was open to substantive or non-substantive conversations. Last but not least, I would like to thank everyone who has been involved in my research, such as interviewees, friends and family.

Finally, I wish you as a reader a lot of pleasure in reading my thesis. If you have any further interest, questions or comments regarding this report, you can reach me by e-mail: o.f.neijenhuis@student.utwente.nl

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Summary

The water sector within the Civil Engineering (CE) industry is subject to an increasing complexity within their projects caused by global and national transformations in the field of for example politics, climate change, economics and innovation. This thesis focuses specifically on multi-functional flood defence projects and three essential CE topics which continuously co-develop alongside these transformations, namely sustainability, functionality and stakeholders. The expanding complexity of the multi-functional flood defence projects results in more design and building issues, which need to be tackled by innovative solutions. The Hydraulic Engineering department of Consultancy Movares recently has thought of a new innovation specifically for the flood defence sector: the water-filled dyke (WFD). Movares' idea for the WFD concept originates from a tender for the Dutch municipality 'Haarlemmermeerpolder' case.

The aim of this research is to gain insight into the three research topics and to develop an assessment framework for multi-functional flood defence projects with the aid of the WFD concept as an example. The framework assures a more efficient working process within Movares and it acts as a tool to develop and assess innovations. The main research question following from the research aim is:

What does a framework look like that assesses the feasibility of multi-functional flood defence solutions, from a sustainable, functional and stakeholder perspective?

Afterwards, a research methodology is set up to obtain an answer to the main research question. The first part of this research consists of a literature study and eight interviews conducted with colleagues from Movares and clients Rijkswaterstaat and the water board Drents Overijsselse Delta. Each interviewee has their own expertise in a specific work field, such as hydraulic engineering, water safety, sustainability & circularity and innovation. Subsequently, obtained knowledge is processed to gain insight into the topics and to create an overview of all the results. With respect to the WFD concept as an example, it is possible to answer the research sub-questions and give direction to the further development of the WFD concept in the aspects of sustainability, functionality and stakeholders.

Next, the assessment framework is developed on the basis of literature reviews, the opinions of the interviewees and the researcher's personal estimation and valuation. The framework includes the three main topics as categories, where each category has its own framework criteria which can be judged individually with the aid of a scoring-scale and priority weights. Finally, the framework is applied to two self-conceived WFD alternatives with each their own strengths and weaknesses to validate the functioning and output of the tool. The first alternative focuses on sustainability, safety and ecology. On the contrary, the second alternative concentrates on multi-functionality, practicality and recreation. The

framework results consist of three sub-total scores for each individual category and a total overall score. In Table 1, the scores are presented in a summarised format together with the maximum achievable score.

Table 1: Summarised scores of assessment framework on two WFD alternatives

	Alternative 1	**Alternative 2**
Sustainability	53/54	34.5/54
Functionality	27/54	50.5/54
Stakeholders	37/44	35.5/44
TOTAL SCORE	117/152	120.5/152

After the summation of all sub-total scores, the second alternative edges the first alternative with only a 3.5 point difference overall, while having a lower sub-score in both the sustainability and stakeholder categories. Since the framework assesses the feasibility of multi-functional flood defence solutions, the highest overall scoring alternative appears to be the most feasible and attractive design to realise out of both alternatives.

In the final part of the research it is concluded that within this study, an assessment framework has been developed to design and build future multi-functional flood defence projects more efficiently within Movares with the aid of the WFD concept as an example. The framework distinguishes criteria which are essential, important or desirable and which are not relevant at all. Additionally, the research gives insight into developments within the discussed three topics of multi-functional flood defence projects. Also, the visions of both RWS and the water boards have been discussed. Prior to this, literature research was carried out, interviews were conducted and results were drawn from the framework with WFD alternatives. Lastly, the following discussion points were found during thesis:

- The interviews with colleagues and clients covered a sufficient amount of knowledge on relevant topics to create a functional framework. However, conducting more interviews with other client representatives will decrease the chance of biased answers, inaccuracies or a lack of information
- The three research topics have been investigated thoroughly, but the qualitative nature of the results leads to uncertainty and assumptions
- More framework categories could be added into the assessment framework to obtain a more complete and realistic end product
- The assessment framework definitely has the potential to be valuable for Movares, although it needs more validation by applying the framework in real-life projects and discussing results with colleagues

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Table of Abbreviations

Abbreviation	Meaning
CDE	Common Data Environment
DBFM	Design, Build, Finance, Maintain
D&C	Design & Construct
EMVI	Economisch Meest Voordelige Inschrijving
GWW	Grond-, Weg- en Waterbouw
HWBP	Hoogwaterbeschermingsprogramma
IMS	Innovation Management System
ISO	International Organisation for Standardisation
LCA	Life Cycle Analysis
MKI	Milieu Kosten Indicator
NAP	Normaal Amsterdams Peil
PFAS	Poly- and Perfluoralkyl Substances
RWS	Rijkswaterstaat
UAV-GC	Uniforme Administratieve Voorwaarden voor Geïntegreerde Contractvormen
WDO Delta	Water board Drents Overijsselse Delta
WFD	Water-filled Dyke

1. Introduction

The Netherlands are known for their rich history in water management in order to control the risk of flooding, handle excess water and to retain water in storages in times of drought. Primary flood defences were built to protect land against water and thus are located at the major water bodies in the Netherlands, such as the North Sea, the IJsselmeer and the major rivers. Looking at the long-term effects of climate change, the ongoing land subsidence, the growing population and the increase in economic value, there will always be an increase in the risk of flooding. Therefore, Dutch regional water authorities and the Ministry of Infrastructure and Environment keep on working and investing in water management to guarantee the protection from future flooding or to be ready when water needs to be retained at a certain place. One of the innovative solutions to these issues are multi-functional flood defences or specifically water-filled dykes (WFD) in this research. Movares' original motivation for the WFD concept comes from the municipality Haarlemmermeerpolder case.

For this particular case, Movares has thought of an innovative multi-functional flood defence concept, which is called 'the water-filled dyke'. In brief, the WFD is just like a normal dyke, however the sand and clay core of the dyke has been replaced by two large concrete tubes with holes in them, which can fill themselves with water in times of high water levels. The WFD concept will further be elaborated in Section 2.1. On top of that, this concept may be able to save a lot of sand and clay in the building process and possibly decrease the duration of the design and building process as well. Both aspects would have a positive effect on the sustainability of the emergency peak storage. Furthermore, sand and clay, the building materials of a dyke, need to be reused from the Haarlemmermeerpolder to improve the circularity in this project and to comply with the new Dutch PFAS norms (RIVM, 2019), which restrict the usage of external soil.

Haarlemmermeer is a Dutch polder and municipality in the south of the Dutch province of North Holland. In the centuries before the area became a polder (1849-1852), the Haarlemmermeer used to be a huge water plain (Wikipedia, 2020a). The Haarlemmermeerpolder is vulnerable to flooding during long periods of precipitation. Especially the area around the Kagerplassen, which is in fact the furthest from the four Rhine pumping stations for secondary channel systems into first channel systems, which are located in Halfweg, Spaarndam, Gouda and Katwijk (Wikipedia, 2020b). The Haarlemmermeerpolder, Kagerplassen and four pumping stations are all covered by water board 'Hoogheemraadschap Rijnland'. The water board is responsible for the safety of its 1.3 million inhabitants (Hoogheemraadschap van Rijnland, 2019b) and for clean drinking water. In order to prevent the waterways from overflowing due to high water levels, it is necessary to realise a peak storage area in the southern tip of the Haarlemmermeerpolder. The Haarlemmermeerpolder and the precise location of the storage is shown in Figure 1.1 with the red outlining and the red dot respectively. A more detailed planning area of this storage can be seen in Figure 1.2.

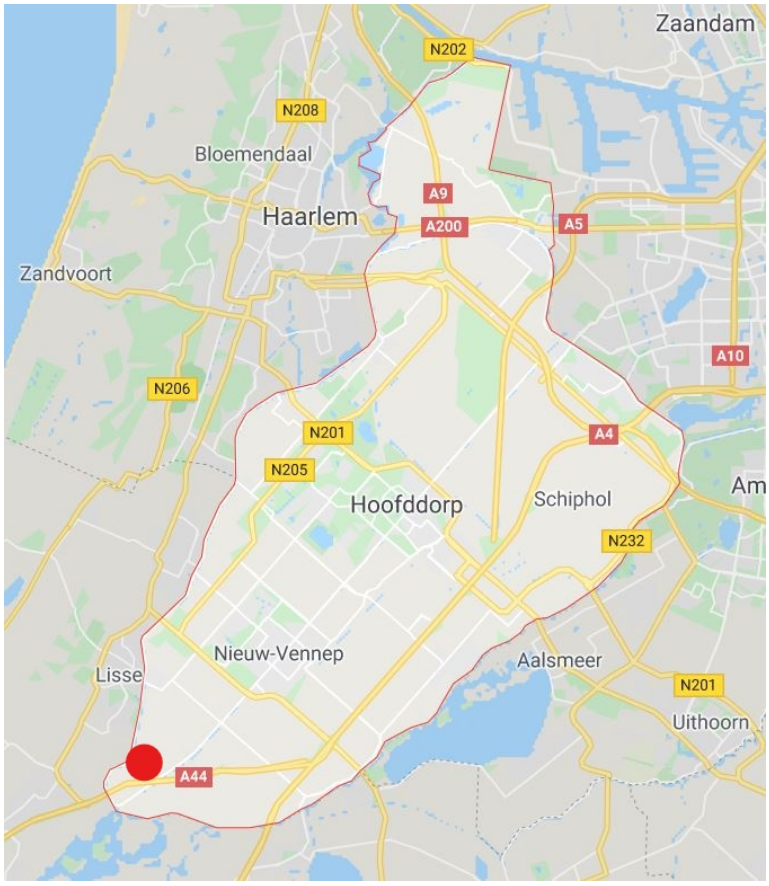

Figure 1.1: Map of Haarlemmermeer municipality (Google Maps, 2020)

Figure 1.2: Planning area peak storage (Hoogheemraadschap van Rijnland, 2019b)

Considering the information given in the previous paragraphs, multiple aspects need to be taken into account to successfully implement such a project. Nowadays, three of the most crucial aspects of a CE project are sustainability, functionality and stakeholders. The latter two have always played a significant role in CE projects. However, due to climate change and the increasing usage of fossil fuels, emission of greenhouse gases and pollution of surface soil by PFAS (RIVM, 2019) or other chemicals, it is necessary that projects take sustainability and circularity into account.

Due to the increasing complexity of CE projects caused by global and national changes regarding sustainability, functionality and stakeholders, the more design and building issues that will arise. Therefore, it is crucial for consultancies such as Movares to develop a robust framework regarding these three crucial CE aspects to address the various types of issues that may arise throughout the design and building phase of the project. Such a framework can be a specific guideline or method which monitors potential issues that could impact your project or organisation. This will make sure that every issue has been assigned, addressed and solved. Having a good framework towards sustainability and functionality issues should increase the quality of design, ensure for more traceable and complete resolution, and should lower the lead time between problem identification and resolution.

1.1 Problem Statement

The Dutch water sector is currently known worldwide for its knowledge in the field of water management and water safety. To maintain this position, it is crucial that the sector continues to develop. Because climate change is increasingly playing a role in water related problems, new techniques and policy measures are needed. These measures must ensure that The Netherlands remains a safe and pleasant living environment, but also more becoming more sustainable is a priority.

Over the past few years, Movares recognized that they and their clients are becoming more aware of the necessity to reduce greenhouse gas emissions and to be more sustainable and multi-functional. In water projects, sustainability is often omitted, however Movares has the ambition to strive for the most sustainable solution in their projects. On the one hand, there is a request from the stakeholders to be more sustainable and circular. On the other hand, there also is an interest in improving the efficiency on the delivered work. Sustainability, functionality and efficiency usually do not go hand in hand. Therefore, it is a really hard and crucial challenge to tackle.

Because the WFD is a relatively new idea, it is still unknown what specific (dis)-advantages the concept has concerning sustainability, functionality and stakeholders. As a result, relevant literature will be researched and colleagues from Movares, Rijkswaterstaat (RWS) and water board Drents Overijsselse Delta (WDO Delta) will be interviewed to obtain a good overview and to make in-depth analyses of these three topics.

On top of that, Movares has no insight on the current developments and requirements in the water management branch. For example, it is not clear what exact project elements regarding sustainability, functionality and stakeholders clients desire from the commercial market when proposing a tender. Consequently, Movares might have trouble to satisfy the governmental institutions on these elements, leading to the following problem statement:

There is no standard, integrated, framework defined for integrating sustainability, functionality and stakeholders within new concepts such as the water-filled dyke and the current vision of RWS on sustainability, functionality and stakeholder cooperation is not known, resulting in an inefficient working process and possibly missing out on interesting and profitable contracts.

1.2 Research Relevance

As mentioned in the problem statement, Movares faces several challenges with implementing sustainability, functionality and stakeholder elements within the design process of projects. This research will attempt to ensure the issues that might affect the project's performance targets such as time, costs, quality and risks can in the future be managed in a more standardised way that is appropriate for Movares. In this process, the opportunity will be provided to develop an increased understanding of the importance of having a solid framework within Movares. At the end of this research, an advice will be drawn up with measures that Movares can take to improve their approach towards multi-functional flood defences and other water projects. As part of the advice, the researcher will indicate how the results could additionally be relevant for other companies who face similar challenges in their design and building process.

1.3 Research Aim

The aim of this research is to gain insight into the three main research topics and to develop a framework to design and build future projects more efficiently within Movares with the aid of the WFD concept as an example case. As a result, in-depth analyses of sustainability, functionality and stakeholders concerning other projects within Movares can be provided through the framework. With the aid of the framework, new potential projects can be found where a WFD could be feasible in terms of sustainability, functionality and stakeholders.

1.4 Research Questions

Main Question

With the aid of the problem statement and research aim, the research questions are drafted. The main question is formulated as follows:

What does a framework look like that assesses the feasibility of multi-functional flood defence solutions, from a sustainable, functional and stakeholder perspective?

Sub-Questions

Subsequently, several sub-questions have been drafted in order to answer the main question and to divide the answer into smaller sections which makes the writing more clear and manageable. As of content-wise, the three main topics stakeholders, sustainability and functionality and their feasibility can all be found in the sub-questions.

1. How can the cooperation between commercial market, Rijkswaterstaat and the Dutch water boards be stimulated in the water-filled dyke concept?
2. What measures can be taken in the building, operating and maintenance phases of the water-filled dyke to obtain a more sustainable and circular construction?
3. What (extra) functions and benefits of water-filled dykes and multi-functional flood defence projects are relevant for stakeholders?
4. How can a general framework be developed to improve the resolution of problems regarding sustainability, functionality and stakeholders based on literature and interviews?

1.5 Research Scope

During this research, the focus of the sub-questions lay on the Haarlemmermeerpolder case and the WFD concept, so that the results can be applied to two alternatives in Chapter 5. Moreover, eight different interviews will be held with colleagues from Movares, RWS and water board Drents Overijsselse Delta, all with their own expertise and experience. More information on these interviews can be found in Section 1.6.5 and appendices A.1 and A.2. Furthermore, an assessment framework including sustainability, functionality and stakeholders is made for Movares. RWS, the water boards and Movares are currently working on projects which could already be assessed with the aid of the framework. However, it is the intention that the easily applicable method can also be used for other future projects within Movares.

1.6 Research Methodology

This section describes the methodology that will be used to achieve the research aim and answer the main question. Moreover, the section is sub-divided into six paragraphs, containing specific methodology for the four research sub-questions and interviews plus a schematic overview of the research methodology. Qualitative research will be conducted for all four research sub-questions, however the results of research sub-question 4 will also contain some quantitative research elements.

1.6.1 Stakeholder Cooperation

First of all, literature research within Movares will be conducted to explore the current cooperation between governmental institutions and the commercial market. Moreover, semi-structured interviews will be conducted with employees from RWS and the WDO Delta who are experts in Hydraulic Engineering, sustainability and project experience.

The information obtained from the interviews will generate multiple measures and recommendations to improve stakeholder cooperation. These findings will be listed in Section 3.1.2 to create an overview of different possibilities for stakeholder cooperation.

1.6.2 Sustainable & Circular Solutions

Similar to the previous methodology, a literature research is done to investigate all possibilities for sustainable and circular solutions for the WFD. On top of that, investigating finished comparable projects will help to explore these possibilities. Besides this, the interviews with sustainability and circularity specialists from Movares, RWS and WDO Delta are crucial for this research as well. The knowledge and experience gained from the interviews will present multiple greener alternatives than current design and construction methods.

From the knowledge gained by this research, a list of sustainable and circular measures can be set up to create an overview of what is possible within the boundaries of the four project phases of the WFD. These measures can then be applied into the currently used methods for calculating sustainability and circularity costs of the WFD. In Chapter 5, several measures will be applied and compared for the WFD case to see which solutions have the best effect on sustainability and circularity.

1.6.3 Feasible Functionalities & Benefits

Considering the exploration of functionalities and benefits for the WFD and multi-functional flood defences in general, literature research and interviews both are as equally important as described in the first two methodologies.

The literature component will consist of analysing finalised multi-functional flood defence projects projects to identify suitable functionalities and benefits for the WFD. In addition, interviewing experts in innovation and hydraulic engineering departments from Movares,

RWS and WDO Delta is a convenient method to gain their knowledge and experience on possible functions and benefits.

1.6.4 Framework for Problem Resolution

For the final research sub-question, all previous obtained information from research sub-questions 1-3 will be processed and all relevant elements are taken into account for the framework. On the same token, literature research is conducted to identify the necessities and requirements (e.g. specific experts, knowledge, visions) for winning a tender. For this, public online contracts of finalised multi-functional flood defences will be used in order to give Movares an advice what to invest in or pay attention to and what already is sufficient. Last but not least, interviews with specific colleagues from Movares, RWS and WDO Delta who were involved in multi-functional defence projects will be organised to gain insight in the three main topics of this research: sustainability, functionality and stakeholders. However, other project elements such as political, ecological, financial and juridical aspects are interesting to cover during the interviews as well.

The three elements of obtained knowledge, literature studies and interviews will be combined in order to make justified choices on what criteria needs to be included in the framework to make it valuable for a comparative study.

The result of this sub-question is a general framework which provides a full understanding of the existing literature and the tender approaches of Movares, RWS, WDO Delta for flood defence projects. Moreover, in Chapter 5 a comparison between two WFD alternatives is drawn to validate the framework.

1.6.5 Interviews

As discussed in the previous paragraphs, a vital method for all the research questions are the interviews conducted with eight colleagues from Movares, RWS and WDO Delta. The interviewees and their functions within the organisation are listed in Table 1.1. In appendices A.1 and A.2, the interview set-up and schedule for each individual interview can be found. This includes all interview respondents, objective, structure and questions.

Table 1.1: Interviewees and their functions

Name	**Function**
Martijn van den Elzen (Movares)	Project Manager Hydraulic Engineering
Teun Dekker (Movares)	Innovation Manager Buildings and Infra
Mieke van Eerten-Jansen (Movares)	Advisor Sustainability & Circularity
Sjoerd Keetels (Movares)	Advisor Sustainability & Circularity
Richard Rijkers (Movares)	Senior advisor Hydraulic Engineering & Geo-engineering
Jan Gruppen (WDO Delta)	Specialist Water Safety
Eric van Kuijk (RWS)	Senior Large Projects and Maintenance in Hydraulic Engineering
Gerwin Schweitzer (RWS)	Senior advisor Climate Neutrality and Circular Purchasing

The interviews will all be semi-structured because this allows the interviewer to improvise follow-up questions based on a participant's response. Additionally, it allows for participants to freely express their opinions and views without obstructing the interview's direction (Kallio et al., 2016). Also, the duration of the interview will be approximately one hour to ensure there is enough time to ask all questions and hold the attention of the interviewee optimally.

For the interviews, it is necessary that a solid explanation of the WFD concept is ready to be presented for RWS, water boards and other contractors to ensure everyone is on the same page concerning the concept and research goals and that the concept is supported from the start. The explanation of the WFD concept and interview preparation is done by three means. Firstly, with the aid of my supervisor Thom Olsthoorn, a technical drawing and calculation for the WFD has been made which is discussed further in Section 2.1. Secondly, an informative PowerPoint including background information, the drawing and calculation has been made. Thirdly, personal interview questions are drafted for each individual interviewee. Combining these three means, the interviewee is prepared as optimal as possible for the interview. The bundled answers (in Dutch) per interview question and PowerPoint can be found in the ZIP-file 'Interview Answers and PowerPoint'.

In these interviews, the goal is to gain an understanding in the three main research topics, how to develop and innovation and to investigate important stakeholders of Movares and their cooperation. More specifically, what are the short- and long-term sustainability and circularity goals for both RWS and WDO Delta and what priorities are set for choosing a tender submission. Furthermore, their opinion and comments on the WFD concept are essential to learn to evaluate the feasibility of the concept. Possibly there are any projects where this concept could be implemented already. Moreover, it is essential to know the vision and goals of RWS and the water boards on safety, functionality and sustainability. Additionally, the interviews will probably result in a better understanding and insight concerning general functionality within hydraulic engineering projects. Subsequently, the information and goals can then be taken into account for Chapter 5 to compose a framework which complies with the vision of RWS and the waterboards.

1.6.6 Schematic Overview Methodology

In this section, a schematic overview of the full research methodology is presented in Figure 1.3. Where the yellow rectangles are representing the research questions and the green rectangles represent the obtained results. Furthermore, the diamond shaped rectangles are the methods used throughout the research, distinguishing two blue methods which gather information and a red method that links all obtained results together into an application of the framework. The black arrows represent the steps which are taken or what the outcome is of a certain rectangle. Lastly, several rectangles include chapter numbers where more information about the concerning subject can be found.

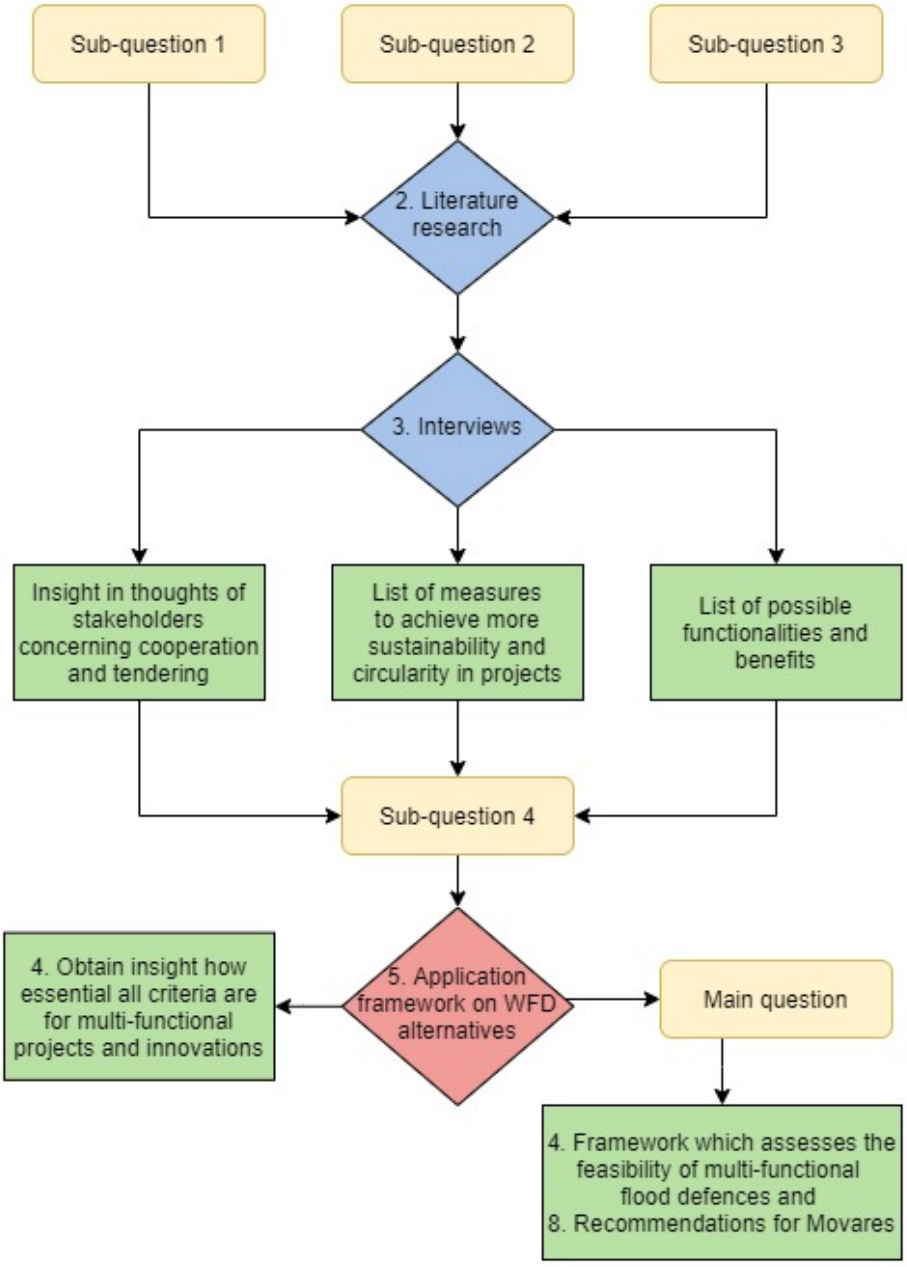

Figure 1.3: Schematic overview research methodology (Neijenhuis, 2020b)

1.7 Thesis Outline

The following paragraph will contain a reading guide for this thesis report. First of all, in Chapter 2 a theoretical framework has been developed to explore and discuss all relevant literature and knowledge. Themes that will be discussed include the operation of an emergency storage, the specific issues with the Haarlemmermeerpolder case and several practice examples. Subsequently, in Chapter 3 all interviews and literature will be further discussed, analysed and all the important findings will be stated here as well. Afterwards, these findings will be used in Chapter 4 to create an integrated framework which assesses the feasibility of multi-functional flood defence projects from a sustainable, functional and stakeholder perspective. Next, the framework will be applied to the example case of the WFD concept in Chapter 5. Two alternatives for the WFD design and their final results concerning sustainability, functionality and stakeholders will be discussed here as well. This will be followed by a discussion of the results in Chapter 6. Last but not least, chapters 7 and 8 will finalise the report with a conclusion and recommendations for Movares and further research.

2. Theoretical Framework

2.1 Water-filled Dyke in the Haarlemmermeerpolder

As mentioned in Chapter 1, Rijnland has four large pumping stations, in Katwijk, Gouda, Halfweg and Spaarndam, and hundreds of polder pumping stations. With the aid of pumps, the water level of the polder is regulated. When there is too much water, the excess water from the polders is pumped to the outflows of the region. These outflows are the most important supply and discharge system and storage system in Rijnland, consisting of large lakes, ponds and channels. However, large amounts of rainwater can be too much to handle for the pumping stations, resulting in flooding. A good solution is to collect the excess water in a peak storage area. A peak storage usually is a dyke section of polder that can be flooded during heavy and prolonged rainfall to temporarily relieve the outflows. The storage will contain water for several weeks and will be empty for the rest of the time (Hoogheemraadschap van Rijnland, 2019a).

Because the Haarlemmermeerpolder is 6 meters below Normaal Amsterdams Peil (NAP: a zero point that represents the average water level of the North Sea) on average, the groundwater levels are relatively high as well due to its low altitude. The high groundwater levels exert a high pressure on the ground level, because ground water tends to go up and the soil layer in between separates the groundwater from the surface. The ground water is in this case stopped by an impermeable clay layer. However, when you dig up too much clay from the surface level, the groundwater will rise due to the lack of clay and the high pressure. As a result, the challenge is to make a dyke that does not need as much soil, but is heavy enough to exert enough pressure on the ground water to keep the ground level dry. Movares has thought of a solution for this problem in the form of a water-filled dyke, which will be elaborated in the following paragraph.

Specifically for the Haarlemmermeer case, Movares has thought of innovative ideas to tackle the outlined problem. The reasoning for a smart flood defence solution is due to the Dutch norms on soil usage in the Haarlemmermeerpolder. Namely, these prescribe that not too much surface soil (clay) can be utilised because of ground water flowing upwards. Besides that, the new PFAS rules restrict the usage of external soil in the Haarlemmermeerpolder. PFAS stands for poly- and perfluoroalkyl substances, which are man-made substances that do not naturally exist and are harmful for the environment. Therefore, strict rules apply so that only soil from the polder itself can be utilised in constructions like dykes.

To save soil usage and ensure the dyke is sufficiently stable and safe horizontally as vertically, the WFD concept has been introduced. This construction is a normal dyke, however the sand and clay core of the dyke has been replaced by two large concrete tubes with holes in them. In brief, these tubes can fill up with water when water levels are rising on the outer

slope of the dyke due to high precipitation for example. As a result, less soil is needed to construct the dyke and therefore the construction will be more lightweight, circular, sustainable and multi-functional in the form of water storage and perhaps cables or pipes can be mounted in the tubes as well. A schematic AutoCAD drawing of the water-filled dyke with assumed dimensions in meters is given in Figure 2.1. A standard 3:1 ratio dyke (width:height) is assumed with 9 meter wide slopes on both sides and a 3 meter high crest , because this represents reality quite accurately in a simple design (Olsthoorn, 2020). The 1 meter top layer of the dyke is made from an impermeable clay layer to prevent water from penetrating the dyke and avoid piping mechanisms from arising. Under the clay, a sand layer is placed as the foundation of the dyke. In addition, there is an inlet from the ground level of the inner slope to the bottom of the tubes, which are made of 30 centimeter thick concrete. By connecting the reservoir and tubes in this manner, the tubes will never drain or fill up on time. Moreover, a water filter is placed on the inlet to prevent unwanted substances, plants or animals from flowing into the tubes.

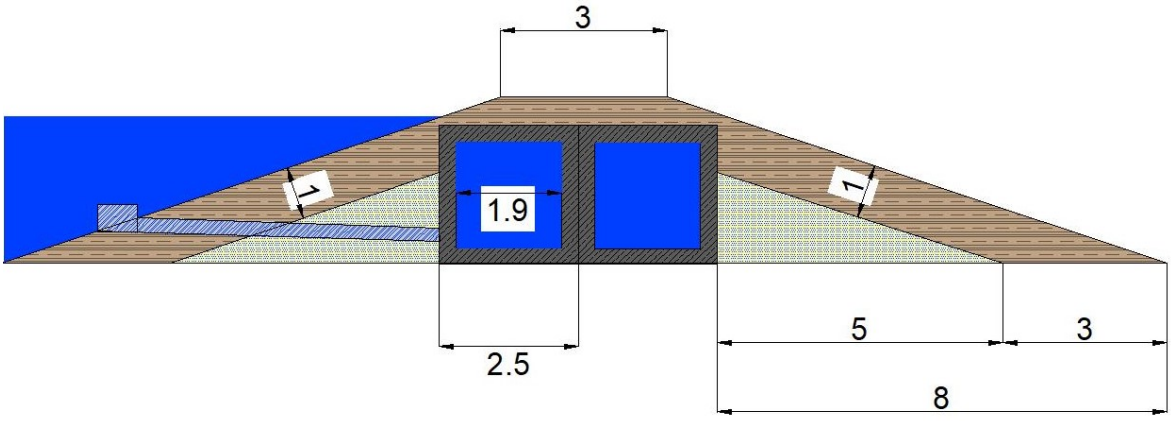

Figure 2.1: Schematic AutoCAD drawing of water-filled dyke with assumed dimensions in meters (Neijenhuis, 2020a)

2.2 Water Safety

2.2.1 Failure Mechanisms

Over the past centuries, The Netherlands has obtained much experience and knowledge in designing and building flood defences. However, there were also countless moments in history where flood defences have failed to achieve their main purpose, for example the 'Watersnoodramp' in 1953 and the Meuse floodings in 1993 and 1995. These flood defence failure mechanisms have been studied thoroughly by multiple experts. Figure 2.2 contains the most commonly encountered failure mechanisms for flood defences, see Jonkman et al., 2018 for a review. Most of them are also relevant for other hydraulic structures like flood gates, locks, sluices or multi-functional flood defences like the WFD. In the following paragraphs, short descriptions of failure mechanisms will be given. These are especially relevant for building a WFD, because these five situations occur most often, while others rarely or never occur at all (Olsthoorn, 2020).

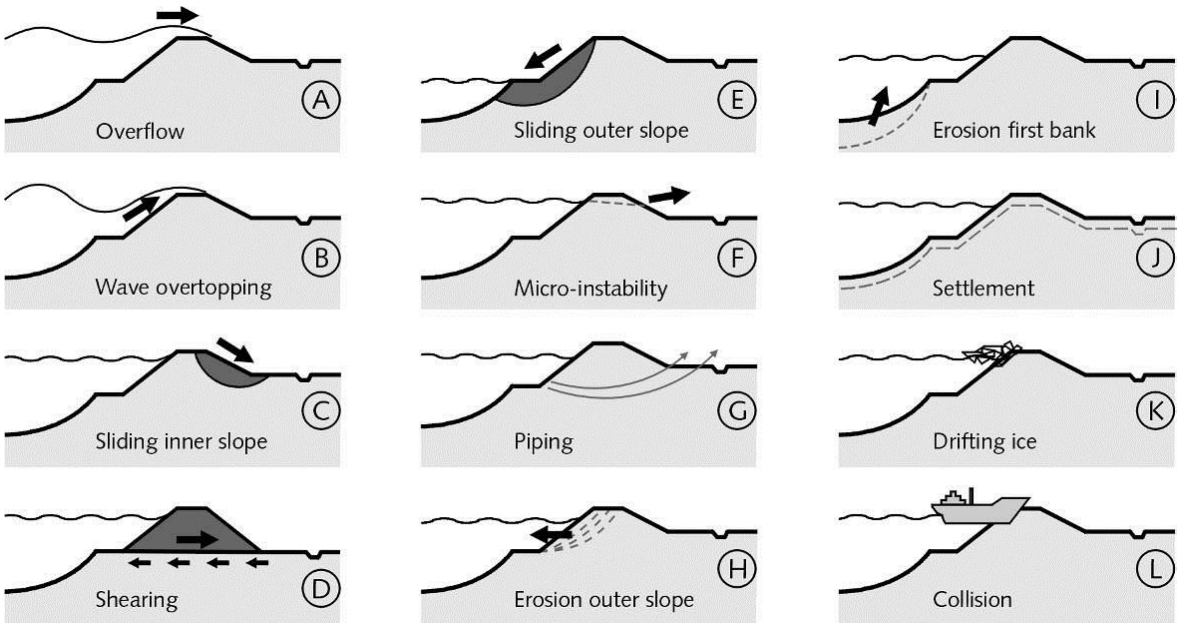

Figure 2.2: Flood defence failure mechanisms (Jonkman et al., 2018)

A: Overflow

Overflow of a dyke or levee means that the still water level (i.e. without waves or the average level considering waves) is higher than the crest level of the flood defence and the water flows into the protected area. In most cases there will be concentrated, local flow, because the height of the crest is not exactly the same everywhere along the dyke. Therefore, overflow is also associated with crest reductions from trampling by livestock. If erosion of the covering layer (grass and clay) takes place, this can increase the concentration of the flow, making the erosion process even faster. If the dike becomes saturated with water, shearing and leaching of the material in the dyke core can easily take place. Eventually, a breach can arise in the dyke and the polder will flood (Deltares, 2020a).

C: Sliding Inner Slope

The most common (mechanical) stability problem with dykes is the instability or sliding of the inner slope. As the outside (e.g. river) water level rises, water infiltrates leading to saturation of the dyke body and to increasing pore pressures. The effective stresses reduce and so does the shear strength of the soil, which can lead to the development of sliding planes in the slope. The mechanism is usually analysed with classical limit-equilibrium methods for slope stability such as Bishop or Spencer. Sliding of the inner slope is typically an issue for river dykes, where the water levels come close to the crest level and flood duration could be long (i.e. days or weeks).

D: Shearing or Horizontal Sliding

Similarly to sliding of the inner slope, sliding or shearing can also occur along the base of the dyke body. In this case, the main driving force is the horizontal force of the water exerted on the outer slope. This mechanism is typically an issue for dyke and levees made of relatively light material such as peat, where the effective stresses at the base are very low. The problem usually exacerbates in long drought periods, when the pore water evaporates from the dyke body and it becomes even lighter.

F: Micro-instability

Micro-instability occurs when the seepage water causes the phreatic surface to rise and reach the inner slope of a dike. In case of impermeable cover layers (e.g. clay) on the inner slope, the increased pressure inside the dyke body can just push off that cover. If in turn the inner slope consists of permeable, granular material, internal erosion can be initiated. The term 'micro' is used to distinguish the stability problems related to this phenomenon from the 'macro-instability', which essentially concerns the whole dyke body directly, like sliding of the slopes or the dyke's base. Though the initial damage may be minor, the progressive nature of micro-instability mechanisms can endanger the integrity of the entire dyke structure.

J: Settlement

Dutch soils, just like soils in any Delta area, are highly compressible and thus susceptible to consolidation, creep and settlements. After construction or reinforcement dykes often settle in the order of decimeters or meters in the years and decades after completion of the works. Rather than a failure mechanism in the sense of the definition provided in the beginning of this chapter, settlements are an aspect to be taken into account, such that, for example, the dyke is not just high enough to prevent overflow right after construction but during its entire design lifetime, which is typically 50 years.

2.2.2 Soil Types

Almost the entire surface of the polder is occupied by gray, sulphurous and clayey soils, which generally becomes heavier upwards of profiles. Also, clay is a relatively strong building material and is nearly impermeable for water due to them small grain size of 2 micrometers, which makes it a useful material for constructing dykes.

Almost everywhere the profile deeper than 75 centimeter to l meter below ground level consists of slightly sulphurous to sandy, calcareous material. Sand is a strong and relatively dry soil compared to clay. However, it can absorb water easily due to the larger grain size of 2 to 50 micrometers and the larger pores content (Bodemrichtlijn, 2020) and sand is therefore also more permeable than clay. The above lying soil is generally heavier, but can vary widely in gravity and lime content. These differences in soil are explained by the silting process that took place throughout the years (Haans, 1954). On average, the polder lies 6 meters below NAP.

According to a soil measurement (ground level altitude is -4.36m NAP) done in the exact location of the planning area of the emergency storage in the Haarlemmermeerpolder which can be found on DINOloket. The website confirms the upper layer is usually clay (green), followed by sand (yellow) and then peat (orange), see Figure 2.3.

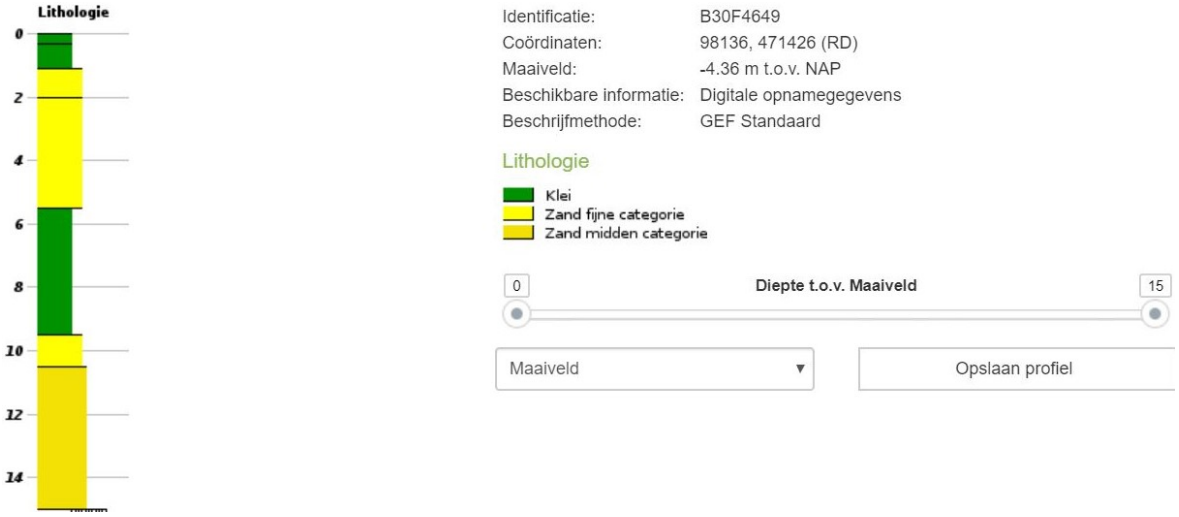

Figure 2.3: DINOloket soil measurement in planning area (DINOloket, 2020)

2.2.3 Settlement

Settlement is the process of soil compression. It is an important phenomenon for hydraulic engineering because it results in a decrease of the ground level including all structures resting on shallow foundations. Especially for flood defences this is relevant because settlement will reduce their water retaining height, which immediately affects their primary function if the design does not sufficiently takes this effect into account. Furthermore, uneven settlements should be avoided or compensated for, in order to prevent structural failure due to too high stresses in the structure.

Settlement can take place in the subsoil ('zetting') or in an embankment ('klink'). Land subsidence also causes a drop in ground level, but this takes place at another geological scale and should also be taken into account when designing flood defences.

Settlement can mainly be caused by two different natural phenomena. It can be caused by expulsion of water out of the pores between the soil particles due to an increase in vertical loading, which is called 'consolidation'. It can also be the result of an ongoing, slower, densification process during which the soil properties gradually change, which is called 'creep' ('kruip'), 'secondary settlement' or 'secular effect' (Molenaar and Voorendt, 2016).

2.3 Caissons

2.3.1 Definition

The name 'caisson' is French and is to be translated as a 'large chest', which refers to the general shape of caissons. In CE terms, a caisson could be defined as a retaining watertight case or box, in order to keep out water during construction, but also for more permanent purposes. The WFD concept could for example also be replaced by a caisson which does not need any soil to keep water out. Figure 2.4 shows schematic drawings how caissons could be positioned if it serves as a flood defence.

Caissons are usually always part of a larger structure, such as a breakwater, substructure or foundation. Therefore, caissons serve a wide variety of purposes in bridges, quays, lock heads, breakwaters or other projects. Caissons are also the result of a development of prefabrication to avoid the painstaking and costly construction of on-site concrete being 'in the wet'. Frequently, caissons are prefabricated and transported to their final position at a later moment in time (Voorendt, Molenaar, and Bezuyen, 2016).

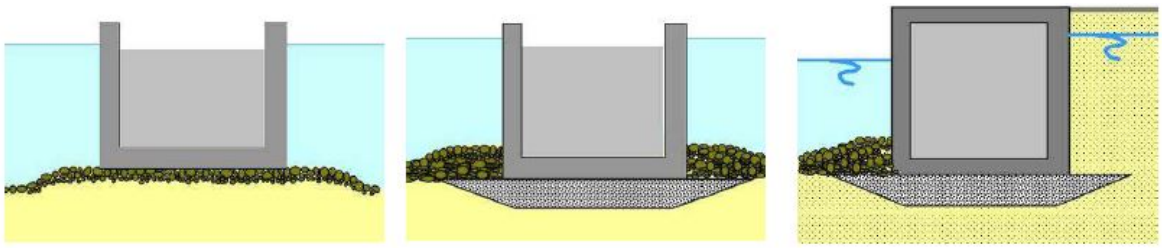

Figure 2.4: Schematic drawings of final caisson positions, standing free (left) and partially embedded (middle & right) (Voorendt, Molenaar, and Bezuyen, 2016)

2.3.2 Functions

The main functions of caissons generally are soil or water retention and transfer of vertical and horizontal loads into the subsoil. Less common functions are provision of space for equipment or machinery, and locking through of ships, if the caisson is part of a lock or barrier. More specifically with respect to functionality, one could distinguish the following functions:

- Closure of breaches in dykes and dams

- Breakwater
- Quay wall
- Storage
- Tunnel element
- Foundation for bridge pier, lighthouse, wind mill, etc.
- Special cases, e.g.:
  - Casing for hydro-electric plant
  - Gate for a dry-dock

Of course a combination of functions can be made, like in Monaco, where a 352 meter long caisson functions as breakwater, quay and car parking. In Monaco this structure is known as 'digue flottante', Anglo-Saxons describe the structure more correctly as a floating breakwater. Another example specifically for the WFD case could be the combination of functions at an existing quay wall of caissons which are also used for the storage of water (Voorendt, Molenaar, and Bezuyen, 2016).

2.4 Innovation Management

Since the WFD is an innovation created specifically for the Haarlemmermeerpolder case, the process of developing such innovations need to be managed from within Movares. Fortunately, there is a certain innovation policy within Movares that prescribes how to handle new ideas and innovations and how to develop them further on. Firstly, the global standards towards innovation will be elaborated with the aid of the International Organisation for Standardisation (ISO). More specifically, ISO56000 describes the standards towards innovation management and also gives a general framework to support companies in managing their innovations (Merrill, 2020). Because certain elements of these standards are also adopted within the innovation policy of Movares, the ISO56000 will be discussed here to create a good foundation for the next chapters.

A globally agreed guiding standard for innovation management will establish a common terminology and a credible reference framework, including innovation management principles. This will help managers to understand what innovation is and what it takes to effectively manage innovation activities. Companies and organizations can adopt a systemic and systematic approach to address their innovation challenges that will increase the likelihood for success (Inngage Consulting AB, 2020).

An Innovation Management System (IMS) is a guiding framework for all types of companies and other organisations that want to strengthen their innovation capabilities. It is a check list, based on a systems approach, of what the organization should consider implementing given its overall innovation ambitions and abilities. The guiding framework is generic and adaptable and does not prescribe specific tools or methods. Also, it can be integrated, with management systems in other areas, such as quality, sustainability and environment (Inngage Consulting AB, 2020).

The systems approach to innovation management recognizes that there are several interrelated and interacting elements or factors in an organization that must be in place to ensure innovation success. The structure of the guiding standard for IMS covers seven key elements, which will be briefly explained below (Inngage Consulting AB, 2020). As mentioned at the beginning of the paragraph, the innovation policy of Movares and ISO56000 have multiple elements in common, which will be discussed in Section 3.1.2.

1. Context

The organization should track external and internal issues and trends, e.g. user preferences, technology developments, and internal capabilities, in order to identify opportunities and challenges that can trigger innovation activities.

2. Leadership

Based on the understanding of the context, top management should demonstrate leadership and commitment by establishing an innovation vision, strategy, and policy, including the necessary roles and responsibilities.

3. Planning

Innovation objectives, organizational structures, and innovation portfolios should be established based on the direction set by top management and the identified opportunities and risks.

4. Support

The support necessary for innovation activities should be put in place, e.g. people with the right competences, financial and other resources, tools and methods, communication and awareness creating activities, as well as approaches for intellectual property management.

5. Operations

Innovation initiatives should be established in line with the strategies and objectives. Innovation processes should be configured according to the types of innovations to be achieved: identify opportunities, create and validate concepts, and develop and deploy solutions.

6. Evaluation

The performance of the Innovation Management System as a whole should regularly be evaluated to identify strengths and gaps.

7. Improvement

Based on the evaluation, the system should be improved by addressing the most critical gaps with regards to the understanding of the context, leadership, planning, support, and

operations.

In Figure 2.5, a visualised model of an IMS is given, including the seven key elements and all its processes.

Figure 2.5: Model innovation management system (Inngage Consulting AB, 2020)

2.5 Multi-functionality and Flood Defence Examples

In this section, the definition of multi-functionality is given and explained. Also, several examples of multi-functional flood defences are given to form an overview what projects have already been realised thus far and to obtain more knowledge and ideas to support me in making a framework.

Multi-functionality can be defined as an advanced form of the multiple use of space whereby the functions in question not only share the space, but are also mutually reinforcing. Multiple use of space is an important concept in understanding multi-functionality. It consists of intensifying and interweaving the use of space by creating floors above or below ground, or introducing relationships in time. Creating floors can also be referred to as 'parallel switching', which means that a space serves two or more functions simultaneously. Just think, for example, of building underground and of high-rise. Relationships in time can also be referred to as 'serial switching', or allowing two functions to take place after each other (consecutively) in the same space. An example of this is an agricultural area that sometimes serves to store water. The only difference between parallel and serial switching is one of time. In both cases, they lead to an intensified use of space, because two or more functions take place either simultaneously or consecutively in the same place. This intensive and multiple use of space goes a step further if these functions become interwoven and start to reinforce each other. Then we speak of multi-functionality (Heijden, 2013).

2.5.1 Step dyke ('Trapdijk') Rotterdam

The project 'Waterwegcentrum (Waterway Centre) Hoek van Holland' gave rise to the idea of the 'step dyke', which is shown in Figure 2.6. Through the use of vertical walls, diaphragm walls or sheet piling, no space-demanding embankments are needed with dyke reinforcement, so the available horizontal surface can be designed efficiently for urban use. This signifies an operational combination. After all, use as flood defence is possible as well as there being space available for urban functions. Urban functions are even strengthened as new space is created, for example also with roads which have been better integrated and cause less nuisance. Moreover, the function of flood defence is further reinforced if the urban functions contribute towards the strength of the flood defences. That is possible, for example, by creating a park on the bottom 'step of the ladder', which can absorb the initial flooding in a simple way. If everything is built at the same time, we can also speak of a constructional combination (Heijden, 2013).

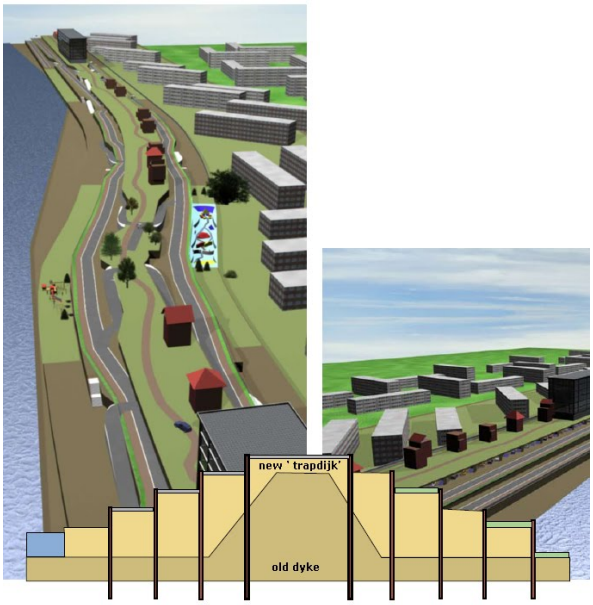

Figure 2.6: Step dyke design (Heijden, 2013)

2.5.2 Super Dyke Tokyo

In Tokyo, a super dyke is being built with other buildings and roads on top of and inside it. This super dyke is reinforced underground with steel sheet piling and strengthened internally with concrete slabs. The dyke has already been partially completed and is being built in phases. Analogous to the Japanese example, concepts for super dykes are also being developed in the Netherlands. It is clear that these are all constructional combinations, so that the building costs for both the dyke and buildings could decrease. It is also clear that super dykes are operational combinations because the dike and the buildings physically reinforce one another. Integrating the foundations of the buildings with the underground strength of the dyke has advantages for the dyke as flood defence and for the land with urban functions.

In some Asian countries, public spaces in densely-populated areas subject to flooding have been designed in a well thought-out way for multiple use. In the Netherlands, the best example up to now is the water plaza, which was created in Rotterdam. The water plaza might not serve a direct function as flood defence, but it certainly helps avoid wet feet. The retention basin is part of a larger system in which flood defences also play a role. The example in Yokohama described below is much more an integral part of a flood defence system than the water plaza in Rotterdam (Heijden, 2013).

2.5.3 Glass Dyke at the Meuse

Another great example of multi-functional flood defences is given here, where the extra function is mostly focused on the aesthetics and satisfaction of inhabitants. Namely, a dyke reinforcement is required along the Meuse river. However, a higher dyke would block the beautiful environment for the inhabitants of the surrounding villages. Therefore, the local water board wants to partially raise the quay in the village of Neer with glass panels. Residents of five houses would otherwise lose the free view on the Maas and literally look at a wall. Eighty meters of quay will have a glass window (Deltares, 2020b).

The construction of a flood defense with glass plates is being tested in the 'Deltagoot' at Deltares in Delft, which is shown in Figure 2.7. The plate used here is 6 centimeter thick and a 800 kilogram heavy tree trunk is hitting the glass plate over and over to reconstruct realistic situations that could occur in the Maas. Sensors and laser light then detect the exact stretch and deformation of the glass. This data is then used to create the most optimal dimensions and characteristics of the dyke (Deltares, 2020b).

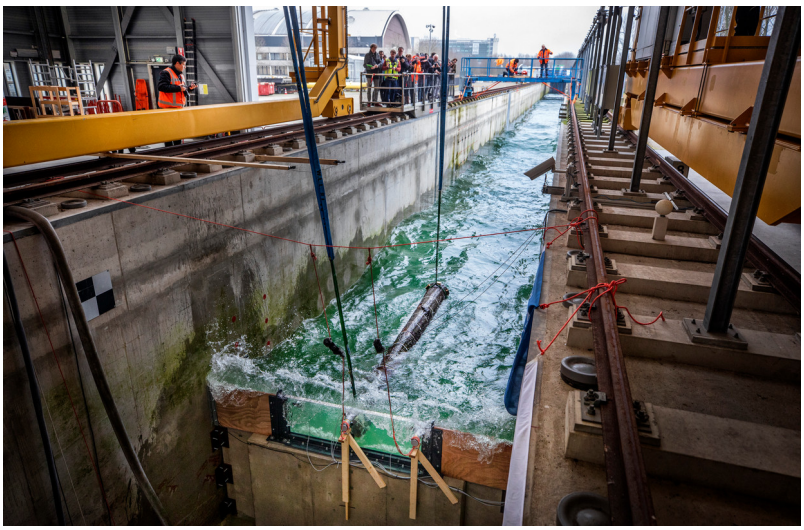

Figure 2.7: Glass dyke test with trunks at the Deltagoot in Delft (Deltares, 2020b)

In cooperation with the experienced glass supplier Scheuten, the glass panels are made up of several layers of glass and foil: 3 structural panels in the middle, 2 so-called "sacrificial panels" on the outside and films of 1.5 mm in between. The ideal thickness and composition in terms of strength and transparency have been calculated and determined, always keeping

the goal in mind to maintain a view of the Meuse and at the same time meet the water safety standards. The glass and foil that is used, is of high quality so that it is also resistant to external influences, such as weather influences. The glass panels are installed over a total length of 80 meters, divided over four routes, the longest of which has a length of 30 meters (Deltares, 2020b).

2.5.4 BoxBarrier

The BoxBarrier is a very effective temporary flood defense system that can be used for temporarily raising a dyke or for creating a temporary dyke on flat terrain. In this way, the BoxBarrier can prevent flooding of the terrain behind. The concept behind the BoxBarrier can be described as simple, because it uses its own opponent: it stops water with water (BoxBarrier, 2020).

The Box Barrier is quick and easy to install. No additional equipment is required for the installation, except for a pump. Removing the system is even easier than installation and does not result in leftover waste or system parts. This is often the case when removing weathered or cracked sandbags. Another advantage of this temporary flood defense is that there is no need for a special permanent foundation in the ground. As a result, the system can be freely applied at many locations. In Figure 2.8, an example can be seen of one of the many functions of the BoxBarrier.

Figure 2.8: BoxBarrier impression (BoxBarrier, 2020)

3. Interview and Literature Analyses

3.1 Interview Review

The eight interviews that have been conducted, will be compared in this section and the most noticeable findings and recommendations will be listed below.

3.1.1 Comparative Analysis

In this section a comparative analysis is given to see what the similarities and differences are in interview responses of Movares colleagues and the clients RWS and water boards. The goal of this analysis is to see whether there is a disconnect between contractor and client and what opinions or visions overlap.

As can be seen in Appendix A.2, several general questions have been drafted to be able to compare answers of all interviewees and improve the overall trustworthiness of the research. There are multiple overlapping specific questions which can be compared as well.

Similarities

Also, everyone in the interviews is on a par concerning past and current structures of tenders. Namely, in the past RWS and water boards usually would offer the commercial market specification drawings and designs of the projects they would like to realise. Afterwards, companies then obtained a contract to build the design for them, after which RWS takes over the operation and maintenance of the project again.

However nowadays, the utilisation of integrated contracts is the new standard, which results in placing all responsibilities with one contracted party. Common examples of these contracts are Design & Construct (D&C) or Design, Build, Finance and Maintain (DBFM) contracts. These contracts fall under the 'Uniforme Administratieve Voorwaarden voor Geïntegreerde Contractvormen' (UAV-GC). Furthermore, it has become common to give an 'Economisch Meest Voordelige Inschrijving' (EMVI) discount to companies when offering tenders. All of these terms will be further explained in Section 3.2.

Last but not least, almost all interviewees are enthusiastic about the WFD concept and they think it has the potential to be implemented in The Netherlands eventually, provided that all aspects of the concept have been elaborated, the stakeholders are willing to cooperate and that a suitable project location is available.

Differences

First of all, every interviewee agrees on the fact that the CE sector nowadays is still relatively conservative compared to other sectors when it comes to innovation. Namely, innovations will only be tolerated by clients such as RWS and water boards if it is a proven concept within the industry. As a contractor or consultancy, you will need references and substantiation to convince stakeholders of your innovative idea. The crux of innovation is conveying confidence. This can be done with a convincing story, proven concept or practical example (Elzen, 2020). The noticeable difference in conception here is that the commercial market is willing and able to produce innovations, but the clients are still hesitant to risk a failed project or their national reputation of protecting the country (Kuijk, 2020).

A noticeable difference in project cooperation are the online tools and programs used to design structures and to communicate with other stakeholders/colleagues (Gruppen, 2020). More specifically, digital folder structures within contractors, RWS and water boards could differ from each other. Also, working hours and locations can be contrasting which could lead to miscommunication within the project. Furthermore, certain design tools and software could vary per stakeholder and sometimes there is an embargo that prevents you from seeing designs as a client (Gruppen, 2020). According to Jan Gruppen, the worst problem is the folder structure; when the design process cannot be viewed (intermediate steps) and certain data cannot be retrieved. These online work environments are called 'Common Data Environments' (CDE), which will be explained in Section 3.2.1.

According to Movares' sustainability experts, circularity is often a forgotten subject in projects due to the little knowledge and expertise on circular methods (Eerten-Jansen, 2020) (Keetels, 2020). On the other hand, the clients believe circularity is being considered in projects increasingly (Schweitzer, 2020) due to new climate goals and by cooperation programs such as the 'Hoogwaterbeschermingsprogramma' (HWBP), which will be discussed in Section 3.2.1.

3.1.2 Obtained Recommendations

Besides the comparison of similarities and differences in responses and feedback, the main recommendations obtained from colleagues and clients for creating a framework which assesses sustainability, functionality and stakeholders within multi-functional flood defence projects are shown below per interviewee. These recommendations form the basis for chapters 5 and 8, which include the research results and recommendations respectively.

First of all, Martijn van den Elzen has told me about the daily routine and tasks as a project manager in the Movares Hydraulic Engineering department. Furthermore, he has thought with me about several possible functionalities for the WFD concept (Elzen, 2020), which are listed in Section 3.2.3.

Secondly, Teun Dekker has explained me the innovation policy of Movares during our interview and he advised me and Movares to utilise the following road map for developing the WFD concept (Dekker, 2020). The road map consists of seven themes with corresponding questions listed below which are essential to take into account when developing an innovation.

1. Opportunity: What is the problem and how does the innovation solve this?
2. Client: What is the positive business case?
    - Are there any clients or client segments for this innovation?
    - What is the power of this client?
3. Motivation: Who is interested in the innovation and why?
4. Resistance: Who is not interested in the innovation and why?
5. Costs: What is our investment in terms of financing and working hours ?
6. Income: How do we earn money from the innovation and what is the revenue model?
7. Danger: What are the risks?

Furthermore, Eric van Kuijk has explained that multi-functional flood defence projects must fulfill certain criteria. Namely, the design must fulfill the main purpose, it must be cost-effective and the price/quality ratio must be correct. Also, the life span should be good (50 to 100 years). Maintenance and management must also be reflected upon in the design, so if something goes wrong with the dyke, you know how to repair it (Kuijk, 2020).

For the stakeholder cooperation, a list has been made to highlight the most important and relevant measures that can be taken. These measures and recommendations have been suggested by the three external interviewees.

- Organise meetings physically instead of online to improve work cohesion and the alignment of agreements (Kuijk, 2020)
- Ensure clear communication at all times and keeping close contact with each other (Kuijk, 2020)
- Enable colleagues and clients to share all their data and designs with each other efficiently via universal CDEs or other online work environments like SharePoint and Organiser (Gruppen, 2020)
- Minimise the online restrictions and/or embargoes on the viewing of designs, calculations and papers to improve working efficiency (Gruppen, 2020)
- Ensure being on par with regard to each others visions, goals and expectations to avoid disappointment or disagreements later on in the project (Kuijk, 2020)
- Reward innovation, sustainability and circularity more in tenders. This is already increasingly implemented within the HWBP cooperation between RWS and the Dutch water boards (Schweitzer, 2020)

Lastly, a list of relevant sustainability and circularity measures has been set up. These measures and recommendations have been suggested by multiple different interviewees from Movares and clients.

- Usage of sustainable materials such as wood, bio-materials, non-toxic plastics (Keetels, 2020) or innovative alternatives like geo-polymers (Schweitzer, 2020) are extremely important in projects due to the profits gained over non-sustainable materials in all project phases
- Significant sustainability profits can be made in the building phase by transporting soil in a more sustainable manner. For example, transport by electric trains or ships is already more sustainable than by fossil-fueled trucks or ships (Eerten-Jansen, 2020)
- Construction work during the building phase can be more sustainable as well by utilising machinery on site running on green electricity or bio-fuel (Keetels, 2020)
- Apply the 10-R circularity principle as much as possible to maximise circularity profits in all project phases (Eerten-Jansen, 2020)
- Clients should implement MKI-calculations and EMVI-discounts in all tenders, because the commercial market will try to score as good as possible on both values and this will ensure more sustainability and circularity profits (Schweitzer, 2020)

3.2 Literature Review

3.2.1 Stakeholder Cooperation

UAV-GC

As discussed in Section 3.1, nowadays UAV-GC policy is applied within the majority of CE projects. As a result, integrated tenders and contracts such as D&C or DBFM are quite popular within RWS and waterboards. Characteristic of an integrated contract form is the merging of tasks and responsibilities within the construction process functions into one contracted party. The client continues to fulfill the role of initiator of the project and the contractor realises the project by means of design and implementation work. Within the framework of the UAV-GC, four different roles are distinguished, namely:

- Initiative from client
- Design
- Construction
- Multi-year maintenance

The client, as initiator in the construction process, must shape the project from the very first initiative up to and including the management and/or exploitation phase (Projectburo B.V., 2015). This means contract forms can vary from only two roles (e.g. D&C) to multiple roles (e.g. DBFM).

The main difference between the former contract types and current integrated contracts is the shift in responsibility for the design decisions from client (RWS or water boards) to

contractor (Movares). With the traditional contract, the client draws up the implementation design (for example, a specification drawing). While with integrated contracts, three variants can be chosen in which the client draws up at least a Program of Requirements with functional specifications, possibly supplemented with a provisional design or even a final design (Projectburo B.V., 2015).

Moreover, the UAV-GC provides that the responsibility for obtaining the necessary permits can be shifted to the contractor. In fact, the UAV-GC based contract offers the possibility of achieving an optimal risk distribution between the client and the contractor, not only with regard to permits but also risks arising from design methods and implementation techniques. The basic principle must be that risks must be placed with the party that is best able to bear, limit or control them (Projectburo B.V., 2015).

In addition, the client can determine the extent to which they remain involved in the work in a contract based on the UAV-GC. Traditional terms such as 'management and supervision' in which the products of the contractor are inspected are replaced by 'testing and acceptance'. Testing is an activity that the client performs for themselves to determine whether the contractor is fulfilling its obligations. The acceptance procedure involves a process interrupting moment that leads to a 'go' or 'no-go' decision by the client on the basis of which the contractor must resume its activities (Projectburo B.V., 2015).

EMVI-discount

In the past, tenders in The Netherlands were awarded on the basis of the lowest offered price. Due to numerous 'Bouwfraude' scandals (Wikipedia, 2015), politicians in the Netherlands realised that awarding tenders based on the lowest price does not lead to the highest social added value. The government was looking for a method where they could also award quality. This method has eventually become the EMVI-method, which stands for 'Economisch Meest Voordelige Inschrijving'. By this we mean that both price and EMVI-criteria are taken into account when a contractor submits a tender to a client (ITC Groep, 2020).

Based on the UAV-GC, RWS and water boards use a prescription on how a tender should be assessed. Besides the check for completeness of the submission, an assessment is also made on the basis of the EMVI-criteria. In an integrated contract form, assessments are often not only based on price, but also on quality aspects. Examples of common EMVI-criteria are summed up below:

- Communication with stakeholders
- Relationship with the client
- Risk management
- Planning
- Nuisance and traffic plan
- Safety
- Sustainability

In conclusion, the UAV-GC policy and EMVI-discount make the contractor's internal cooperation more essential then ever. The client now checks whether you are following the processes that you have agreed on, or whether you meet all the requirements and EMVI-criteria.

Common Data Environments

Over the last years, digitisation has spread rapidly over the entire world. Also within the CE sector project work which is executed online has risen considerably, both in cooperation with colleagues and individual tasks. One of the online tools that clients and contractors utilise to cooperate in their online working space is a 'Common Data Environment' (CDE). The CDE is a central repository where construction project information is housed. The contents of the CDE can include documentation, graphical models, non-graphical assets, contracts, minutes of meetings etc. By using CDEs, collaboration between project members should be enhanced, mistakes reduced and duplication avoided (NBS, 2016). Examples of widely used CDEs are Microsoft SharePoint, Organiser and BIM environments (Gruppen, 2020).

Hoogwaterbeschermingsprogramma

The HWBP is a crucial and unique cooperation for flood defence projects between stakeholders in The Netherlands. The HWBP has been developed with the aim of improving quality and stakeholder cooperation in flood defence projects, stimulating innovation and sustainability and reinforcing all primary flood defences before 2050 (Hoogwaterbeschermingsprogramma, 2020). Therefore, as a contractor it is important to know about this program to anticipate to tenders or changes in the market.

3.2.2 Sustainable & Circular Solutions

Climate Goals & Visions of Movares and Stakeholders

First of all, for Movares sustainability and circularity are of paramount importance. This can be seen in their vision towards sustainability and circularity on the website. "Movares works on the development of a sustainable living environment and the infrastructure of the future. Based on our social commitment, we use our knowledge and skills to design complex urban and infrastructure challenges with respect for people, the environment and the economy. For us, sustainable work means that our efforts are focused on minimizing our environmental impact and that of our clients' projects. Sustainability is therefore an integral part of our business operations and project cycle" (Movares, 2020).

Also, the CO2-ladder and -footprint are crucial gauges for the developments in sustainability and circularity. "Every year we organise a Sustainability Day at Movares to work on awareness and exchange of knowledge, to which our clients, suppliers and chain partners also contribute. But we make the real difference by coming up with innovative solutions for our clients with creativity, innovative strength and knowledge. Sometimes we do this solicited, sometimes unsolicited. As a result, we make the difference between a project and a sustain-

able project. Furthermore, Movares pursues an active CO2 policy. This is visible in our certification on the ProRail CO2 performance ladder (level 5), but also in our CO2 footprint. Our footprint is less than 1 ton CO2 per FTE. This gives us by far the lowest CO2 footprint of all major engineering firms. To achieve this, Movares has implemented an ambitious CO2 policy, including taking CO2-reducing measures in its own operations and offsetting the remaining part. For example, Movares has been CO2 neutral since 2010." (Movares, 2020).

On the other hand, clients such as RWS and the waterboards have their own goals and visions towards sustainability and circularity. RWS wants to be energy neutral by 2030 (RWS, 2020) and WDO Delta in 2025 (WDO Delta, 2020), which means: generating as much energy as is consumed, completely sustainable. In addition, RWS and WDO Delta both assess the CO2 emissions of market parties with the CO2 performance ladder. This measuring and certification instrument has 5 steps. RWS and the water boards are one of the first governmental organisations to be certified on step 3. This means that measures are taken to reduce their CO2 emissions. The goal is to reach step 5, the highest level, by 2020 at the latest. This means that we are also increasingly taking measures to reduce CO2 emissions from the work that we outsource to the market (RWS, 2020). Lastly, RWS and waterboards both address circularity in the plan 'Nederland Circulair in 2050', which aims to achieve a fully circular organisation and pursues the interim target of at least 50% less primary resources usage such as minerals, metals and fossils fuels in 2030 (WDO Delta, 2020).

Duurzaam GWW

Within 'Grond-, Weg, en Waterbouw' (GWW) projects, the approach 'Duurzaam GWW' is widely applied in early policy and planning phases to the realisation of projects. The purpose of the Duurzaam GWW approach is to make concrete sustainability goals in CE projects during planning, construction, tendering, management and maintenance phases without prescribing in advance how sustainability gains are achieved. However, these goals are underpinned by the challenge of major changes. This change assignment is translated into four transition lines that the signatories are working on together and individually. These four transition lines are stated as follows (CROW, 2017):

1. **From costs to value:** An essential condition for this transition is that sustainability is seen as an added value, a yield instead of an extra expense. Sustainability can lead to savings in construction and operation, but also add value to a CE project and the environment, which is called 'value creation'. Value creation is stimulated by creating opportunities for innovative sustainable solutions.
2. **From reactive to proactive:** Sustainability must be 'business-as-usual'. This requires a proactive attitude from the employees who are involved in a CE project at all levels in the organisation. It requires understanding each other's interests, responsibilities and needs and actively communicating experiences and successes.
3. **From unique to uniform:** The Duurzaam GWW approach helps to take the correct process steps in a uniform and systematic manner. By embedding sustainability in

the business processes, the parties within the CE sector implement sustainability in projects in the same way and their expectations are clearly stated in advance.

4. **From alone to together:** Collaboration within the CE sector is necessary for sustainability to be an integral part of all CE projects. Contractors play a crucial role in the realisation of these projects and consider it desirable that they are being involved in a timely and intensive manner by clients. Parties are committed to strengthening mutual cooperation and exchange knowledge within CE projects.

DuboCalc & Milieu Kosten Indicator

DuboCalc is a calculation program that assesses constructions in the CE sector on sustainable material and energy consumption. It was developed by RWS, in dialogue with other governments and market parties. DuboCalc is based on the standardised method of 'Life Cycle Analyses' (LCA). Within DuboCalc, the environmental effects of a GWW project are expressed with the value of the 'Milieu Kosten Indicator' (MKI).

In brief, the DuboCalc instrument is convenient in three different ways (Duurzaam GWW, 2012):

1. To determine whether the environmental performance requirement is met (expressed in MKI), such as that is included in the question specifications
2. To determine whether the design process pursues sustainability effects by demonstrably optimising to a lower MKI value for parts of the design
3. As an award criterion, where the contractor distinguishes itself with a lower MKI solution

The MKI is an indicator that expresses the environmental impact of a product in Euros (€). It weighs all relevant environmental impacts that arise during the life cycle of a product and adds them to a single, monetary score. The MKI, or shadow price of a product, is an easy way to compare and communicate the environmental impact of products or projects (Ecochain, 2020).

Governmental organisations can use MKI in EMVI-tenders, whereby the lowest possible MKI-score is used as an award criterion. Contractors can offer the environmental costs of various designs and proactively reduce the environmental performance of their product or work to increase their chances of winning the tender. This means that even if the actual price of the bid is higher, better environmental performance increases the chance of winning the tender (Ecochain, 2020).

Circularity

The Netherlands are making the transition to an economy where raw materials will be used efficiently and re-used optimally. That raw resources will be extracted from the earth in a sustainable manner, but that fewer raw materials are necessary because there are more efficient products and services being developed as well. Also, that damage to the climate, living environment and individual health is prevented as much as possible (PBL, 2018).

The Dutch government has set an interim target for 2030 to reduce the usage of primary abiotic resources (minerals, fossil fuels and metals) by 50 percent. On the long term, The Netherlands want to be completely circular in 2050, which is achieved by using renewable and commonly available raw materials which are sourced in a sustainable way sourced as much as possible (PBL, 2018).

In a circular economy, materials ideally retain their original quality. This enables us to recycle these recovered materials into the same type of products. Natural resources are then no longer needed for the production of materials, and discarding products does not lead any longer to emissions and waste. Several circularity strategies exist to prevent resource extraction and primary material demand as well as waste production. There is also a priority order in those circularity strategies. As a rule of thumb, more circularity means more environmental gain (PBL, 2017).

A commonly used framework for measuring circularity is the so-called R-ladder, which is displayed in Figure 3.1. The higher a strategy is on this list (ladder) of circularity strategies, the more circular the strategy is.

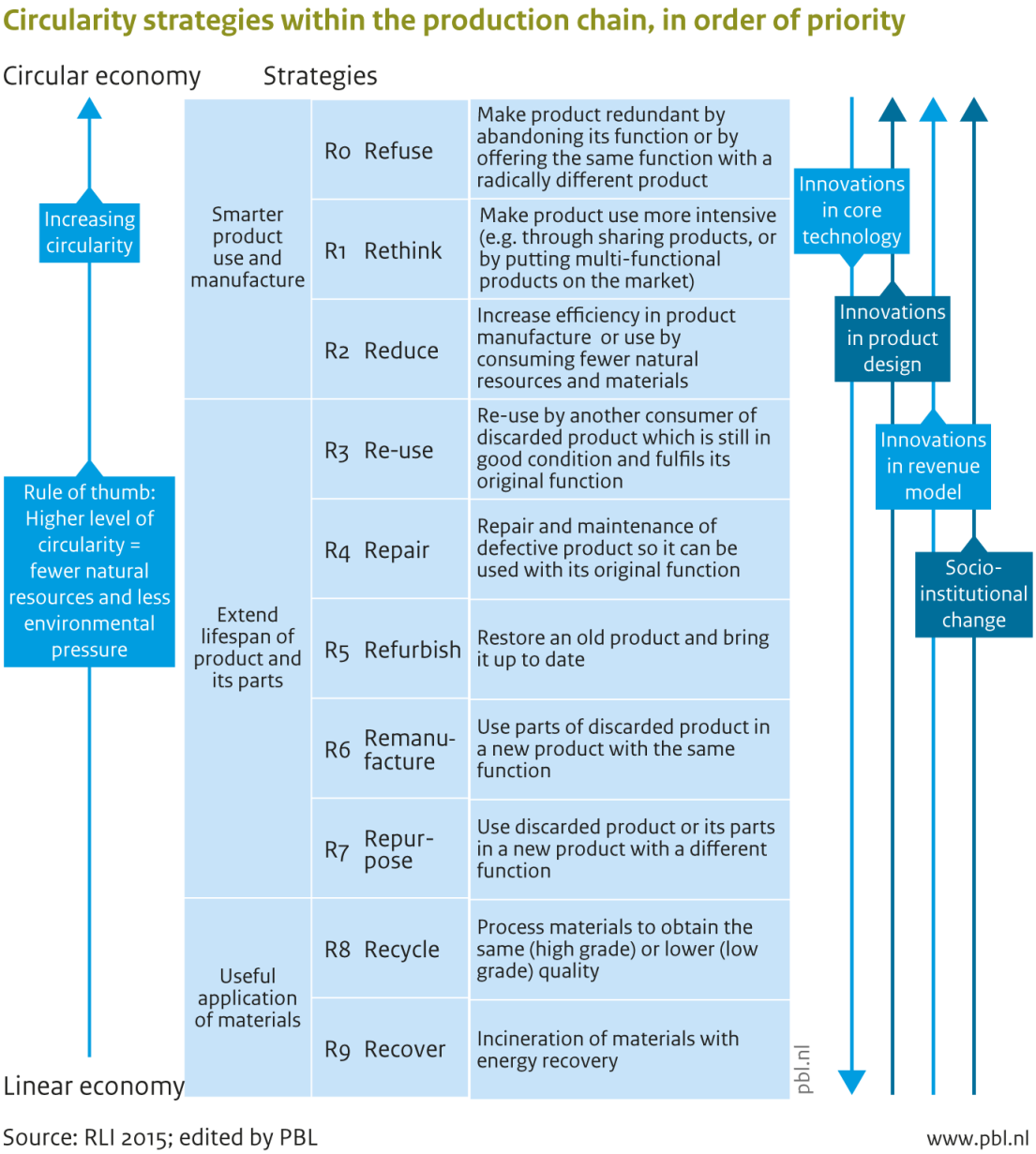

Figure 3.1: R-ladder circularity framework (Het Groene Brein, 2020)

3.2.3 Feasible Functionalities & Benefits

Water-filled Dyke

From the discussions with Thom and other colleagues (Olsthoorn, 2020), multiple interesting functionalities and benefits arose for the WFD which are listed below.

- Storage of extra excess water inside the dyke
- Less soil usage from Haarlemmermeerpolder
- Lighter dyke when empty
- Temporary flood defence and water retainer (comparable to BoxBarrier concept in Section 2.5.4)

- Caissons (the dyke could be made out of just caissons to save soil, see Section 2.3)
- Sewerage, pipes and cables

Multi-functional Flood Defences

Apart from the WFD functionalities, a list of possible functionalities and benefits for multi-functional flood defences in general has been assembled with the aid of literature (Heijden, 2013) and input from interviews (Elzen, 2020).

- Recreational areas, such as walking and cycling routes
- Sport facilities, such as skating, basketball, beach volleyball etc.
- Green zones, such as parks or flora and fauna areas
- Trash disposal/storage
- Bicycle storage
- Parking garage and/or lots
- Urban areas, such as neighbourhoods or shopping centers
- Infrastructure such as highways, roads, train tracks, cycling and walking paths

In figures 3.2 and 3.3, two different multi-functional dyke concept examples are shown, containing various functions from the lists above. First of all, the 'quiet' dyke is located in the middle of a green zone. On top of the dyke, there is a walking path, the cyclists are diverted from the dyke to a heightened wooden path on piles in the flood plains. When the river water level rises, only water is visible on both sides of the path (De Ingenieur, 2016). Secondly, the 'village' dyke regains its intimacy, the car traffic disappears in a tunnel within the dyke. The inner slope of the dyke receives a staircase, which makes the dyke stronger and creates new living space for the village at the outer slope (De Ingenieur, 2016).

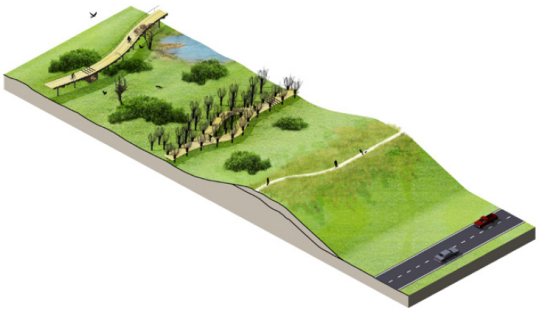

Figure 3.2: Quiet dyke concept (De Ingenieur, 2016)

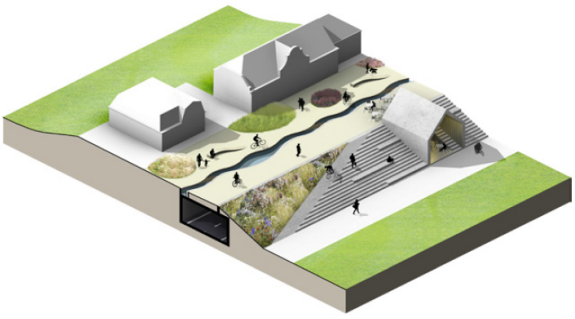

Figure 3.3: Village dyke concept (De Ingenieur, 2016)

4. Assessment Framework Multi-functional Flood Defence Projects

In the previous chapter, all three topics have been discussed thoroughly. The literature research and interviews with colleagues from Movares, RWS and WDO Delta both have provided various ideas and directions to compose a framework for the research. The goal of this chapter is to process the knowledge gained from the previous chapters to develop an integrated framework which assesses the feasibility of multi-functional flood defence projects from a sustainable, functional and stakeholder perspective. The framework should act as a tool to support Movares with the development of future projects or innovations like the WFD and to see which criteria are essential and what their potentials and limits are. The content and assessment method of the framework will be presented in detail. Also, the research questions will be answered in this chapter as well as Chapter 5.

4.1 Framework Criteria

First of all, it is necessary to create a separate category for each main topic that has been studied, which are sustainability, functionality and stakeholders. This is crucial because each topic can now be judged individually on its strengths and weaknesses. Afterwards, these main topics will be divided into relevant and assessable sub-topics, which are called the framework criteria. These specific criteria follow from the conducted theoretical framework and interviews.

On top of that, each criterion will receive a well-considered weight to prioritise certain criteria over others. The weights have been determined on the basis of literature, the opinion of the interviewees and the researcher's personal estimation and valuation. The weights are indicated in brackets behind all criteria including: essential (1), important (2) and desirable (3). The framework criteria for each separate topic are listed below in alphabetic order together with a short elaboration what the essence is of each criterion and why the weights are chosen in this fashion.

Sustainability

- Circularity (3): In literature circularity is often mentioned alongside sustainability, because the two aspects have a strong correlation. In the interviews with sustainability experts came forward that circularity is often a forgotten subject due to the lack of knowledge and little current project implementation. However, it is important to take into account circularity for future projects, although it is not as crucial as the other criteria in this category. For now, the desirable weighting is attached to this criterion. However, in the future this may shift to an important weighting as circularity receives increasing attention.

- Material usage (2): From the literature interviews came forward that there are still countless developments in progress concerning sustainable materials. In the CE sector there are several material improvements possible which would enhance the sustainability scores of CE projects. My advice is to use sustainable materials where possible like wood, bio-materials, non-toxic plastics or innovative alternatives like geo-polymers (Schweitzer, 2020). However, sustainable material usage is not as impactful on for example the MKI-value as soil transportation and water/climate adaptation are (Rijkers, 2020). Therefore, this criterion receives the important weighting.
- Soil transportation (1): Specifically for multi-functional flood defence projects, soil transportation and usage will always be a crucial factor. Mainly because flood defences are mostly built from soil in a natural environment. On top of that, the recent PFAS and nitrogen regulations (RIVM, 2019), as discussed in Chapter 1, have made this criterion even more important than it already was, since projects are being cancelled due to PFAS and nitrogen. Currently, RWS and WDO Delta desire to keep a closed soil cycle (Rijkers, 2020), which means no external soil may be used for a construction. As a result, the essential weight is given to this criterion.
- Water and climate adaptation (1): The Netherlands have fought the battle with water for centuries and will continue to do so in the future. Besides this, new climate goals prescribe strict targets which must be met within a certain time. The PFAS and nitrogen regulations for this criterion are as equally crucial as for the soil transportation criterion. Considering these aspects, water and adaptation are crucial for a sustainable project, resulting in an essential criterion weight.

Functionality

- Innovation (2): Since the WFD is an innovative concept, innovation needs to be taken into account in the framework too. Innovation is becoming increasingly important in the CE sector, since programs such as the HWBP stimulate innovative ideas and it usually adds extra value in the form of sustainability, safety or functionality. Although innovation is not as essential as multi-functionality and spatial usage/quality, it will still receive the important weighting.
- Multi-functionality (1): This criterion has an essential weight attached, because the research revolves around multi-functionality in flood defence projects. Also, the third research sub-question explores the possible functionalities for the WFD concept.
- Practicality (3): This criterion usually has a high priority in CE projects, since designs have to be practical and accessible for the users. However, in this research the focus will lay more on functionality and spatial quality, hence the desirable weight.
- Spatial usage and quality (1): Due to the small Dutch land area and the increasing urban areas in The Netherlands, this criterion has become extremely important. On top of that, spatial quality has a strong connection with multi-functionality, since multiple functions in one location usually increases spatial quality as well. The interviews with clients also showed that spatial quality or value is a priority when reviewing tender submissions (Rijkers, 2020). Therefore, this criterion receives the essential weight.

Stakeholders

- Ecological impact (2): As mentioned in the sustainability category, the climate is playing a greater role than ever before. As a result, the impact of a project on nature and wildlife is taken into account seriously, though safety remains the main priority. Therefore, the important weight is given to the ecological impact of a project.
- Economy (3): the economy is intervened in the reasoning behind tenders, since all financing will always be part projects. Nonetheless, this criterion is the least important within this topic, because the focus of this research is not particularly on economy. However, it is worth to consider financial benefits a project can offer, thus the weighting is desirable. Additionally,
- Safety (1): The safety of inhabitants will always be the top criterion for stakeholders, hence the essential weighting.
- Social relevance (2): Lastly, it became clear from the interviews that stakeholder participation is important to create a support base for a project or concept. If the interests of stakeholders are considered, the project outcome will have a high social relevance, which is valuable to society, but not as much as safety. Thus, the important weight is given.

4.2 Scoring-scale

Now that the framework criteria are chosen and weights are attached, a scoring-scale is necessary to enable the full assessment of the criteria. For this, a scoring-scale example from a multi-criteria analysis will be utilised. This is done because all three topics mostly have qualitative output and the conducted interviews are a qualitative method of data collection.

Subsequently, a fitting scoring-scale of the criteria is determined, in this case it will be a '++/- -' scoring-scale. This specific score-scale is suitable for the framework, because it corresponds with the degree to which a framework criterion is met. Combining the scoring-scale with the weighting will result in a final score for each individual criterion.

To create an easy-to-use but effective scoring method, a base score of 10 is assumed for an important criterion with score ++. From here, all other scores are determined with the aid of factors for the scoring-scale and weighting. The scoring-scale multipliers are chosen as follows: ++ stands for factor 2, + is factor 1.5, 0 is factor 1, - is factor 0.5 and – is factor 0. Secondly, the weighting multipliers are simply 2, 1 and 0.4 for essential (1), important (2) and desirable (3) criteria respectively. As an example, an important (2) criterion (factor 1) with a + score (factor 1.5) will give a final score of 7.5. See Table 4.1 for an overview of all possible final scores a criterion can receive.

When the criteria, scoring-scale and weighting are combined into one tool, an assessment framework is created which provides an overview of all the strengths and weaknesses of different alternatives and it will also point out which alternative has the highest total score (Wikipedia, 2019) and thus is the most feasible and attractive to realise.

Table 4.1: Framework criteria scoring-scale and weighting

		Weighting		
Degree to which framework criteria are met	**Scoring-scale**	Essential (1)	Important (2)	Desirable (3)
High degree	++	20	10	4
Moderate degree	+	15	7.5	3
Low degree	**0**	10	5	2
Barely present	-	5	2.5	1
Not at all	- -	0	0	0

Table A.2 in Appendix A.3 shows a completely blank version of the framework which can assess two alternatives simultaneously. In Chapter 5, two self-conceived WFD alternatives will be assessed by using this framework and handing out a score to each criterion.

5. Framework Application: Water-Filled Dyke Concept

In this chapter, the framework will be applied to two self-conceived WFD alternatives which include different aspects of the three main research topics to validate whether the framework gives credible output. In Section 5.2, the framework will be filled in with scores and the highest total score will therefore be the most attractive and feasible to realise.

5.1 Two Alternatives

5.1.1 Alternative 1: Sustainable, safe and ecological

The first alternative has the focus on sustainability, circularity, safety, nature and ecology. In practice, this will translate in the use of sustainable materials like wood, bio-materials, non-toxic plastics or innovative alternatives like geo-polymers, which were discussed in Section 3.2.2. These materials will be utilised for the water-filled tubes and other non-soil components in the design. The building materials will also be as circular as possible by being re-usable or recyclable for example, following the principles of the R-ladder and Dutch circularity goals, see Section 3.2.2. Moreover, the transportation and construction work will be done as green as possible by utilising electric machinery and soil transport by ships, trucks and trains which are powered by renewable energy such as green electricity, bio-fuel or hydrogen. Besides this, the construction itself will of course be safe and sound, with room for nature and wildlife to develop freely in the form of a green or flora and fauna zone. This results in nature organisations being very enthusiastic about the project. However, under ordinary citizens this plan might have a small support base, due to the possible lack of social relevance and practicality.

In brief, alternative 1 is a durable and solid WFD design utilising sustainable materials and building techniques while giving nature the space to develop in the newly formed ecological landscape. This WFD alternative can be compared to most of the 'Ruimte voor de Rivier' projects, where sustainability, safety, ecology and spatial quality are of paramount importance (Rijkswaterstaat, 2020b). Figure 3.2 in Section 3.2.3 presents a visualisation of a comparable flood defence design which strives for sustainability, ecology and spatial quality as well.

5.1.2 Alternative 2: Multi-functional, practical and recreational

On the other hand, the second alternative has the focus on multi-functionality, practicality and recreation. This will translate in a project area which is filled with a combination of different functions such as recreational zones with walking and cycling routes, sport facilities for various outdoor sports, green areas such as parks with flora and fauna, parking for bicycles

and/or cars and perhaps even urban areas such as housing, shops or offices. All these possible functions are listed in Section 3.2.3. As a result, this alternative will also stimulate the general support base, innovations and the economy, because stakeholders and inhabitants are closely involved in the design process from start to finish. On the other hand, due to the focus on functionality and stakeholders, there is less attention for sustainability. Nevertheless, some measures which are implemented in this alternative are the utilisation of sustainable materials for components of the WFD and taking nature and wildlife into account as well.

In short, alternative 2 is a multi-functional WFD concept which combines the best of all possible functionalities while maintaining a safe and practical design. This WFD alternative is very similar to the multi-functional projects in Rotterdam and Tokyo discussed in sections 2.5.1 and 2.5.2 respectively. In these projects functionality, safety, spatial quality and social relevance are key aspects as well. Figure 3.3 in Section 3.2.3 presents a visualisation of a comparable flood defence design which strives for multi-functionality and practicality as well.

5.2 Results

In this section, the assessment framework presented in Chapter 4 and Table A.2 will be applied to draw results from the proposed WFD alternatives and finally conclude which framework criteria score good and which bad and what impact they have on the total final score. In the next two paragraphs, scale scores (++/- -) with a short motivation will deliberately be given to the criteria for both alternatives and the framework results will be displayed in Section 5.2.3. The scale scores are based on the knowledge and experience obtained throughout the research and the specific focus points of each alternative.

5.2.1 Alternative 1: Safe, sustainable and ecological

Sustainability

- Circularity (3): score +, with the R-ladder and Dutch circularity goals in mind, circularity has been applied to a moderate degree with re-usable and recyclable materials. A completely circular alternative is currently almost impossible to obtain, therefore the criterion is met to a moderate degree
- Material usage (2): score ++, sustainable materials are utilised for all components in the design. Therefore, the criterion is met to a high degree
- Soil transportation (1): score ++, soil transportation will be done as green as possible by utilising ships, trains and trucks powered by green energy. Therefore, the criterion is also met to a high degree
- Water and climate adaptation (1): score ++, due to the room given for development of nature and wildlife and other measures taken to adapt to climate change, the final sustainability criterion is also met to a high degree

Functionality

- Innovation (2): score 0, because the focus is more on nature and less on designs, innovation is less applied as well. Therefore, the criterion is met to a low degree
- Multi-functionality (1): score -, hardly any multi-functionality is being applied here. Therefore, the criterion is barely present
- Practicality (3): score 0, a flora and fauna zone may be beautiful for the eye. However, it is not as practical as the other alternative. Therefore, the criterion is met to a low degree
- Spatial usage and quality (1): score +, although the practicality of the alternative is low, usually people tend to appreciate spatial usage for nature and wildlife areas. Therefore, the criterion is met to a moderate degree

Stakeholders

- Ecological impact (2): score ++, the green zones and flora and fauna appreciation have the best impact on ecology. Therefore, the criterion is met to a high degree
- Economy (3): score 0, the alternative hardly offers any way of creating revenue out of the area. Therefore, the criterion is met to a low degree
- Safety (1): score ++, due to the durable and solid with sustainable materials, safety is always guaranteed. Therefore, the criterion is met to a high degree
- Social relevance (2): score 0, due to the lack of functions, social relevance is minor for this alternative. Therefore, the criterion is met to a low degree

5.2.2 Alternative 2: Multi-functional, practical and recreational

Sustainability

- Circularity (3): score 0, circularity has been applied less than alternative 1, but is still practiced by e.g. recyclable materials. Therefore, the criterion is met to a low degree
- Material usage (2): score +, sustainable materials are utilised for components of the WFD, but not on all components. Therefore, the criterion is met to a moderate degree
- Soil transportation (1): score 0, little attention is given to a sustainable soil transportation method. Therefore, the criterion is met to a low degree
- Water and climate adaptation (1): score +, less relevant measures have been applied than alternative 1, but nature and wildlife are still considered. Therefore, the final sustainability criterion is met to a moderate degree

Functionality

- Innovation (2): score +, the multi-functional and stakeholder participation approach stimulates innovation. Therefore, the criterion is met to a moderate degree
- Multi-functionality (1): score ++, this is the main criterion for this alternative, which can be seen in the many functions mentioned in the alternative description. Therefore, the criterion is met to a high degree
- Practicality (3): score +, the social relevance of the alternative is high, thus the practicality of the alternative is high as well. Therefore, the criterion is met to a moderate

degree

- Spatial usage and quality (1): score ++, this criterion has a strong connection with multi-functionality, when multiple functions are realised in one location, usually the spatial quality increases as well. Therefore, the criterion is met to a high degree

Stakeholders

- Ecological impact (2): score +, the multiple functions may cause a lesser effect on the ecology. But it still is considered sufficiently. Therefore, the criterion is met to a moderate degree
- Economy (3): score +, the functions offer opportunities to create revenue and strenghten the economy. Therefore, the criterion is met to a moderate degree
- Safety (1): score +, not as good as alternative 1 due to the higher risk of damage here. Therefore, the criterion is met to a moderate degree
- Social relevance (2): score ++, the multi-functional area offers countless of opportunities for social activities or events. Therefore, the criterion is met to a high degree

5.2.3 Framework Water-filled Dyke Alternatives

The individual scores given to each criterion in the previous paragraph are now combined with the corresponding weighting. This results in one of the final scores that are stated in Table 4.1. All final scores and maximum achievable scores are stated in Table 5.1 below, where the colours represent the degree to which the framework criterion is met, similarly to the colour scheme in Table 4.1.

Table 5.1: Scores of assessment framework on two WFD alternatives

	Alternative 1	**Alternative 2**
Sustainability		
Circularity (3)	3	2
Materials (2)	10	7.5
Soil transportation (1)	20	10
Water and climate adaptation (1)	20	15
Sub-total score/Maximum score	*53/54*	*34.5/54*
Functionality		
Innovation (2)	5	7.5
Multi-functionality (1)	5	20
Practicality (3)	2	3
Spatial usage and quality (1)	15	20
Sub-total score/Maximum score	*27/54*	*50.5/54*
Stakeholders		
Ecological impact (2)	10	7.5
Economy (3)	2	3
Safety (1)	20	15
Social relevance (2)	5	10
Sub-total score/Maximum score	*37/44*	*35.5/44*
TOTAL SCORE/MAX. SCORE	**117/152**	**120.5/152**

When the results in the table are studied closely, it is remarkable that the first alternative, with the focus on sustainability, safety and ecology, scores better on the Sustainability and Stakeholders categories, but has a lower total score of 117 points compared to the 120.5 points of alternative 2. This means the second alternative with the focus on multi-functionality, social relevance and spatial quality, has scored significantly better in the Functionality category and scored relatively moderate on the other categories. In conclusion, alternative 2 appears to be the most feasible and attractive design to realise out of both alternatives. However, it is clear that both alternatives are feasible since they have sufficient total scores of approximately 79.3% and 77.0% out of the maximum possible score for alternative 1 and 2 respectively.

6. Discussion

6.1 Interviews

First of all, the conducted interviews together with literature research provided the foundation for the research. However, interviews will always have a degree of subjectivity. It has been tried to avoid suggestivity when asking all questions and thus positively influence the objectivity of the interviews. Despite this approach, it cannot be said with certainty interviewees gave a completely self-directed answer. For the interviews a wide variation of interviewees has been chosen to improve trust-ability and versatility of the research, but also to give the research a broad perspective into the subject. For example, the choice of interviewing Movares colleagues from different departments like Innovation, Sustainability & Circularity and Hydraulic Engineering is mainly based on the above mentioned reasons. On top of that, it was essential to obtain a good overview and understanding of the subject and the interviews definitely supported me in that perspective.

Secondly, a crucial component of the research has been the interviewing of external colleagues from RWS and WDO Delta. Three stakeholder representatives have been interviewed, which should already give a sufficient overview of the client's opinions and visions. However, conducting more interviews with other client representatives will decrease the chance of biased answers, inaccuracy or even lack of information. Correspondingly, these consequences can cause the research results to be different from reality. Also, crucial components to answer the research questions may be entirely lacking. Nevertheless, the interviews with clients covered a sufficing amount of knowledge on relevant topics to create a functional framework. In addition to that, the interviews revealed the enthusiasm for the WFD concept and the framework which can assess these innovative concepts and already existing multi-functional flood defence projects.

6.2 Results

As a result of the short graduation period and Movares' working-from-home policy due to the Corona virus, certain assumptions and choices had to be made in order to complete the research. This results in uncertainties and limitations for the outcome of the research.

Firstly, sustainability and circularity have been assessed in a qualitative manner in this research, but both can be investigated more quantitatively. This can be done in DuboCalc for example as described in Section 3.2.2, such that a real EMVI-discount or MKI-value is obtained and a price tag can be attached to the environmental impact a project causes. These quantitative results could help in removing uncertainty and assumptions from the research.

Secondly, possible functionalities and benefits for the WFD and multi-functional flood defences in general have been explored quite well. However, since technology is rapidly

evolving and innovations are being realised on a daily basis, practical limitations discussed in the literature or interviews may become less relevant or vanish altogether. Similarly, Movares' stakeholders and clients have been researched such that a sufficient picture about their visions and goals is outlined to guarantee a good cooperation in the future. Though, these visions and goals may change over time and external influences can cause a weaker cooperation. Therefore, it is necessary to keep an eye on these developments.

Moreover, more categories and corresponding criteria could be added into the assessment framework to obtain a more complete end product. Although the three main categories and framework criteria already cover the most crucial aspects of the ideal framework, the structure can be improved by including categories such as legality, finances, safety, risk and time management. These five additions would already make the framework much more valuable, since they examine other important project aspects as well.

In reality, Movares is often limited by clients as RWS and water boards when it comes to innovation or progressive solutions, as the clients prefer more conservative and traditional designs, which is discussed in detail in Section 3.1.1.

This study is mainly based on conducting literature research and interviews. Despite the choice of comparing two different WFD alternatives in Chapter 5, the generalisability of the framework within Movares remains uncertain for some framework criteria. It might be the case that some criteria, weights or scores appear to be invalid or wrong. This needs to be tested by validating the framework on real projects.

Apart from all assumptions and limitations, this research definitely has the potential to be valuable for Movares as an advice can be derived from the assessment framework how to design and build future projects more efficiently within Movares, integrating sustainability, functionality and stakeholders within new concepts such as the WFD on a company-wide level. The implementation of the framework should provide a decrease in reworks in the design process and increase the success-rate with tenders, ultimately resulting in less costs and more income and work for Movares. However, this has not been tested and validated yet in practice, so the potential benefits cannot be confirmed.

Lastly, not only is this study valuable Movares, but it can also be used by other engineering or architecture firms in the CE industry who wish to improve their assessment of sustainability, functionality and stakeholders within tenders, innovations or existing projects. This assessment framework can be used by other companies to uncover trends in their projects and to identify points of improvement based on their circumstances.

7. Conclusion

Within this study, a framework has been developed to design and build future multi-functional flood defence projects more efficiently within Movares with the aid of the WFD concept as an example. Also, the visions of both RWS and the water boards have been discussed. Prior to this, literature research was carried out, interviews were conducted and results were drawn from the framework with WFD alternatives.

To complete the research, conclusions will be given in this chapter based on the performed methods and results from the assessment framework. Before the conclusion to the main question is provided, the conclusions per research sub-question as stated in Section 1.4 are shown below.

Sub-question 1: *How can the cooperation between commercial market, Rijkswaterstaat and the Dutch water boards be stimulated in the water-filled dyke concept?*

The interviews provided most of the measures which would stimulate the cooperation between the commercial market, Rijkswaterstaat and the Dutch water boards in the WFD concept. The measures and suggestions that colleagues mentioned during the interviews are listed below.

- Organise meetings physically instead of online to improve work cohesion and the alignment of agreements
- Ensure clear communication at all times and keeping close contact with each other
- Enable colleagues and clients to share all their data and designs with each other efficiently via universal CDEs or other online work environments like SharePoint and Organiser
- Minimise the online restrictions and/or embargoes on the viewing of designs, calculations and papers to improve working efficiency
- Ensure being on par with regard to each others visions, goals and expectations to avoid disappointment or disagreements later on in the project
- Reward innovation, sustainability and circularity more in tenders. This is already increasingly implemented within the HWBP cooperation between RWS and the Dutch water boards

Sub-question 2: *What measures can be taken in the building, operating and maintenance phases of the water-filled dyke to obtain a more sustainable and circular construction?*

Both the literature study and interviews yielded interesting measures in the building, operating and maintenance phases of the WFD ensuring more sustainability and circularity. The measures and suggestions that were found in the research are listed below.

- Usage of sustainable materials such as wood, bio-materials, non-toxic plastics or innovative alternatives like geo-polymers are extremely important in projects due to the profits gained over non-sustainable materials in all project phases
- Significant sustainability profits can be made in the building phase by transporting soil in a more sustainable manner. For example, transport by electric trains or ships is already more sustainable than by fossil-fueled trucks or ships
- Construction work during the building phase can be more sustainable as well by utilising machinery on site running on green electricity or bio-fuel
- Apply the 10-R circularity principle as much as possible to maximise circularity profits in all project phases
- Clients should implement MKI-calculations and EMVI-discounts in all tenders, because the commercial market will try to score as good as possible on both values and this will ensure more sustainability and circularity profits

Sub-question 3: *What (extra) functions and benefits of water-filled dykes and multi-functional flood defence projects are relevant for stakeholders?*

Both the literature study and interviews have revealed multiple functions and benefits for water-filled dykes and multi-functional flood defence projects in general. However, some functions are more relevant for clients than others. For example, functions which facilitate social relevance, spatial quality or sustainability usually have a high priority within RWS and the water boards. As a result, relevant functions may be recreational or green areas, such as walking and cycling routes, parks and ecological zones. Or integrating infrastructure and urban areas in a dyke design while guaranteeing the safety of the construction.

The representatives from clients believed that the WFD concept has the potential to be implemented in The Netherlands eventually, since it contains several relevant functions and benefits such as the storage of extra water inside the tubes of the dyke, less soil usage from the Haarlemmermeerpolder and a lighter construction when filled and empty. However, before implementation all aspects of the concept need to be fully elaborated, the stakeholders should cooperate and a suitable project location must be available.

Sub-question 4: *How can a general framework be developed to improve the resolution of problems regarding sustainability, functionality and stakeholders based on literature and interviews?*

Firstly, all the obtained information and relevant elements resulting from the literature study and interviews had been processed to gain insight into the sustainability, functionality and stakeholder topics and to create an overview of all the results. Subsequently, the assessment framework is developed by setting categories and framework criteria which can be judged individually. Besides that, it is important to understand the essence of each individual criterion to distinguish which criteria are more essential than others and to be able to make deliberate choices in reality. This understanding is supported by a scoring-scale and priority

weights, which are explained in Chapter 4. Finally, all these components need to be assembled to develop a general framework which improves the resolution of problems regarding sustainability, functionality and stakeholders based on literature and interviews.

Last but not least, combining the conclusions from the four sub-questions, the conclusion for the **main research question** can be composed. The main question was stated in Section 1.4 as follows:

What does a framework look like that assesses the feasibility of multi-functional flood defence solutions, from a sustainable, functional and stakeholder perspective?

The main question resulted from the problem statement in Section 1.1. In brief, the problem statement explained there was no assessment framework defined for integrating sustainability, functionality and stakeholders within new concepts such as the WFD. Plus the current vision of clients on sustainability, functionality and stakeholder cooperation was not known, resulting in an inefficient working process and possibly missing out on interesting and profitable contracts.

The final assessment framework including the scores from both WFD alternatives can be seen in Table 5.1. The scores represent the feasibility for each individual framework criterion and the total final score resembles the overall feasibility of multi-functional flood defence solutions. The scores have been deduced from Chapter 4, where the framework criteria, scoring-scale and weighting system are explained thoroughly. Lastly, several conditions need to be satisfied to keep the framework usable and up-to-date. Namely, some framework criteria tend to develop quickly over a short period of time, which could drastically change the way people interpret the criterion and its essence. Examples of these quickly shifting criteria are circularity, soil transportation, innovation, social relevance. Therefore, these criteria need to be revised after a certain period of time to keep up with the developments and maintain the functionality of the framework.

In the following chapter, recommendations will be given to Movares based on the discussion and conclusions. Also, suggestions for future research are proposed.

8. Recommendations

Within this research, several ways of utilising and interpreting the framework have been studied. However, this subject includes a wide range of possibilities and issues and is also linked with subjectivity in some instances. Therefore, this chapter suggests several recommendations for Movares and further research, which have not been addressed within this research. These recommendations mostly follow from the discussion in Chapter 6. The recommendations are divided in two sections, namely methodological and practical recommendations.

Methodological

As mentioned in Section 6.1, although five Movares colleagues and three client representatives from RWS and WDO Delta have been interviewed, there may be a possibility of bias, inaccuracy or lack of information in the answers they gave. Therefore, a recommendation would be to interview more experts within all three topics, especially from RWS and the water board. In the end, this will increase the trust-ability, accuracy and quality of the research and the results will lay closer to reality.

In addition, Section 6.2 mentioned the qualitative nature of sustainability and circularity results in this research. It is recommended to investigate the sustainability and circularity in a more quantitative way to eliminate assumptions with quantitative results. Programs such as DuboCalc can calculate the environmental impact of a project and monetises that impact into a usable MKI-value.

Lastly, for future research it is suggested to add more categories and criteria in the assessment framework besides the three main topics to obtain a more adequate and realistic representation. Examples of categories are: legality, financial and safety, risk and time management.

Practical

Besides all methodological recommendations, there are also several practical suggestions to be made. First of all, if there was more time available after this research, it would be recommended to validate the framework even more by conducting more interviews with colleagues and clients and by testing it on real-life projects with measurable and comparable framework criteria.

Section 6.2 explains that the functionality and stakeholder topics have already been explored adequately. However, it is recommended to watch developments in technology and innovation closely and to stay in contact with clients to follow their interests and future plans.

Last but not least, the advice to Movares is given to implement the framework for future multi-functional flood defence projects to potentially increase the success-rate with

tenders, which generates more income and work for Movares. For future research it would be interesting to see if the framework can be utilised for other projects than multi-functional flood defences, so that the assessment framework can be functional within multiple Movares departments such as building and infrastructure projects as well. For this, the assessment framework needs to be discussed with colleagues from other departments and it should be tested on real-life projects with measurable and comparable framework criteria too.

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A. Appendices

A.1 Interview Set-Up

A.1.1 Interviewees

Martijn van den Elzen (Movares)
Function: Project Manager Hydraulic Engineering
Subjects: Water, construction, stakeholders

Teun Dekker (Movares)
Function: Innovation Manager Buildings and Infra
Subjects: Innovation, communication, stakeholders

Mieke van Eerten-Jansen (Movares)
Function: Advisor Sustainability & Circularity
Subjects: Sustainability, circularity, regulation, stakeholders

Sjoerd Keetels (Movares)
Function: Advisor Sustainability & Circularity
Subjects: Sustainability, circularity, regulation, stakeholders

Richard Rijkers (Movares)
Function: Senior advisor Hydraulic Engineering & Geo-engineering
Subjects: Stakeholders, water, construction, PFAS & nitrogen, spatial law

Jan Gruppen (Water board Drents Overijsselse Delta)
Function: Specialist Water Safety
Subjects: Stakeholders, water, construction, safety

Eric van Kuijk (RWS)
Function: Senior Large Projects and Maintenance in Hydraulic Engineering
Subjects: Stakeholders, water, construction

Gerwin Schweitzer (RWS)
Function: Senior advisor Climate Neutrality and Circular Purchasing
Subjects: Stakeholders, sustainability, circularity, water, construction

A.1.2 Objective of the Interview

The objective of our interview is to gain more knowledge from Movares colleagues and RWS/water board externals about visions on sustainability, functionality and stakeholders. These three topics will be discussed in-depth and results of the interview will serve as input for the framework and report.

A.1.3 Structure of the Interview

The interview will be a semi structured interview. In this way space is left for discussion and possibly obtain unexpected information that can be valuable for Movares, and thus making sure the main topics are dealt with. Because I do not have a hypothesis for our objective, and with a semi-structured interview we can guarantee a sort of direction while leaving the eventual answer open.

A.1.4 Type of Questions and their Implications

Mostly open questions with occasionally a closed question, followed up by a how/why question to steer the interview in the right direction. Also, open questions give the interviewees the possibility to provide an elaborate answer based on their experiences. In this way, the most knowledge will be extracted to reach the objective.

A.2 Interview Schedule

Table A.1: Interview schedule

Name	Martijn van den Elzen	Teun Dekker	Mieke van Eerten-Jansen	Sjoerd Keetels	Richard Rijkers	Jan Gruppen	Eric van Kuijk	Gerwin Schweitzer
Number	1	2	3	4	5	6	7	8
Date	12 May 2020	15 May 2020	18 May 2020	20 May 2020	26 May 2020	8 June 2020	11 June 2020	18 June 2020
Time	15:30h-16:30h	14:45h-15:45h	14:30h-15:00h	11:00h-12:00h	15:30h-16:30h	11:00h-12:00h	10:00h-11:00h	15:00h-16:00h
Place	MS Teams	MS Teams	MS Teams	MS Teams	MS Teams	MS Teams	MS Teams	MS Teams

A.2.1 Interview Introduction

Before the start of the interview, mention the following points:

- The purpose of the research/interview is to gain more knowledge from Movares colleagues and RWS/water board externals about visions on sustainability, functionality and stakeholders
- Respondent is one of the eight interviewees
- Each respondent has several overlapping questions to be able to compare answers and also some questions are directed to their specific field of work and expertise
- Processing: recording of the interview, need to ask for permission beforehand
- Duration of interview: 60 minutes

A.2.2 Interview Questions

General Questions

These questions were asked to all respondents to create a trustworthy and comparable foundation for the interviews.

1. Can you give a short introduction about your background? (Education, work experience, current function/expertise?)
2. What is your experience with innovative concepts being introduced in the Civil sector?
3. Do you now notice any differences in a tender approach compared to the past? If so, what differences?
4. Does the water-filled dyke concept have the potential to be implemented somewhere in The Netherlands, and why?

Specific Questions

Martijn van den Elzen, Project Manager Hydraulic Engineering (Movares)

1. What types of issues could be encountered during the design phase? What are the most common issues?
2. How do you experience the cooperation with RWS and water boards? Are there any improvements possible?
3. Does Movares have any general protocol or guidelines concerning sustainability and circularity in projects?
4. How does Movares perform on sustainability and circularity compared to other contractors?
5. What (extra) functions of water-filled and multi-functional dykes do you think are relevant for stakeholders?
6. What elements of sustainability, functionality and stakeholders need to be included to make a valuable framework for Movares?

Teun Dekker, Innovation Manager Buildings and Infra (Movares)

1. What do you think are the most important characteristics for a concept to possess, to be potentially successful?
2. Which process steps are usually undertaken when developing an innovation or new concept?
    - Extra question: Are indirect benefits such as reputation, image and social themes such as sustainability and circularity taken into account?
3. What elements of the ISO56000 are important to take into account?
4. Which setbacks/problems could be encountered when developing an innovation or new concept?
5. What are clients sensitive to in terms of innovation at the moment? In other words, what elements need to be included to make the concept appealing to

clients?
6. What aspects of the concept need attention in your opinion to make this concept a good contender for future tenders?

Mieke van Eerten-Jansen, Advisor Sustainability & Circularity (Movares)

1. What current developments is the civil sector going through concerning sustainability? The focus of this question is on clients like RWS, water boards and provinces.
2. What differences in sustainability and circularity approaches do you notice compared to the past?
3. Does Movares have any general protocol or guidelines concerning sustainability and circularity in projects?
    - Extra question: What do you do at the end of the life span of a project?
4. What measures can be taken in the design, building, operating and maintenance phases of the water-filled dyke to obtain a more sustainable and circular construction?
5. What building materials should or should not be used for the dyke?
6. Is there any possibility to re-use constructions of the dyke?
7. Could the transport of materials and the construction of the dyke be CO2-neutral?
8. Are there any examples related to these 3 previous aspects you can think of which are similar to my case?

Sjoerd Keetels, Advisor Sustainability & Circularity (Movares)

1. What current developments are the civil sector going through concerning sustainability? The focus of this question is on clients like RWS, water boards and provinces.
    - Extra question: How are RWS and the water boards doing now for their climate goals for 2030 and 2050?
2. What differences in sustainability and circularity approaches do you notice compared to the past?
3. Does Movares have any general protocol or guidelines concerning sustainability and circularity in projects?
4. What measures can be taken in the design, building, operating and maintenance phases of the water-filled dyke to obtain a more sustainable and circular construction?
5. What building materials should or should not be used for the dyke?
6. Is there any possibility to re-use constructions of the dyke?
7. Could the transport of materials and the construction of the dyke be CO2-neutral?
8. Are there any examples related to these 3 previous aspects you can think of

which are similar to my case?

Richard Rijkers, Senior advisor Hydraulic Engineering & Geo-engineering (Movares)

1. What types of issues could be encountered during the design and building phase? What are the most common issues?
2. How do you experience the cooperation with RWS and water boards? Are there any improvements possible?
3. Does RWS/water boards have any general protocol or guidelines concerning sustainability and circularity in projects?
4. How does Movares and RWS cope with the current new rules regarding PFAS and nitrogen?
5. What do you have to take into account when it comes to soil transportation? Think for example of legal, sustainable and stakeholder aspects.
6. What (extra) functions of water-filled and multi-functional dykes do you think are relevant for stakeholders?
7. What elements of sustainability, functionality and stakeholders need to be included to make a valuable framework for Movares?

Jan Gruppen, Specialist Water Safety (WDO Delta)

1. How do you experience the cooperation with contractors/consultancies and water board Drents Overijsselse Delta?
2. What types of issues could be encountered when cooperating with contractors? What are the most common issues?
3. How can these issues be solved?
4. Does WDO Delta have any general protocol or guidelines concerning sustainability and circularity in projects?
    - Extra question: Are the goals of the HWBP necessarily different from the water board?
5. How does WDO Delta cope with the current new rules regarding PFAS and nitrogen?
6. What do you have to take into account when it comes to soil transportation? Think for example of legal, sustainable and stakeholder aspects.
7. What (extra) functions of water-filled and multi-functional flood defences do you think are relevant for WDO Delta?
8. Are there any more functions that need to be taken into account when designing multi-functional flood defenses?
9. What elements of sustainability, functionality and stakeholders need to be included in your opinion to make a valuable framework for Movares?
10. What is WDO Delta's vision on sustainability, functionality and stakeholders?
11. Are there any differences on vision concerning sustainability, functionality and stakeholders compared to RWS? If so, which?

Eric van Kuijk, Senior Large Projects and Maintenance in Hydraulic Engineering (RWS)

1. How do you experience the cooperation with contractors/consultancies and RWS?
2. What types of issues could be encountered when cooperating with contractors? What are the most common issues?
3. How can these issues be solved?
4. What do you have to take into account when it comes to soil transportation? Think for example of legal, sustainable and stakeholder aspects.
5. What (extra) functions of water-filled and multi-functional flood defences do you think are relevant for RWS?
6. Are there any more functions that need to be taken into account when designing multi-functional flood defenses?
7. What elements of sustainability, functionality and stakeholders need to be included in your opinion to make a valuable framework for Movares?
8. What is RWS' vision on sustainability, functionality and stakeholders?
9. Are there any differences on vision concerning sustainability, functionality and stakeholders compared to water boards? If so, which?

Gerwin Schweitzer, Senior advisor Climate Neutrality and Circular Purchasing (RWS)

1. How do you experience the cooperation with contractors/consultancies and RWS?
2. What types of issues could be encountered when cooperating with contractors? What are the most common issues?
3. How can these issues be solved?
4. What do you have to take into account when it comes to soil transportation? Think for example of legal, sustainable and stakeholder aspects.
    - Extra question: How are RWS and the water boards doing now for their climate goals for 2030 and 2050?
5. What (extra) functions of water-filled and multi-functional flood defences do you think are relevant for RWS?
6. Are there any more functions that need to be taken into account when designing multi-functional flood defenses?
7. What elements of sustainability, functionality and stakeholders need to be included in your opinion to make a valuable framework for Movares?
8. What is RWS' vision on sustainability, functionality and stakeholders?
9. Are there any differences on vision concerning sustainability, functionality and stakeholders compared to water boards? If so, which?

A.2.3 Other

- Do you have any recommendations, suggestions or questions to add to the interview?
- Do you have any relevant literature or tips I can possibly use in my research?
- Thank the interviewee for their time and repeat what will happen with the data retrieved from the interview

A.3 Assessment Framework Table

Table A.2: Blank assessment framework

	Alternative 1	**Alternative 2**
Sustainability		
Circularity (2)		
Materials (2)		
Soil transportation (1)		
Water and climate adaptation (1)		
Sub-total score		
Functionality		
Innovation (2)		
Multi-functionality (1)		
Practicality (2)		
Spatial usage and quality (1)		
Sub-total score		
Stakeholders		
Ecological impact		
Economy (2)		
Safety (1)		
Social relevance (2)		
Sub-total score		
TOTAL SCORE		